



# Third European IRPA Congress

NSFS

*Radiation protection – science, safety and security*

14 – 18 June 2010

Helsinki, Finland

[www.irpa2010europe.com](http://www.irpa2010europe.com)



## ABSTRACTS

## Contributing organisations

IRPA – International Radiation Protection Association  
 NSFS – Nordic Society for Radiation Protection  
 STUK – Radiation and Nuclear Safety Authority, Finland  
 SSM – Swedish Radiation Safety Authority  
 NRPA – Norwegian Radiation Protection Authority  
 SIS – National Institute of Radiation Protection, Denmark  
 GR – Icelandic Radiation Protection Institute  
 NKS – Nordic Nuclear Safety Research  
 Radiological Society of Finland  
 EC – European Commission  
 IAEA – International Atomic Energy Agency  
 OECD/NEA – Organisation for Economic Co-operation and Development/Nuclear Energy Agency  
 WHO – World Health Organization  
 UNSCEAR – United Nations Scientific Committee on the Effects of Atomic Radiation  
 ICRP – International Commission on Radiological Protection  
 ICNIRP – International Commission on Non-Ionizing Radiation Protection  
 ICRU – International Commission on Radiation Units and Measurements  
 ICRM – International Committee for Radionuclide Metrology  
 EFOMP – European Federation of Organisations for Medical Physics  
 ILO – International Labour Organization



**IAEA**  
International Atomic Energy Agency  
Atoms for Peace



United Nations Scientific Committee  
on the Effects of Atomic Radiation



International Commission on  
Radiation Units and Measurements, Inc.



ABSTRACTS

# **Third European IRPA Congress**

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Publisher: NSFS – Nordic Society for Radiation Protection

Graphic design and layout:  
Nina Sulonen, STUK – Radiation and Nuclear Safety Authority, Finland

ISBN: 978-952-478-549-5 (print)

ISBN: 978-952-478-550-1 (pdf)

Editia Prima Oy, Helsinki 2010

# Abstracts of the third European IRPA Congress 2010

## Dear colleagues from all over Europe and beyond

This book contains the abstracts of the presentations given at the regional European IRPA Congress in Helsinki in 14–18 June, 2010. This is the third European IRPA congress and it is organised by the Nordic Society for Radiation Protection (NSFS). The two preceding congresses in 2002 and 2006 were held in Florence, Italy and in Paris, France.

The congress slogan "Radiation protection – science, safety and security" expresses the tight connection between these cornerstones in striving to achieve high level radiation protection. The aim of the congress is to provide an overview of the international state of the art of the radiation protection system for ionising and non-ionising radiation and the latest developments in the field. More than 800 professionals from all over Europe and beyond participated in the congress. We are grateful for the contributing organisations IAEA, ICRP, ICNIRP, European Commission, WHO, ILO, OECD/NEA, ICRU, UNSCEAR, ICRM, EFOMP and Radiological Society of Finland for their contribution to the program.

Abstracts for each session cover both oral and poster contributions. Full papers submitted prior to the congress are available at the Congress website ([www.irpa2010europe.com](http://www.irpa2010europe.com)). Pdf versions of all full papers as well as the abstract book will be made available via the IRPA website ([www.irpa.net](http://www.irpa.net)) after the Congress.

We wish to thank the Associated Societies in the European region for their active contribution to the Congress program. Each society nominated a member in the Scientific Programme Committee.

We are grateful for the sponsors NKS, TVO, Fortum, Mirion Technologies, Helsinki City and the Finnish Ministry of Social Affairs and Health as well as all the Nordic Radiation Protection Authorities. Special thanks go to the Finnish Radiation and Nuclear Safety Authority (STUK), without the support of which it would not have been possible to organize an event of this size. We wish to thank the technical exhibitors that came to Helsinki to show their latest technological innovations and instrumentation.

Visit [www.irpa2010europe.com](http://www.irpa2010europe.com) to find more information on the third European IRPA Congress and related activities.

We hope you enjoy your stay in Helsinki.



Lars-Erik Holm  
Congress president



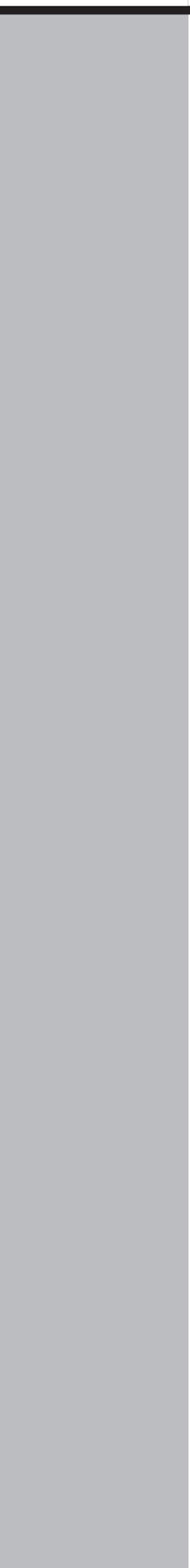
Sigurður Magnússon  
President of NSFS



Sisko Salomaa  
Chair of the scientific programme committee



Raimo Mustonen  
Chair of the local organising committee



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All the abstracts are presented in this book as follows:

Code of the abstract (= oral / poster presentation code).  
Y at the end of the code marks the presentation by a nominee for the Young scientist award.

**Abstract title**

**Author(s); Presenting author (based on the submitted information) underlined**

Affiliation(s), COUNTRY / COUNTRIES

Abstract

PL1

**European low dose risk research strategy****Salomaa, Sisko**

STUK – Radiation and Nuclear Safety Authority, FINLAND

Although much is known about the quantitative effects of exposure to ionising radiation, considerable uncertainties and divergent views remain about the health effects at low doses. Many of the European states have national research programmes in this area, however, beyond the Euratom research programme, little has been done to integrate these programmes in the past. The European High Level and Expert Group (HLEG) recently made a motion for the establishment of a Multidisciplinary European Low Dose Research Initiative (MELODI) that would create a platform for low dose research under a jointly agreed Strategic Research Agenda ([www.hleg.de](http://www.hleg.de)). The research agenda would focus on the key policy questions to be addressed and provide a road map for such research in the coming years and decades. The Letter of Intent expressing the will for the stepwise integration of low dose research activities was initially signed by five national organisations, BfS, CEA, IRSN, ISS and STUK. Since 2009, several other organisations have expressed their commitment on long-term integration of research and their interest to join MELODI. In 2010, a Network of Excellence called DoReMi was launched by the Euratom FP7 programme. DoReMi will act as an operational tool for the development of the MELODI platform during the next six years. The joint programme for research focuses on the areas identified by the HLEG as the most promising in terms of addressing/resolving the key policy questions, namely: the shape of dose response curve for cancer, individual susceptibilities and non-cancer effects. Radiation quality, tissue sensitivities and internal exposures will be addressed as cross cutting themes within the three main research areas.

PL2

**Public health perspective in radiological protection****Smeesters, Patrick<sup>1</sup>; Eggermont, Gilbert<sup>2</sup>**<sup>1</sup>Federal Agency for Nuclear Control (FANC), Regulation, International Affairs & Development, BELGIUM;<sup>2</sup>University Brussels, BELGIUM

Recent new insights about radon risk and increasing patient exposure due to medical imaging, as well as unexpected cardiovascular effects of ionizing radiation are challenging our classical radiological protection approaches and should be viewed in a larger public health perspective. Concepts as global indoor air quality, long term sustainability, risk awareness or precaution ask for a wider approach encompassing scientific vigilance, value judgements, risk communication and sociological participation in risk governance. Progress in radiological protection needs a new transdisciplinary framing of complexity where social sciences and humanities are more actively involved to complete scientific insight.

PL3

**IRPA Radiation Protection  
Culture initiative: An opportunity  
for the nuclear industry**Le Guen, Bernard

EDF and IRPA EC, Nuclear Power operation, FRANCE

Considerable progress has been made in all the fields of application of radiation protection over the past 40 years, supported by an enthusiastic generation of professionals. We are observing now significant development in the nuclear industry throughout the world and the profession is faced with renewal of the generation who thought up today's radiation protection. We must remain vigilant as all the conditions are fulfilled for radiation protection to make no further progress and in this case even to go backwards. One way of preventing or at least limiting the risk is to root radiation protection in culture, to develop a radiation protection culture. Sharing of our know-how and simultaneous optimisation initiatives set up for constant improvement of our practices are common radiation protection values. IRPA is proposing a brainstorming with other radiation protection societies with a view to possibly drawing up the IRPA's "Guiding Principles" for Radiation Protection Culture. This presentation will present the first results of the First international IRPA workshop in Paris (December 2009).

PL4

**Medical management of  
radiation accidents**Gourmelon, Patrick

FRANCE

PL5

### Novel measurement and analysis technology for safety, security and safeguards

Toivonen, Harri; Peräjärvi, Kari; Pöllänen, Roy

STUK – Radiation and Nuclear Safety Authority, FINLAND

Nuclear interactions have been measured through molecular phenomena since early days of radiation research. Rutherford used ZnS(Ag) in his famous experiments to detect alpha radiation; counting happened visually through a microscope. Recent technical advances have again turned molecular phenomena attractive for the basis of nuclear instrumentation.

The present paper reviews scientific advances which may ultimately lead to operational methods for safety, security and safeguards. The following examples give a flavour of results of such research:

- Ionizing radiation may produce UV through excitation of molecules of nitrogen. This creates a possibility for remote detection of alpha emitters.
- The highest quality spectra are measured with a bolometer having resolution about ten times better than the best operational semiconductor instruments in analytical laboratories. The measurement principle is simple: energy absorption raises temperature of the medium.
- Scintillation detectors are sensitive to photons and to particles, such as neutrons. Modern nuclear electronics, based on pulse shape discrimination, can distinguish one type of radiation from the other.
- The detection limits are drastically improved by combining analysis methods through coincidences. For example, alpha radiation can be used as a trigger signal for acquisition of gamma spectra.
- Novel mathematical algorithms provide powerful means to unfold complex spectra acquired with non-destructive techniques.

PL6

### Good regulators and good operators: in search of mutual trust

Valentin, Jack

SWEDEN

Everybody 'knows' what is expected of a regulatory body and how a licensee establishment is supposed to behave. This presentation aims to show that these concepts can be more elusive than first impressions may indicate. Well-known facts are frequently forgotten by new generations of regulators and operators, and ground once conquered and regarded as secured must be re-captured, time and again. Obviously, a regulatory body needs to trust each operator: a license (for instance, to use x-ray equipment) constitutes proof of that trust, and indicates that the licensee is perceived as having sufficient competence, responsibility, and resources in view of the risks involved in the licensed activity. However, all too often, inexperienced regulators focus on prescriptive instructions and follow-up of minute details, thus 'stealing' responsibility from the licensee. And all too often, inexperienced operators focus on compliance with prescriptive instructions instead of finding out the reasons behind the instructions and negotiating when required the best way of ensuring that goals are met and deviations are spotted before they turn into incidents.

Similarly, an operator needs to trust the regulator: licenses must be awarded, denied, or retracted on relevant grounds only. However, the operator must also be convinced that the regulator's primary aim is safety rather than punishments. Incident reporting is a vital safety tool, but it can only work if the operator is reasonably sure that an incident report will not generate undue punishments. Performance-based regulation does not mean lax control compared to prescriptive regulatory systems, nor does it permit careless or non-uniform operating procedures. It does call, however, for genuine mutual trust, and collaboration towards a common goal of safety. Good examples are available in other safe industries, such as aviation.

These concepts are discussed in the 2007 ICRP Recommendations, but only briefly and actually the 1990 ICRP Recommendations provided more advice in this respect. They are also discussed in various IAEA publications, but unfortunately there is some scope for unnecessarily prescriptive solutions, for instance if 'immaturity' is invoked.



S01-01

**A plausible radiobiological model of cardiovascular disease at low or fractionated doses****Little, Mark; Gola, Anna; Tzoulaki, Ioanna**

Imperial College, Epidemiology and Public Health, UNITED KINGDOM

Atherosclerosis is the main cause of coronary heart disease and stroke, the two major causes of death in developed society. There is emerging evidence of excess risk of cardiovascular disease at low radiation doses in various occupationally-exposed groups receiving small daily radiation doses. Assuming that they are causal, the mechanisms for effects of chronic fractionated radiation exposures on cardiovascular disease are unclear. We outline a spatial reaction-diffusion model for atherosclerosis, and perform stability analysis, based wherever possible on human data. We show that a predicted consequence of multiple small radiation doses is to cause mean chemo-attractant (MCP-1) concentration to increase linearly with cumulative dose. The main driver for the increase in MCP-1 is monocyte death, and consequent reduction in MCP-1 degradation. The radiation-induced risks predicted by the model are quantitatively consistent with those observed in a number of occupationally-exposed groups. The changes in equilibrium MCP-1 concentrations with low density lipoprotein cholesterol concentration are also consistent with experimental and epidemiologic data. This proposed mechanism would be experimentally testable. If true, it also has substantive implications for radiological protection, which at present does not take cardiovascular disease into account. The Japanese A-bomb survivor data implies that cardiovascular disease and cancer mortality contribute similarly to radiogenic risk. The major uncertainty in assessing the low-dose risk of cardiovascular disease is the shape of the dose response relationship, which is unclear in the Japanese data. The analysis of the present paper suggests that linear extrapolation would be appropriate for this endpoint.

S01-02

**Quantification of  $\gamma$ -H2AX foci in Jurkat cells following irradiation with  $\alpha$ -particles and  $\gamma$ -rays****Unverricht-Yeboah, Marcus<sup>1</sup>; Giesen, Ulrich<sup>2</sup>; Kriehuber, Ralf<sup>1</sup>**<sup>1</sup>Forschungszentrum Juelich, Department of Safety and Radiation Protection, Radiation Biology Unit S-US, GERMANY;<sup>2</sup>Physikalisch-Technische Bundesanstalt Braunschweig, GERMANY

**Objectives:** Phosphorylation of histone H2AX occurs at sites flanking DNA double-strand breaks (DSBs) and can provide a measure of the number of DSBs within a cell. We investigated whether the mean intensity and the mean number of radiation-induced  $\gamma$ -H2AX foci per cell vary as a function of radiation quality and dose.

**Materials and methods:** Jurkat cells were irradiated with different doses of either low linear energy transfer (LET) <sup>137</sup>Cs  $\gamma$ -rays or high LET <sup>241</sup>Am  $\alpha$ -particles. The  $\gamma$ -H2AX foci were detected using immunocytochemistry and quantified by measuring the mean signal intensity of  $\gamma$ -H2AX foci per cell using flow cytometry and by counting the number of  $\gamma$ -H2AX foci with a fluorescence microscope.

**Results:** The mean numbers of  $\gamma$ -H2AX foci per cell increase with dose and they are fairly identical at 1 Gy for both investigated radiation qualities. The mean intensity of  $\gamma$ -H2AX foci per cell after  $\alpha$ -irradiation is significantly increased when compared to  $\gamma$ -irradiation at the same radiation dose. A more advanced flow cytometry analysis reveals that the percentage of  $\gamma$ -H2AX-negative cells as well as the distribution of single  $\gamma$ -H2AX fluorescence signals depend on the radiation quality.

**Conclusion:** The mean signal intensity, but not the mean number, of  $\gamma$ -H2AX foci per cell depends on the LET in Jurkat cells. When comparing the induction of  $\gamma$ -H2AX foci in Jurkat cells after exposure to  $\gamma$ -rays and  $\alpha$ -particles, the analysis by flow cytometry is more appropriate than the microscopical quantification by eye, considering the LET-dependence of foci-size and -intensity, the cell cycle dependence of  $\gamma$ -H2AX frequencies and the distributions of single  $\gamma$ -H2AX fluorescence signals.

S01-03

**Radiation-induced transgenerational instability and genetic risk****Dubrova, Yuri E.**

University of Leicester, Department of Genetics, UNITED KINGDOM

Mutation induction in the directly exposed cells is currently regarded as the main component of the genetic risk of ionizing radiation. However, recent data on the delayed effects of exposure to ionizing radiation represent a new challenge to the existing paradigm. The results of numerous studies show that ionizing radiation can not only induce mutations in the directly exposed cells, but can also lead to delayed effects, with new mutations arising many cell divisions after irradiation.

Apart from the studies on mutation rates in somatic cells, considerable progress has been made in the analysis of radiation-induced instability in the mammalian germline, where the effects of radiation exposure were investigated among the offspring of irradiated parents. Our results show that mutation rates at tandem repeat DNA loci and protein-coding genes are substantially elevated in the germline and somatic tissues of non-exposed offspring of irradiated male mice. According to our data, the transgenerational destabilization can be attributed to the presence of a subset of endogenous DNA lesions. We have recently shown that paternal treatment by the alkylating agent ethylnitrosourea also results in the transgenerational effects, thus implying that this phenomenon is most probably triggered by a stress-like response to a generalized DNA damage.

Our data imply that instability detected in the non-exposed offspring is caused by some DNA-dependent signal transmitted from the irradiated father and implicate an epigenetic mechanism for the transgenerational instability. The potential implication of these results for the estimates of genetic risks for humans will be discussed.

S01-04

**Low doses of irradiation on nervous cells impairs neurite outgrowth and causes neuronal degeneration****Samari, Nada<sup>1</sup>; Abou-El-Ardat, Khalil<sup>1</sup>; Pani, Giuseppe<sup>1</sup>; de Saint-Georges, Louis<sup>1</sup>; Baatout, Sarah<sup>1</sup>; Leyns, Luc<sup>2</sup>; Benotmane, M. Abderrafi<sup>1</sup>**<sup>1</sup>SCK-CEN, radiobiology, BELGIUM; <sup>2</sup>Free University of Brussels (VUB), BELGIUM

Brain damage induced by prenatal irradiation is a major concern and an important issue in radiation protection. The embryonic stage of brain development is known to be highly sensitive to radiations, since most of the concerned cells are still mitotic. Thus, an acute irradiation during pregnancy could selectively damage cells, which at that particular time of exposure, are proliferating or migrating. Data collected from the epidemiological studies on the children that were irradiated in utero during Hiroshima and Nagasaki's A-Bombing, showed an increase of some mental and/or cognitive disorders. Depending on the received radiation dose, the severity of the damage occurs at crucial embryonic stages for neuronal survival, proliferation, migration, and/or neural network formation. In this study, we investigate the main cellular and molecular mechanisms involved in radiation-induced neurite outgrowth and apoptosis. Various time points and irradiation doses were compared at different neuronal maturation stages. Image analysis of immuno stained control compared to irradiated neuron cells with low and moderate doses (0.1, 0.2 and 0.5 Gy), showed a clear negative radiation effect on neurite outgrowth depending on the maturation stage of neurons. In particular, the main radiation-induced morphological effects were: shortened neurite length, decreased number of neurite per neuron and reduced synapse branching. These effects could lead to a defect in neural network formation and consequently to possible cognitive disorders at the adult age. The molecular and biochemical events will be further analysed using transcriptomic, proteomic and metabolomic technologies in order to identify the compromised molecular and signaling pathways in neuron cells after exposure to moderate and low doses of X-rays. Molecular strategies (overexpression or silencing) would help to validate the identified pathways.

S01-05

**The European Radiobiological Archives: online access to data from radiobiological experiments**

**Birschwilks, Mandy<sup>1</sup>; Adelmann, Clemens<sup>1</sup>;  
Gruenberger, Michael<sup>2</sup>; Tapio, Soile<sup>2</sup>;  
Schofield, Paul<sup>2</sup>; Grosche, Bernd<sup>1</sup>**

<sup>1</sup>Federal Office for Radiation Protection, GERMANY; <sup>2</sup>University of Cambridge, Department of Physiology, Development and Neurosci, UNITED KINGDOM; <sup>3</sup>Helmholtz Centre Munich, Institute of Radiation Biology, GERMANY

Today's research is providing us more and more with the opportunity to quantify radiation risks at the individual level. New approaches allow the re-analysis of old data using new techniques. Thus, the retrospective analysis of earlier studies is an important resource for modelling and evaluating risk parameters. The European Radiobiology Archives (ERA), together with corresponding Japanese and American databases, hold data from nearly all experimental animal radiation studies carried out between the 1950s and the 1990s, involving more than 400,000 animals. These experiments were performed on different species with the aim of understanding the effects of irradiation. This mass of information has led to the requirement for a computerized database to store, organize and index this data. The previously existing ERA archive has now been transferred to a web-based database to maximise its usefulness to the scientific community and bring data coding and structure of this legacy database into congruence with currently accepted semantic standards for anatomy and pathology. The accuracy of the primary data input was assessed and improved. The original rodent pathology nomenclature was recoded to Mouse Pathology (MPATH) and Mouse Anatomy (MA) ontology terms. A pathology panel sampled histopathological slide material and compared the original diagnoses with currently accepted diagnostic criteria. The mean non-systematic error rate was low with only 1.7%. Detected errors were corrected. The majority of the original pathology terms have been translated into a combination of MPATH and MA ontology terms. The database is accessible online at <http://era.bfs.de>. It has the potential of becoming a world-wide radiobiological research tool for numerous applications, such as the re-analysis of existing data and using the database as an information resource for planning future animal studies.

S01-06

**A large-scale gene expression database on the effect of low doses of radiation: a systems biology approach.**

**Monsieurs, Pieter; Quintens, Roel;  
Janssen, Ann; Michaux, Arlette; Jacquet, Paul;  
Baatout, Sarah; Benotmane, M. Abderrafi**  
Belgian Nuclear Research Centre, SCK-CEN, Molecular and Cellular Biology, BELGIUM

Current radiation protection regulatory limits are based on the linear non-threshold theory using health data from atomic bombing survivors. Studies in recent years sparked debate on the validity of the theory, especially at low doses. Recent advances in molecular biology have shown that different genes are triggered by low doses and by high doses of ionising radiation. Identifying the genes involved in the response to low doses is therefore critical for a better prediction of a possible clinical outcome following radiation exposure. The increasing interest in the effect of low doses of radiation coincides with the breakthrough in the development of new high-throughput technologies in molecular biology. Microarrays constitute a good example, allowing simultaneous measurement of the expression of thousands of genes. As gene expression is the predominant level controlling cell functioning, this technology has become a powerful tool to measure the impact of low doses of radiation. A major challenge is how to integrate all data resulting from a wide range of experiments and use them to improve our global understanding of the general molecular response of a cell after radiation exposure to low doses. Therefore, we organized into one microarray compendium all radiation expression studies performed within our laboratory. In total, our compendium comprises 233 arrays representing 79 different biological conditions. Applying a systems biology approach on these data will shed light on the relationship between gene expression and different parameters like dose, tissue and organism. Additionally, identification of pathways triggered upon low doses of radiation might open new opportunities towards biodosimetry and appropriate regulation regarding medical exposure and intrinsic radiation sensitivity.

*This work is financially supported by the EU Euratom program (GENRISK-T FP6-36495 and NOTE/RADDEF FP6-36465) and the FANC-SCK-CEN contract (CO-90 06 2024.00).*

S01-07

### A combined analysis of three European studies on the joint effects of radon exposure and smoking on lung cancer risk among uranium miners

Leuraud, Klervi<sup>1</sup>; Schnelzer, Maria<sup>2</sup>; Tomasek, Ladislav<sup>3</sup>; Kreuzer, Michaela<sup>2</sup>; Laurier, Dominique<sup>1</sup>

<sup>1</sup>IRSN, FRANCE; <sup>2</sup>Bfs, GERMANY; <sup>3</sup>SURO, CZECH REPUBLIC

**Objectives:** Three case-control studies nested in the French, German and Czech cohorts of uranium miners were conducted in the frame of Alpha-Risk, a European research project on the quantification of health risks associated with multiple radiation exposures. These studies aimed at investigating the joint effects of radon and smoking on lung cancer risk. A combined analysis of individual data of the three studies is presented.

**Methods:** The combined data set includes 1476 cases and 3389 matched controls. Cumulated radon exposure during employment was obtained from measurements or a job exposure matrix. Smoking habits were determined from medical archives and questionnaires. Analysis was performed by conditional logistic regression using a linear excess relative risk model.

**Results:** Smoking status was established for 1046 cases and 2492 controls. Ninety four percent of cases and 76% of controls were ex- or current smokers. Mean five-year lagged cumulated radon exposure was 335 Working Level Months (WLM) for cases and 211 WLM for controls. The excess relative risk per WLM adjusted for smoking was 0.79% (95% confidence-interval: 0.44–1.41%). Lung cancer excess relative risk per unit exposure was about two times higher among non-smokers than among smokers and the results suggest a sub-multiplicative interaction between smoking and radon exposure on lung cancer mortality risk.

**Conclusions:** This collaborative study is the largest uranium miners case-control study on lung cancer with smoking information in Europe. It confirms the persistence of radon effect on lung cancer risk when smoking is taken into account and allows investigating the interaction between radon and smoking.

S01-08a

### Cerebrovascular diseases in the cohort of Mayak PA nuclear workers

Azizova, Tamara<sup>1</sup>; Muirhead, Colin<sup>2</sup>; Druzhinina, Maria<sup>1</sup>; Grigoryeva, Evgenia<sup>1</sup>; Vlasenko, Elena<sup>1</sup>; Sumina, Margarita<sup>1</sup>; O'Hagan, Jacqueline<sup>2</sup>; Zhang, Wei<sup>2</sup>; Haylock, Richard<sup>2</sup>; Hunter, Nezhahat<sup>2</sup>

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Incidence of and mortality from cerebrovascular diseases (CVD) have been studied in a cohort of 12210 workers first employed at one of the main plants of the Mayak nuclear facility during 1948–1958 and followed up to 31 December 2000. Information on external gamma doses was available for virtually all of these workers (99.9%); the mean ( $\pm$  SD) total external gamma dose was  $0.91 \pm 0.95$  Gy (99% percentile 3.9 Gy) for men and  $0.65 \pm 0.75$  Gy (99% percentile 2.99 Gy) for women. In contrast, plutonium body burden was measured only for 30% of workers; amongst those monitored, the mean ( $\pm$  SD) absorbed cumulative liver dose was  $0.40 \pm 1.15$  Gy (99% percentile 5.88 Gy) for men and  $0.81 \pm 4.60$  Gy (99% percentile 15.95 Gy) for women. 4418 disease cases and 753 deaths from CVD were identified in the study cohort. Having adjusted for non-radiation factors and internal alpha exposure, there was statistically significant increasing trend in CVD incidence with total external gamma dose; ERR/Gy was 0.464 (95% CI 0.360, 0.567). Much of the evidence for the raised incidence in relation to external dose arose for workers with cumulative doses above 1 Gy. Having adjusted for non-radiation factors and external gamma exposure, there was statistically significant increasing trend in CVD incidence with total absorbed internal liver dose; ERR/Gy was 0.155 (95% CI 0.075, 0.235). CVD incidence was statistically significantly higher among workers with a plutonium liver dose above 0.1 Gy, although the trend estimates differed between workers at different plants. There was no statistically significant trends in CVD mortality risk with either external gamma dose or internal liver dose from alpha exposure. The risk estimates for external radiation are generally compatible with those from other large occupational studies, although the incidence data point to higher risk estimates compared to those from the Japanese A-bomb survivors.

S01-08b

**Ischemic heart disease in the cohort of Mayak PA nuclear workers**

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Incidence of and mortality from ischemic heart disease (IHD) have been studied in a cohort of 12210 workers first employed at one of the main plants of the Mayak nuclear facility during 1948–1958 and followed up to 31 December 2000. Information on external gamma doses was available for virtually all of these workers (99.9%); the mean ( $\pm$  SD) total external gamma dose was  $0.91 \pm 0.95$  Gy (99% percentile 3.9 Gy) for men and  $0.65 \pm 0.75$  Gy (99% percentile 2.99 Gy) for women. In contrast, plutonium body burden was measured only for 30% of workers; amongst those monitored, the mean ( $\pm$  SD) absorbed cumulative liver dose was  $0.40 \pm 1.15$  Gy (99% percentile 5.88 Gy) for men and  $0.81 \pm 4.60$  Gy (99% percentile 15.95 Gy) for women. 3751 disease cases and 1495 deaths from IHD were identified in the study cohort. Having adjusted for non-radiation factors, there was statistically significant increasing trend in IHD incidence with total external gamma dose; ERR/Gy was 0.109 (95% CI 0.049, 0.168). This trend with external dose was little changed after adjusting for internal dose. Much of the evidence for the raised incidence in relation to external gamma dose arose for workers with cumulative doses above 1 Gy. The trend with external dose in IHD mortality was not statistically significantly greater than zero, but was consistent with the corresponding trend in IHD incidence even once adjustment for internal dose was made. There was stronger evidence for an association with internal alpha dose to liver in the IHD mortality data than in the corresponding incidence data, although the associated confidence intervals overlap. Furthermore, the estimated trend in IHD mortality with internal dose was lower and not statistically significant once adjustment was made for external dose. The risk estimates for IHD in relation to external radiation are generally compatible with those from other large occupational studies and the Japanese A-bomb survivors.

S01-09

**Risk of thyroid cancer among Chernobyl liquidators**

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**Aims:** While the increased risk of thyroid cancer is well demonstrated in children exposed to radioactive iodines in the most contaminated areas around the Chernobyl power plant, the effect of exposure on adults remains unclear. The objective of the study was to evaluate the radiation-induced risk of this disease among Chernobyl liquidators.

**Methods:** A collaborative case-control study of thyroid cancer was conducted, nested within cohorts of Belarussian, Russian and Baltic liquidators of the Chernobyl accident. The liquidators were mainly exposed to external radiation, although substantial dose to the thyroid from iodine isotopes may have been received by those who worked in May–June 1986 and who resided in the most contaminated territories of Belarus. Individual doses to the thyroid from external radiation and from iodine-131 were estimated for each subject.

**Findings:** 107 case patients and 423 matched controls were included in the study. Median age at the moment of first exposure was 37 years. Most subjects received low doses (median 69 mGy). The doses were much higher for women (median 196 mGy) than for men (median 64 mGy). ►►

▶▶ A significantly elevated Odds Ratio was seen at doses of 300 mGy and above. The overall Excess Relative Risk (ERR) per 100 mGy was 0.38 (95% confidence interval (CI): 0.10, 1.09). Risk estimates were similar for iodine-131 and external exposure – ERR per 100 mGy was 0.45 (95% CI: 0.10, 1.61) and 0.38 (95% CI: -0.11, 2.07), respectively.

**Conclusions:** Although higher than risk estimated from a-bomb survivors exposed as adults, the significantly elevated risk observed in the present study is similar to that obtained in the recent studies of thyroid cancer following exposure to iodine-131 in childhood in the areas contaminated after the Chernobyl accident. The increased risk appears to be related to iodine-131 exposure, as well as to doses from external radiation.

S01-10

### Lenticular opacities in the eyes of radiologists

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We carried out a pilot study to assess whether occupational radiation exposure increases the risk of cataract among radiologists.

**Material and methods:** A total of 120 individuals were invited and 59 participated. The mean age was 59 years and duration of work 24 years with mean recorded radiation dose of 42 mSv. They filled in an extensive questionnaire and underwent an ophthalmological examination with grading of changes based on Lens Opacities Classification System, version II (LOCS II).

**Results:** Lens changes were found in 42% (95% CI 29–56%) of the subjects. Nuclear opacities were the most common findings (11%, 95% CI 4–22%), while posterior subcapsular changes were found in 5% of the subjects (95% CI 1–15%). Lens changes were associated with age, smoking and cumulative recorded radiation dose.

**Conclusion:** Our result suggest that protracted exposure to low doses of radiation may increase occurrence of cataracts. For risk assessment, larger studies with comparable reference groups re needed.

S01-11

**Occupational cataracts and lens opacities in interventional cardiology: The O'Cloc study**

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Interventional cardiologists are repeatedly and acutely exposed to scattered ionizing radiation (X-rays) during their diagnostic or therapeutic procedures. These exposures may cause damages to the eye lens and induce early cataracts known as radiation-induced cataracts. The O'CLOC study is a French epidemiological study designed to test the hypothesis of an increased risk of cataracts among interventional cardiologists as compared with unexposed cardiologists. This multicenter cross-sectional study will include a total of 300 cardiologists aged > 40 years: a group of interventional cardiologists (approx. 2/3 of coronary interventionists and 1/3 of electrophysiologists) and a group of unexposed cardiologists (clinicians or echocardiographers), matched for age, sex and place of work. Individual information, including risk factors of cataracts (age, diabetes, myopia, etc. ...), will be collected during a telephone interview. For the exposed group, a specific section of the questionnaire is focusing on their occupational history, the procedures description (type, frequency, use of radiation protection tools) and will be used to classify "comparable exposure level" groups according to their estimated cumulative dose. For all participants, clinical eye examinations will be performed to specifically detect cataracts even at the early stages (lens opacities, LOCS according to the international standard classification). The overall analysis will provide an estimation of the risk of cataract in interventional cardiology comparatively to not-exposed reference group, taking into account other risk factors. A complementary comparative analysis of risks according to the level of exposure is also planned.

This epidemiological study will provide further knowledge on the potential risk of occupational radiation-induced cataracts in interventional cardiology and will contribute to the awareness of cardiologists in radiation protection.

S01-12

**Cardiovascular disease and radiation  
– review and meta-analysis of  
epidemiological evidence at low doses****Little, Mark<sup>1</sup>; Tawn, E. Janet<sup>2</sup>; Tzoulaki, Ioanna<sup>1</sup>;****Wakeford, Richard<sup>3</sup>; Hildebrandt, Guido<sup>4</sup>;****Paris, Francois<sup>5</sup>; Tapio, Soile<sup>6</sup>; Elliott, Paul<sup>1</sup>**

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Although the link between high doses of ionizing radiation and damage to the heart and coronary arteries has been well established for some time, the association between lower dose exposures and late occurring cardiovascular disease has only recently begun to emerge, and is still controversial. In this paper, we extend an earlier systematic review by Little and colleagues on the epidemiological evidence for associations between low and moderate doses of ionizing radiation exposure and late occurring blood circulatory system disease. Excess relative risks per unit dose in epidemiological studies vary over at least two orders of magnitude, possibly a result of confounding and effect modification by well known (but unobserved) risk factors, and there is statistically significant ( $p < 0.00001$ ) heterogeneity between the risks. This heterogeneity is reduced, but remains significant, if adjustments are made for the effects of fractionated delivery or if there is stratification by endpoint (cardiovascular disease vs stroke, morbidity vs mortality). One possible biological mechanism is damage to endothelial cells and subsequent induction of an inflammatory response, although it seems unlikely that this would extend to low dose and low dose-rate exposure. A recent paper of Little et al. proposed an arguably more plausible mechanism for fractionated low-dose effects, based on monocyte cell killing in the intima. Although the predictions of the model are consistent with the epidemiological data, the experimental predictions made have yet to be tested. Further epidemiological and biological evidence will allow a firmer conclusion to be drawn.

P01-01

**Co-exposure to radiation and methyl mercury during critical phase of neonatal brain development in mice enhances developmental neurobehavioral defects**

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Organisms, including man, are continuously exposed to low doses of ionizing radiation as well as persistent and nonpersistent chemicals in the environment. Hence, in the process of developing numerical limits for environmental protection, there is a strong need to consider interactive effects between radiation and other environmental stressors. It is known that ionizing radiation, as well as methyl mercury, can give rise to neurotoxicological and neurobehavioural effects in mammals and that developmental neurotoxic effects can be seen after exposure during gestation. However, there is a lack of knowledge concerning effects and consequences from low-dose exposure during critical phases of perinatal and/or neonatal brain development and the combination of ionizing radiation and environmental chemicals. Epidemiological studies of patients with haemangioma have indicated that radiation exposures to the brain during infancy might deteriorate cognitive ability in adulthood. Ten-day old neonatal NMRI male mice were exposed to a single oral dose of MeHg (0.40 or 4.0 mg/kg bw). Four hours after the MeHg exposure the mice were irradiated with <sup>60</sup>Co gamma radiation at doses of 0,2 and 0,5 Gy. The animals were subjected to a spontaneous behaviour test at the ages of 2- and 4-months, and the water maze test at the age of 5 months. Neither the single dose of MeHg (0.4 mg/kg bw) nor the radiation dose of 0.2 Gy affected the spontaneous behavior, but the co-exposure to radiation and MeHg caused developmental neurotoxic effects. These effects were manifested as disrupted spontaneous behavior, lack of habituation, and impaired learning and memory functions. Studies are continuing to verify the effects and to elucidate possible underlying mechanisms.

P01-02

**DNA-Triplex-forming-oligonucleotides as a tool to target specific DNA sequences**

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**Purpose:** Triplex-forming-oligonucleotides (TFOs) are able to bind complementary DNA sequences in a sequence specific manner and are therefore a promising tool to manipulate genes or gene regulatory units in a cellular environment. TFOs might have also therapeutic potential e.g. as a carrier for Auger-Electron-Emitter (AEE) to target DNA of tumour cells. A main obstacle is the access of the TFOs to their targets in the cell nucleus. Thus we studied the intracellular biokinetics of TFOs with the focus on the intracellular transfer from the cytoplasm into the nucleus.

**Method:** TFOs specific for the genes p16ink4a and survivin were designed using (TFO Target Sequence Search, Univ. of Texas). DNA-Triplex-formation was confirmed by electrophoretic-mobility-shift-assay (EMSA) in vitro. For biokinetic studies SCL-II cells were transfected by electroporation with Alexa488-labeled TFOs. Transfected cells were subsequently cultured for 1 h, 6 h, 12 h, 18 h, 24 h and 30 h and TFO signal intensity was determined in single cells and in isolated cell nuclei by flowcytometry (FACS-Canto II, BD) at each time point.

**Results:** Sequence design of TFOs by (TFO Target Sequence Search, Univ. of Texas) for the desired genes is generally not suitable to predict DNA-Triplex-formation in vitro as could be demonstrated by EMSA. The desired Triplex-DNA-formation could be confirmed for only two TFOs by EMSA. The biogenetic studies showed that TFO-Alexa488 positive cells were detectable as soon as 1 h after transfection and the signal intensity remained constant for at least 30 h. TFO-positive cell nuclei were not detectable for up to 6 h. After 12 h a significant increase of TFO-Alexa488-positive cell nuclei was observed.

**Conclusion:** Stable Triplex-DNA-formation in vitro can not be predicted by the sequence of TFOs only. TFOs initially located in the cytoplasm are re-located to the cell nucleus within 12 h after delivery of the TFOs probably during cell division.

P01-03

### Molecular, metabolic and genomic response of TPC-1 cells to external X-irradiation

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The release of radioactive iodine isotopes into the atmosphere in the wake of the Chernobyl disaster and the subsequent increase in the cases of thyroid cancer amongst children provided us with solid evidence of the link between irradiation and thyroid cancer. The link between the radiation dose and the adverse effects on human health has been established and a linear correlation drawn. However, that correlation only holds for doses higher than a certain threshold, below which there is lack of unanimity in the scientific community. We attempted to subject TPC-1, a cell line of human papillary thyroid carcinoma origin to a range of X-ray doses from low to high (0.0625 to 4 Gy) and test their effect on cellular proliferation, apoptosis and molecular signaling to uncover the effect of low doses of radiation on them. We observed a decrease in proliferation concomitant with a decrease in cells in the S phase of the cell cycle even at the lowest dose. On the other hand, there was no significant increase in apoptotic or necrotic cells at the same time point. On the protein level, an increase in p53 and some of its targets (e.g. p21 and mdm-2) was observed whereas an absence of p73 was apparent. An up-regulation of anti-apoptotic proteins such as Bcl-2 and Akt was also noted. A microarray run was performed and revealed an up-regulation in the p53 pathway whereas one gene, RFLP-1, appeared to be consistently up-regulated at all doses tested. Further research into this gene are underway. In addition, analysis of the metabolic profile of control and irradiated cells will be done on the supernatants of these cells. Metabolomics is a relatively new high throughput technique and is sensitive enough to hopefully measure the effect of low doses of radiation. Finally, analysis of the changes in microRNAs in irradiated versus control cells is currently underway.

*This work is financially supported by the EU Euratom programme (contract GENRISK-T FP6-36495).*

P01-04

### Irradiation of mouse zygotes and genomic instability : influence of genes involved in DNA repair, cell cycle regulation and apoptosis

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Studies under way in our laboratory aim at investigating how heterozygous mutations in important genes might influence the radiation sensitivity of early embryos. We mainly focus on the zygote (first day of gestation in mammals), which occurs while women cannot be aware of pregnancy. Moreover, x-irradiation of wild-type zygotes has been reported to result in the development of a genomic instability in two different mouse strains. The results presented here concern the development of such effect after x-irradiation of zygotes of other strains, carrying a mutation in either the p53 gene or the PARP gene. P53<sup>+/-</sup> embryos were obtained by mating CF1 p53<sup>+/+</sup> females with CF1 p53<sup>-/-</sup> males, while PARP<sup>+/-</sup> embryos were obtained by mating PARP<sup>-/-</sup> females/males (C57BL genetic background) with C57BL males/females. Females showing a vaginal plug were x-irradiated 2 h after fertilization (0.2 or 0.4 Gy) and sacrificed on day 8 of gestation. Their gastrulas were collected and cultured for 7 h in rat serum supplemented with colchicine and their cells were fixed for chromosome analysis. The frequencies and types of chromosome anomalies did not differ between control p53<sup>+/-</sup> and p53<sup>+/+</sup> cells or between control PARP<sup>+/-</sup> and PARP<sup>+/+</sup> cells. Anomalies were essentially of the chromatid-type, with a majority of chromatid gaps. No increase of chromosome damage was found after irradiation of p53<sup>+/-</sup> or PARP<sup>+/-</sup> zygotes and, again, chromatid-type anomalies largely predominated over chromosome-type anomalies. These results differ from those obtained by others in wild-type embryos irradiated with higher doses. Moreover, they suggest that the presence of one mutated allele for two important genes would not result into an increased risk of developing a chromosomal instability after irradiation with moderate doses at the zygote stage. Similar studies are under way with other important DNA responses genes (supported by a contract between the SCK•CEN and the Federal Agency for Nuclear Control).

P01-05

**Individual sensitivity in targeted and non-targeted effects of radiation – ATM as a model for characterizing individual susceptibility****Kämäräinen, Meerit<sup>1</sup>; Kiuru, Anne<sup>1</sup>; Lindholm, Carita<sup>1</sup>; Koivistoinen, Armi<sup>1</sup>; Chapman, Kim<sup>2</sup>; Winqvist, Robert<sup>3</sup>; Kadhim, Munira<sup>2</sup>; Launonen, Virpi<sup>1</sup>**<sup>1</sup>STUK – Radiation and Nuclear Safety Authority, FINLAND;<sup>2</sup>OBU, Oxford Brookes University, UNITED KINGDOM;<sup>3</sup>Laboratory of Cancer Genetics, Dept. of Clinical Genetics and Biocenter Oulu, University of Oulu, FINLAND

The aim of this study is to investigate the role of genetic heterogeneity in the *ATM* gene with respect to the individual variation of response to ionizing radiation. The issues of targeted and non-targeted effects particularly at low doses will be addressed. *ATM* is a major activator of cellular response to DNA-double strand breaks. *ATM* germ line mutations cause ataxia-telangiectasia (AT), a rare recessive autosomal disorder. Female carriers are phenotypically normal but there is evidence of increased risk of breast cancer among these women. We hypothesize that cells from *ATM* mutations carriers are more susceptible to bystander signals than *ATM*-proficient cells. The experimental system is based on co-culture technique where irradiated cells communicate through media with unirradiated cells. The co-culture system will be established by using human lymphoblastoid cell line TK6 cells that are irradiated by X-rays with doses of 0.01, 0.1, 1, and 2 Gy and co-cultured with unirradiated bystander cells for 1 hour and 18 hours. The induction of direct and bystander effects of radiation will be analyzed using MTT [3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide] cell viability assay, apoptosis and chromosomal aberration assays. In addition to results from TK6, corresponding data from experiments using cell lines with different *ATM* mutations will be evaluated against the wildtype *ATM* gene.

P01-06

**Influence of genetic polymorphisms on the yield of chromosomal aberrations among Estonian Chernobyl cleanup workers****Kiuru, Anne<sup>1</sup>; Koivistoinen, Armi<sup>1</sup>; Veidebaum, Toomas<sup>2</sup>; Rahu, Kaja<sup>3</sup>; Rahu, Mati<sup>3</sup>; Tekkel, Mare<sup>3</sup>; Hautaniemi, Sampsa<sup>4</sup>; Launonen, Virpi<sup>1</sup>; Lindholm, Carita<sup>1</sup>**<sup>1</sup>STUK – Radiation and Nuclear Safety Authority, Dept. ofResearch and Environmental Surveillance, FINLAND; <sup>2</sup>NationalInstitute for Health Development, ESTONIA; <sup>3</sup>National Institute

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The frequency of chromosomal aberrations (CAs) in peripheral blood lymphocytes has been applied as a biomarker for biodosimetry of radiation. Individual variability in CA frequency is known to be caused by several factors such as age and various kinds of exposures as well as genetic factors. The aim of the present study is to evaluate the effect of individual susceptibility to the amount of CAs in Estonian Chernobyl cleanup workers. The data and biobank of a study cohort of 4832 men contains detailed information of, e.g., recorded doses, smoking habits, medical radiation exposure, and health history. From this cohort, 300 men with doses of 48 – 300 mSv were chosen to the present study. In addition, 100 unexposed Estonian men were used as a control group. CAs were analyzed in peripheral blood lymphocytes using the fluorescence in situ hybridization (FISH) technique. In order to investigate the generic susceptibility, we studied single nucleotide polymorphisms (SNPs) in DNA repair genes, i.e., *ATM* (Phe858Leu, Pro1054Arg, Asp1853Asn, intron 5, rs228599 and intron 61, rs664143), *LIG4* (Thr9Ile, Asp568Asp), *XRCC1* (Arg194Trp, Arg280His, and Arg399Gln), *XRCC3* (Thr241Met), *XRCC5* (intron, rs3835 and 5' near gene, rs11685387), and *XRCC6* (Gly593-Gly and 5' near gene, rs2267437) and in an apoptosis gene, i.e., *CASP8* (Asp302His and 5' near gene, rs6747918). The individual yield of CAs (particularly translocations) will be statistically analysed with respect to the SNPs, recorded dose, and other confounders. The results will bring more knowledge to the underlying mechanisms of individual variation in the induction of CAs. The information is also essential in the context of the well-established association between high CA frequency and increased cancer incidence.

P01-07

### The frequency of the chromatid breaks in G2 peripheral blood lymphocytes as an indicator of human individual sensitivity to ionizing radiation

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Human population differs in its sensitivity to ionizing radiation. There are radiosensitive subgroups with hypersensitivity to carcinogenic risks (stochastic effects) and hypersensitivity to deterministic effects. Predictive markers for individual radiosensitivity of healthy individuals may allow the monitoring of occupational or environmental radiation exposure and may predict a cancer patient's response to radiotherapy.

Exposure to ionizing radiation results in several cytogenetic endpoints, such as chromosomal aberrations, micronuclei, and chromatid aberrations. Chromatid aberrations arise when cell is irradiated in the G2 phase of the cell cycle. Radiosensitivity assessed by analysis of chromatid breaks at metaphase after G2-phase irradiation of human lymphocytes-the G2-assay-has shown that a significant variations exists between individuals. These variations can be explained by intrinsic differences of individuals either in the DNA repair activity or in the cell cycle control mechanisms during the G2 to M phase transition.

In order to establish at the CLOR a screening method of identifying persons with an increased individual radiosensitivity that would facilitate the risk assessment at the individual level, the G2-phase chromosomal radiosensitivity assay by Terzoudi & Pantelias was adapted. The conditions for X-ray irradiation and analysis of the chromosomal aberrations have been optimized and the yield of radiation-induced chromatid breaks in peripheral blood lymphocytes of 30 healthy donors has been started to determine after *in vitro* exposure to 1 Gy X ray-irradiation. A high yield of chromatid breaks should correlate with hypersensitivity.

This assay would allow the screening of a large number of individuals for radiosensitivity in order to direct the positive cases to more relevant screening for cancer susceptibility, especially in accident or chronic occupational exposures.

P01-08

### Comparative cytogenetic analysis of chromosomal aberrations and premature centromere division in persons exposed to radionuclides

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The aim of this research is determining correlation between the frequency of premature centromere division (PCD) in metaphases in persons professionally exposed to radionuclides and noted chromosome aberrations (CA). Biological dosimetry was performed by conventional cytogenetic technique. The presence of PCD was confirmed by fluorescent in situ hybridization (FISH). The assay of pL1.84a repetitive DNA for chromosome 18 was used for detection of centromeric region. The analysis included 50 subjects from the Clinical Centre of Serbia (C) (the average age of  $45.24 \pm 1.18$  and the average exposition time  $17.96 \pm 1.15$ ), and 40 subjects from the control group (K) (the average age of  $44.40 \pm 0.98$  and the average years of  $19.67 \pm 0.98$ ), which were not exposed to genotoxic agents in their workplaces. The results showed that frequencies of CA and PCD are statistically significantly higher in subject exposed to radionuclides than in the control group (Mann-Whitney U test,  $P < 0.001$ ). The number of isochromatid breaks was statistically significantly higher in group of exposed to radionuclides (smokers compared to non-smokers) (Spearman's test,  $r = 0.32$ ;  $P < 0.05$ ). Analysis showed that there was a positive correlation between PCD and dicentrics, acentric fragments and chromatid breaks (Spearman's test,  $r = 0.49, 0.54, 0.29$ ,  $P < 0.05$ ). Applying the FISH method showed the presence of PCD in metaphases and interphase nuclei in subjects exposed to radionuclides. Considering PCD as manifestation of genomic instability, our research suggest that this phenomenon could be used as a possible cytogenetic biomarker for professional exposure to ionizing radiation.

P01-09

**Population study of chromosomal aberrations in air crew members compared to a control group**Prieto, Maria Jesus; Moreno, Mercedes;

Zapata, Leonor; Herranz, Rafael

Hospital Gregorio Marañon, SPAIN

Air crew was included as a radiation exposed occupational group in the last report of the International Commission for Radiation Protection (ICRP 90). Chromosome translocations are considered a biomarker of cumulative exposure to external ionising radiations better than chromosome dicentrics, we analysed the frequency of translocations from peripheral blood of a group of air crew members and controls matched for the age, smoking habits and sex. Metaphases spreads were obtained after incubation of peripheral blood lymphocytes in the presence of PHA for 48 hours at 37° (all procedures were done under laboratory routine procedures). Chromosomes 1 and 2 were painted red and a pancentromeric probe was used simultaneously to coloured all centromers green, to distinguish translocations and dicentrics, this procedure gives an efficiency of 28% when extrapolating to the full genome. There were analysed an average of 2000 metaphases per person, that means 560 cell equivalents. Our preliminary results does not show statistically significance differences in translocations frequency between both populations, but the statistical analyses is in progress, (it will be present in the final work at the Congress).

P01-10

**Assessment of dose response for chromosome aberrations due to internal alpha-radiation**Sotnik, Natalia; Azizova, Tamara; Osovets, Sergey

Southern Urals Biophysics Institute, RUSSIAN FEDERATION

Chromosome slides with Chromosome 5 painted using mBAND were analyzed for 40 employees of the Mayak Production Association. Mean frequency of stable intra-chromosomal aberrations per total cells analyzed was  $0.005 \pm 0.007$ . Correlation analysis indicated the lack of a significant correlation between external dose and the yield of intra-chromosomal aberrations ( $r = -0.02$ ). A linear dependence of the yield of intra-chromosomal aberrations on absorbed dose of internal exposure to incorporated  $^{239}\text{Pu}$  was revealed:  $Y = (0.0303 \pm 0.0065)D_{\alpha}$ , where Y is the yield of intra-chromosomal aberrations (in % per 100 cells);  $D_{\alpha}$  is the absorbed dose to bone marrow due to internal alpha-radiation (cGy).

P01-11

### Cytogenetic damage in cells exposed to ionizing radiation under conditions of a changing dose-rate

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The current international paradigm on radiation effects is mainly based on the effects of dose with some consideration for the dose rate. No allowance has been made for the influence of a changing dose rate (second derivative of dose) and biological effects of exposing cells to changing dose-rates have never been analyzed. Here, we provide evidence that radiation effects on cells may depend on temporal changes in the dose-rate. In the experiments cells were moved to and from a source of radiation. The speed of movement, the time of irradiation and temperature during exposure were controlled. Here we report the results of first experiments with TK6 cells which were exposed to a constant, to an increasing and to a decreasing dose-rate. The average dose rate and the total dose were same for all samples. Micronuclei were scored as the endpoint. The results show that the level of cytogenetic damage was higher in cells exposed to a decreasing dose-rate as compared both to an increasing and a constant dose-rate. This finding may suggest that the second derivative of dose may influence radiation risk estimates and it is expected to trigger further studies on this issue.

P01-12

### The effect of dimethyl sulfoxide on radiation induced chromosome aberrations in cultured CHO cells

Khvostunov, Igor; Pyatenko, Valentina; Korovchuk, Olga  
Medical Radiological Research Centre, RUSSIAN FEDERATION

The radioprotector properties of dimethyl sulfoxide (DMSO) are rather attractive for fundamental and applied implication in radiation biology and medicine. The cultured CHO cell line is a suitable model that allows estimation cell survival and chromosome aberration yield in mammalian cells. The goal of the current study was to investigate the reduction of radiation induced chromosome aberration yield in mammalian cells treated by DMSO. The CHO-K1 wild type cells were used as in vitro experimental model. The cells were grown in DMEM media containing 10% bovine serum albumine and antibiotics in monolayer culture. The cell samples with or without DMSO were irradiated to 1.0, 2.0, 3.0 and 4.0 Gy at a dose rate of 0.3 Gy/min, using 60-Co source. The DMSO was added to samples five min before irradiation in concentration of 0.5 and 1 M. The synchronized (G-1 phase) and logarithmic growing (cycling) cells were investigated. After exposure, cell were washed and fresh 10% bovine serum albumine was added to culture. The cells were fixed at 5, 7 and 9 h after irradiation. Approximately, 600 metaphases for chromosome-type aberrations were scored from each dose sample. It was found that DMSO treatment results in a 40 – 50% reduction of chromosomal aberrant cells as compared with non-treated cells irradiated to the same dose. The radiation-induced frequency of chromosomal aberrations decreased 2-fold having clear dose dependence. This reduction in chromosome aberration frequency is thought to be the result of a free radical scavenging and, perhaps, a suppressing radiation induced bystander effects in CHO culture. The experimental study was accompanied by theoretical Monte Carlo computer simulation of indirect action to DNA of cells by free water radical including OH scavenging in DMSO. The match of experimental and theoretical results is discussed.

P01-13

**The relative biological effectiveness of accelerated 73 MeV protons determined by CHO cell assay****Khvostunov, Igor; Pyatenko, Valentina; Korovchuk, Olga**  
Medical Radiological Research Centre, RUSSIAN FEDERATION

The purpose of the study was to estimate relative biological effectiveness (RBE) of 73 MeV protons using CHO-K1 cells assay. The cells were grown at 37 °C in DMEM media containing 10% bovine serum albumine and antibiotics in suspension. The synchronized (G-1 phase) cells were investigated. The cell samples were irradiated with single doses: 0.5, 1.0, 2.0, 3.0, 4.0, 5.0 and 4.0 Gy, using pulsed proton beam. Gamma-radiation of <sup>60</sup>Co at a dose rate of 0.5 Gy/min was used as a reference source. After exposure cell were washed and fresh 10% bovine serum albumine was added to culture. The cells were fixed at 18, 19 and 21 h after irradiation. Approximately, 500 metaphases for chromosome-type aberrations were scored from each dose sample using traditional Giemsa stain and light microscope. The experiment was carried out twice in a period of a year. The RBE values were determined by comparing the doses needed to obtain the same yield of chromosomal aberrations as with the reference <sup>60</sup>Co gamma source. It was found that the yield of dicentric per 100 cells follows linear-quadratic model:  $Y=1.56D+2.48D^2$  and  $Y=6.88D+2.11D^2$  (where D – absorbed dose in Gy) for <sup>60</sup>Co rays and 73 MeV proton irradiation, respectively. Therefore, protons were somewhat more biologically effective than <sup>60</sup>Co gamma-rays according to criterion of chromosomal aberrations. The proton RBE values obtained by regression fitting ranged 1.1-2.6 for absorbed doses from 6.0 to 0.5 Gy respectively. The data obtained at other proton acceleration centers agree with our results. Although the RBE value for protons was found to be rather small, it could be of radiotherapy importance. Accurate determinations of the RBE are necessary when extra therapeutic dose is inadmissible.

P01-14

**Effect of low dose gamma-radiation upon antioxidant parameters in heart and skeletal muscle of chick embryo****Vilic, Marinko<sup>1</sup>; Jasna, Aladrovic<sup>1</sup>; Blanka, Beer Ljubic<sup>1</sup>; Saveta, Miljanic<sup>2</sup>; Petar, Kraljevic<sup>1</sup>**<sup>1</sup>Faculty of Veterinary Medicine, University of Zagreb, CROATIA;<sup>2</sup>Ruder Boskovic Institute, CROATIA

This study was performed to investigate the effect of low-dose gamma-irradiation upon activity of glutathione peroxidase (GSH-Px), superoxide dismutase (SOD), catalase (CAT) and level of glutathione (GSH) and lipid peroxidation (TBARS) in heart and skeletal muscle of chick embryo and newly hatched chicks. Fertilised chicken eggs were irradiated with the dose of 0.3 Gy gamma radiation (source <sup>60</sup>Co) on the 19th day of incubation. The antioxidant parameters were measured in breast muscle (*m. pectoralis superficialis*), thigh muscle (*m. biceps femoris*) and heart of chick embryos on 1, 3, 6, 24 and 72 h after egg irradiation. All parameters were measured spectrophotometrically. On the 1<sup>st</sup> hour after irradiation lipid peroxidation significantly decreased in all type of muscles. At the same time GSH level and CAT activity were significantly decreased in the breast and thigh muscle of chick embryo while SOD activity was significantly decreased in thigh muscle. On the other side on the 1<sup>st</sup> hour after irradiation GSH-Px activity was significantly increased in thigh muscle. On the 3<sup>rd</sup>, 6<sup>th</sup> and 24<sup>th</sup> hour of experiment there were no significant changes in the investigated parameters between the groups. On the 72<sup>nd</sup> hour after irradiation results showed decreased activity of SOD in thigh muscle; decreased activity of CAT in the breast and heart muscle; decreased TBARS level in thigh muscle; increased level of GSH in the breast and thigh muscle; and increased GSH-Px activity in the breast muscle. The obtained results suggest that acute irradiation of chicken eggs on the 19<sup>th</sup> day of incubation with the dose of 0.3 Gy gamma radiation causes an oxidative stress in all types of muscles immediately after irradiation. However, the results of GSH-Px activity and GSH level on the one-day old chicks (72<sup>nd</sup> hour after irradiation) in skeletal muscle suggest probably a stimulating effect of low dose irradiation.

P01-15

### **Influence of the ionizing radiation on the individual variability of the antioxidant status indices**

**Shishkina, Liudmila; Khrustova, Natalia; Klimovich, Michail; Kozlov, Michail; Kushnireva, Yekaterina**

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As known, the biological consequences of the radiation action are due to the level of the antioxidant activity of the tissue lipids, the activities of the antioxidant defense enzymes and the lipid peroxidation intensity in organs and tissues of animals and also their ability to repair and normalization after the radiation injury. The aim of our work was to reveal the variability of the different parameters of the antioxidant status in tissues of the mice possessing different radiosensitivity (white outbreed mice, CBA and Balb/c) both in norm and under the action of radiation within the wide range of doses and dose rates. The following indices were analyzed: the antioxidant activity of the liver, brain and spleen lipids, the substance content reacting with the 2-thiobarbituric acid (TBA-RS) in the murine organs and blood plasma, the relative mass (index) of the murine liver and spleen and the lipid composition of the liver, spleen and blood erythrocytes of mice. The different variability of these parameters in tissues of control mice depending on their radiosensitivity was found. It was revealed that the radiation dose and dose rate result to the indefinite changes in the variability of the studied parameters. The data obtained allow us to conclude that the high variability of the antioxidant system parameters in the murine tissues plays the important role for the development of the biological consequences after the radiation action depending on the dose range and dose rate.

P01-16

### **STORE – Sustaining access to Tissues and data frOm Radiobiological Experiments**

**Birschwilks, Mandy<sup>1</sup>; Atkinson, Michael<sup>2</sup>; Aubele, Michaela<sup>3</sup>; Azimzadeh, Omid<sup>2</sup>; Bartlett, John<sup>4</sup>; Betsou, Fay<sup>5</sup>; Bijwaard, Harmen<sup>6</sup>; Galpine, Angela<sup>7</sup>; Gruenberger, Michael<sup>8</sup>; Lyubchansky, Edward R.<sup>9</sup>; Schofield, Paul<sup>8</sup>; Tapio, Soile<sup>2</sup>; Thomas, Gerry<sup>7</sup>; Grosche, Bernd<sup>1</sup>**

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The sharing of data and biomaterials from publicly funded experimental radiation science will yield substantial scientific rewards through re-analysis and new investigations. To that end, the STORE Consortium will create a platform for the storage and dissemination of both data and biological materials from past, present and future radiobiological research. STORE will provide a single online portal to radiobiological information that is presently distributed over scientific centres worldwide, and it will provide the necessary SOPs for the evaluation of archived tissue usability. The project will be completed by an assessment of viable financial models for long term support of a bio resource and Data Warehouse for radiobiology. The strategy to achieve these goals is multi-level:

1. to provide a “one-stop-shop” portal integrating international databases and other repositories currently active, such that the user can find material and data held remotely;
2. to archive primary (raw) data or pointers to data in public databases, from radiobiological experiments and studies, while this resource will be open to individual investigators and to funding agencies as a potential central repository for data sharing;
3. to physically archive threatened material resources which are considered to be a valuable resource to the Community, and whose state of preservation is consistent with STORE benchmarks;
4. to provide a single point of access to the integrated biomaterial resources through standardised request procedures.

The provision of a central portal is expected to help in the dissemination of awareness of the existence of these resources, many of which are, anecdotally, underused because their availability and existence is unknown. The generation of benchmarks for sample preservation and usability by preparation of SOPs will also help to disseminate formal standards by which the usefulness of archive material of this type can be assessed.

P01-17

### **Malignant blood diseases and tumors in acute radiation sickness survivors following the Chernobyl accident**

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State Institution "Research Center for Radiation Medicine of Ukrainian Academy of Medical Sciences", UKRAINE

In the result of Chernobyl accident acute radiation sickness (ARS) developed in 134 patients, including 28 ones who had died in 1986 due to severe radiation damages. At the end of 1986 we started follow-up study on oncological pathology development in 91 ARS survivors (doses up to 7.1 Gy) and 99 patients with doses below 1 Gy. All patients were residents of Ukraine. During 22 post-accidental years malignant diseases of hematopoiesis were observed in 5 patients and solid tumors in 15 ones. Oncohematological pathology consisted of hypoplasia of hematopoiesis (1 case; 1986), acute myelomonoblastic leukemia (1 case; 1998) and myelodysplastic syndrome (3 cases; 1993, 1995, 1996). All diseases brought patients to death. Patients' mean age was  $46.3 \pm 7.5$  at the moment of irradiation,  $54.0 \pm 8.1$  on disease onset and  $55.5 \pm 6.8$  years at person's death. Leukemia and myelodysplastic syndromes arose only in ARS survivors. Their latent period was  $9.6 \pm 2.1$  years.

The first malignant tumor, sarcoma of hip soft tissues, was diagnosed in 1992. This patient died in 1993. Before 2009 it was revealed as far back as 14 malignant neoplasms of different localization: cancers of colon (3 cases; 1997, 1999, 2001), stomach (2 cases; both in 2004), thyroid gland (2 cases; both in 2000), throat (1 case; 2000), kidney (1 case; 2000), lung (1 case; 2001), prostate gland (1 case 2001), basal cell carcinoma of head (1 case; 2006), urinary bladder (1 case; 2008), and neurinoma of lower jaw that had a malignant transformation (2003). Amongst persons suffered from cancer, 7 patients were successfully treated but the rest ones died. Totally, malignant tumors were diagnosed in 6 ARS survivors (6.6%) and 9 persons from group of comparison (9.1%). At the moment of death from malignant tumors the patients' age was  $66.2 \pm 9.8$  years. The period from irradiation to neoplasm development averaged  $15.9 \pm 3.1$  years.

P01-18

### Radiation-epidemiological estimation of thyroid pathology risk

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The main source of irradiation of the population after the Chernobyl accident was <sup>131</sup>I and its other short-lived isotopes that effected practically the whole population of Belarus. More than 30% of children aged up to 2 years old received doses over 1 Gy.

The aim of study is the retrospective analysis of clinical data depending on thyroid exposure level among people aged 0–3 at the moment of the Chernobyl accident.

Out of people observed in State registry, we formed 2 groups which are annually examined on thyroid pathology.

1. Basic group including 1004 residents of Gomel oblast aged 0–3 at the moment of the Chernobyl accident who were exposed to short-lived iodine radioisotopes.
2. Control group including 2020 persons born in 1987–1988 in Gomel region and who are observed in State Registry.

As one would expect, the highest estimates of the relative risk were received on thyroid cancer. Even at rather low absorbed thyroid doses, the attributive fraction was more than 94%. In group with high doses, practically all the cases were radiation-induced (AF = 98,5%).

At the same time, the analysis results showed that radiation component was the predominant one at realization of practically all the spectrum of thyroid pathology among subjects irradiated in early childhood. Evident growth of OR was observed in patients with all nodular forms of goiter with increase of thyroid dose. In subjects with thyroid dose above 1 Gy, the attributive fraction of different forms of nodular pathology varied from 60 to 98%.

Statistically significant estimates of relative risk were calculated on all forms of thyroid nodular pathology.

Relative risk of any goiter nodular form in persons affected in early childhood was 3,7 (AF = 71,1%).

These results suggest that considerable part (up to 71%) of goiter nodular form diseases among residents of Gomel region, affected in early childhood, can be referred to thyroid exposure.

P01-19

### Acute myocardial infarction in the cohort of Mayak PA nuclear workers

Grigoryeva, Evgenia<sup>1</sup>; Azizova, Tamara<sup>1</sup>; Muirhead, Colin<sup>2</sup>; Druzhinina, Maria<sup>1</sup>; Vlasenko, Elena<sup>1</sup>; Sumina, Margarita<sup>1</sup>; O'Hagan, Jacqueline<sup>2</sup>; Zhang, Wei<sup>2</sup>; Haylock, Richard<sup>2</sup>; Hunter, Nezahat<sup>2</sup>

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<sup>2</sup>Health Protection Agency, UNITED KINGDOM

Incidence of and mortality from acute myocardial infarction (AMI) have been studied in a cohort of 12210 workers first employed at one of the main plants of the Mayak nuclear facility during 1948–1958 and followed up to 31 December 2000. Information on external gamma doses was available for virtually all of these workers (99.9%); the mean ( $\pm$  standard deviation, SD) total external gamma dose was  $0.91 \pm 0.95$  Gy (99% percentile 3.9 Gy) for men and  $0.65 \pm 0.75$  Gy (99% percentile 2.99 Gy) for women. In contrast, plutonium body burden was measured only for 30% of workers; amongst those monitored, the mean ( $\pm$  SD) absorbed cumulative liver dose was  $0.40 \pm 1.15$  Gy (99% percentile 5.88 Gy) for men and  $0.81 \pm 4.60$  Gy (99% percentile 15.95 Gy) for women. 683 disease cases and 338 deaths from AMI were identified in the study cohort. Having adjusted for non-radiation factors, AMI mortality data showed a statistically significantly increasing trend with external dose, excess relative risk per Gy (ERR/Gy) was equal to 0.265 (95% CI 0.004, 0.526), but the evidence for this trend was greatly reduced if adjustment was made for internal liver plutonium dose. In contrast to the mortality findings, there was very little evidence of an association between AMI incidence and external dose, ERR/Gy was equal to 0.029 (95% CI -0.076, 0.134). Among workers with internal liver doses from plutonium exposures, AMI incidence and mortality were raised at 0.1–0.5 Gy relative to lower doses; there was still borderline evidence of such differences after adjusting for external dose. The trends in AMI incidence or mortality with internal dose were not statistically significant. Whilst the data on AMI incidence and mortality were consistent when analysing internal doses, the same was not true when analysing external doses.

P01-20

**Stroke in the cohort of Mayak  
PA nuclear workers**

Azizova, Tamara<sup>1</sup>; Muirhead, Colin<sup>2</sup>; Druzhinina, Maria<sup>1</sup>; Grigoryeva, Evgenia<sup>1</sup>; Vlasenko, Elena<sup>1</sup>; Sumina, Margarita<sup>1</sup>; O'Hagan, Jacqueline<sup>2</sup>; Zhang, Wei<sup>2</sup>; Haylock, Richard<sup>2</sup>; Hunter, Nezhahat<sup>2</sup>

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<sup>2</sup>Health Protection Agency, UNITED KINGDOM

Incidence of and mortality from stroke have been studied in a cohort of 12210 workers first employed at one of the main plants of the Mayak nuclear facility during 1948–1958 and followed up to 31 December 2000. Information on external gamma doses was available for virtually all of these workers (99.9%); the mean ( $\pm$  standard deviation, SD) total external gamma dose was  $0.91 \pm 0.95$  Gy (99% percentile 3.9 Gy) for men and  $0.65 \pm 0.75$  Gy (99% percentile 2.99 Gy) for women. In contrast, plutonium body burden was measured only for 30% of workers; amongst those monitored, the mean ( $\pm$  SD) absorbed cumulative liver dose was  $0.40 \pm 1.15$  Gy (99% percentile 5.88 Gy) for men and  $0.81 \pm 4.60$  Gy (99% percentile 15.95 Gy) for women. 665 disease cases and 404 deaths from stroke were identified in the study cohort. Having adjusted for non-radiation factors there were no statistically significant trends in either incidence or mortality from stroke with either total external gamma dose or total absorbed internal liver dose; and stroke incidence or mortality rates did not differ significantly between categories for external or internal dose.

P01-21

**Uranium health effects: results  
from the French cohort of  
uranium processing workers**

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A cohort of 2709 male workers (72786 person-years) employed at the AREVA uranium processing plant (1960–2005) in France was constructed to investigate the risk of cancer and non-cancer mortality in relation to occupational exposure to uranium. Cause-specific mortality in the cohort was compared to the national and regional mortality rates (1968–2005) by computing standardized mortality ratios. Exposure to natural and reprocessed uranium compounds, classified by their solubility, was assessed through the plant-specific job-exposure matrix. Internal comparison between exposed and unexposed subjects was then done to estimate relative risk of mortality in regards of each type of exposure. Cox regression models adjusted for age, calendar period and socioeconomic status were used for analyses. At the end of the follow-up, 15% of the cohort was deceased. From 193 cancer deaths, 48 lung cancers and 18 lympho-hematopoietic cancers, considered as uranium target organs, were observed, as well as 101 deaths from cardiovascular diseases. For none of these causes, mortality among the cohort was significantly increased comparatively to the reference mortality rates. Internal comparison showed an elevated risk of mortality from considered causes among workers exposed to reprocessed uranium-bearing compounds. Mortality risk tended to increase with decreasing solubility of uranium compounds. This cohort study provides original results on cancer and non-cancer mortality related to protracted low-dose uranium exposure. Results suggest that effects on mortality differ by type and solubility of uranium compounds. Availability of data on associated exposure to carcinogenic chemical is another interest of this cohort. The cohort is still young but its further follow-up with extension to other AREVA plants will increase statistical power of the future analyses. Further investigation will focus on cardiovascular risk in dose-response analyses including biological parameters into the models.

P01-22

**Leukaemia risk among European uranium miners in dependence on doses from radon, external gamma, and long lived radionuclides**

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Safety, Institute for Radiological Protection and Nuclear, FRANCE; <sup>4</sup>Federal Office for Radiation Protection, GERMANY;

<sup>5</sup>Health Protection Agency, Radiation Protection Division, UNITED KINGDOM; <sup>6</sup>University of Salzburg, AUSTRIA

The study presents recent findings based on leukaemia mortality (69 cases) in three European cohort studies of uranium miners, including 9979 Czech, 3271 French, and 34 994 German miners. The risk is analyzed in relation to cumulated equivalent dose from radon and its progeny, from external gamma radiation, and from inhaled long lived alpha radionuclides. Exposures were estimated from measurements of radon, external gamma, and gross alpha activity in the aerosol. The earlier exposure estimates were based on uranium content in the ore and aerosol measurements in mines. The annual absorbed doses to the red bone marrow from exposure to radon gas, its progeny, long-lived radionuclides, and from exposure to external gamma radiation have been calculated for each miner from the first year of employment to the end of follow-up using the ICRP dosimetric and biokinetic models. The mean cumulated absorbed doses in the entire study are 38 mGy from external gamma, 2.1 mGy from radon and its progeny, and 0.9 mGy from long lived radionuclides. In terms of equivalent dose (using a radiation weighting factor 20 for alpha radiations), about 42% is from radon and its progeny, 39% is due to gamma radiation, and 19% is due to inhalation of uranium and its decay products. The risk coefficients (excess relative risk per sievert) were estimated using Poisson regression analysis. For each separate component, the risk coefficient was significant with p-values: 0.010 (gamma), 0.008 (radon), and 0.020 (long lived radionuclides). The estimated risk coefficient for the combined dose was 3.7 (90%CI: 1.1 – 8.8). Although the estimated risk is subject to some uncertainty due to small numbers and the dose uncertainty, its magnitude is consistent with estimates from other studies.

*The work was supported by the European Commission under FP6 (Contract FI6R 516483) and by the State Office for Nuclear Safety of the Czech Republic (VZ 60022490) and the Czech Ministry of Health (NS 10596-3/2009).*

P01-23

### **Ionizing radiation and mortality from stomach cancer – Results of the German uranium miners cohort study, 1946–2003**

**Kreuzer, Michaela**<sup>1</sup>; **Marsh, James**<sup>2</sup>; **Dufey, Florian**<sup>1</sup>; **Grosche, Bernd**<sup>1</sup>; **Gregoratto, Demetrio**<sup>2</sup>; **Nosske, Dietmar**<sup>1</sup>; **Schnelzer, Maria**<sup>1</sup>; **Tschense, Annemarie**<sup>1</sup>; **Walsh, Linda**<sup>1</sup>

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**Introduction:** In the German uranium miners cohort study a 1.15fold statistically significantly increased risk of mortality from stomach cancer compared to the general male population was observed. The aim of the present analyses is to investigate the influence of ionizing radiation.

**Methods:** The cohort includes 58,987 men who had been employed for at least six months between 1946 and 1990 at the former Wismut uranium mining company in East Germany. By 2003 a total of 20,920 deaths occurred, among them 595 deaths from stomach cancer. Information on exposure to radon progeny in Working Level Months (WLM), external gamma radiation (mSv) and long-lived radionuclides (kBqh/m<sup>3</sup>) is based on a detailed job-exposure matrix. Internal Poisson regression models were used to estimate the excess relative risk (ERR) per unit of cumulative exposure and its 95% confidence limits (CI).

**Results:** There was a statistically significant increase of death from stomach cancer in relation to either cumulative exposure to radon (ERR/100 WLM=0.022; 95% CI: 0.001–0.043), external gamma radiation (ERR/Sv=1.83; 95% CI: 0.41–3.25) or long-lived radionuclides (ERR/kBqh/m<sup>3</sup>=0.018; 95% CI: 0.0044–0.032), respectively. A statistically significantly increased relative risk was observed at exposure categories above 1,500 WLM (RR=1.74; 95% CI: 1.06–1.43) and above 300 mSv external gamma radiation (RR=2.22; 95% CI: 1.07–3.37).

**Conclusion:** The present preliminary analyses suggest that occupational exposure to ionizing radiation may increase the risk for stomach cancer among uranium miners. In a next step stomach doses based on dosimetric models will be calculated and the corresponding risk estimates presented. Moreover, potential confounder like exposure to arsenic, fine or quartz fine dust will be considered.

P01-24

### **Case-control study of lung cancer incidence under combine occupational and domestic radon exposure**

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Case-control study of lung cancer incidence for the population of Lermontov city (Caucasus) was conducted. Near the territory of Lermontov city the uranium mining was conducted from 1947 to 1990. The considerable part of male population of the city worked in uranium mining. In the Lermontov city three main districts with different kinds of houses are exist: multistorey buildings constructed after 1970; one – three storey buildings constructed before 1970; one-storey rural type houses. The average indoor radon concentrations in these districts are 170, 540 and 910 Bq/m<sup>3</sup> respectively. The lung cancer rate considerably above the average regional level was observed for the population of Lermontov city. The indoor radon concentrations and occupation radon exposure levels in the group of 121 lung cancer cases and in control group composed of 196 peoples were analyzed. Both archive and contemporary indoor radon measurements in combination with the retrospective detectors were used for reconstruction of domestic exposure. The temperature normalization approach was used for assessment of average annual radon concentration in dwellings from the results of radon measurements by charcoal absorbers. The average radon exposure reconstruction period was 38 years for case group and 34 years for control group. The occupation expose information was obtained from medical-sanitary department of former uranium mining facility. It was shown that in average 32% of total radon exposure for uranium miners was due to domestic indoor exposure. It means that in epidemiological studies of uranium miners the domestic radon exposure also should be taken into account. The excess relative risk of lung cancer incidence in case of combine occupational and domestic radon exposure was ERR=0.011 (– 0.003 – 0.029) WLM<sup>-1</sup>. After the excluding of uranium miners from analysis (46 men from case group and 9 from control group) the excess relative risk value was estimated as ERR=0.0040 (– 0.003 – 0.034) WLM<sup>-1</sup>.

P01-25

**Late effects of radioactive and chemical contamination**

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The influence of the polluted environment on health of the population has been studied for a decades in industrial countries. It is established that polluted environment can cause great variety of diseases in all categories of inhabitants. Most vulnerable groups are children and pregnant women because of possible genetic or teratogenic defects in the newborns. To prevent this situation, control of the environment is established. Besides the usual industrial pollutions, during the NATO air strikes on Serbia in 1999, many industrial facilities were destroyed and harmful, toxic substances were released in concentrations even ten thousand times higher than maximum permissible. Additionally, depleted uranium ammunitions were deployed in south of Serbia. In the years after, health surveillance of the soldiers who served in DU contaminated regions in Kosovo were organized and increased cancer incidence is noticed as well as non-specific diseases (cardiovascular, rheumatic) and psychological disturbances, including PTSP, alcohol abuse and social problems. According to EUROCAT protocol their children born after the strikes were followed-up too, and higher rate of congenital (skeletal, cardio-vascular) and chromosomal anomalies, immunological disorders and endocrine diseases were noticed. Similar results were found in the inhabitants of the most polluted regions.

P01-26

**Mortality due to gastrointestinal cancers in northern part of East-Ural Radioactive Trace**

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Accidental explosion of waste a storage tank at former Soviet Union plutonium production plant "Mayak" in 1957 had released considerable radioactivity to atmosphere and caused contamination of the environment (East-Ural Radioactive Trace, EURT). Available data on the radioactive contamination allowed the assessment of post-accident population radiation exposure. Due to preferably internal pattern of exposure the gastrointestinal organs received higher doses in comparison with other soft tissues. The objective of the study was to evaluate the register of causes of death, created using deaths certificates issued by rural municipalities at northern part of EURT, as a source of information for analysis of mortality sauced by radiation induced gastrointestinal cancers. In the register the case (6158) and control (4844) groups were formed according to assessments of initial contamination of municipalities by Sr-90 – above and bellow 0.1 Ci per square kilometer respectively. Average colon dose 0.07 Gy and 440 gastrointestinal cancer deaths was observed in case group. The analysis included comparison of gastrointestinal cancers contribution to total number of deaths in the groups and estimation of excess number of deaths for sex, age and time since accident categories. To assess years of life lost (YLL) due to excess cancer cases the life durations were compared. By results of estimation total number of excess cancer deaths is  $57 \pm 39$  (with 90% CI) and total YLL is  $893 \pm 279$  for period from 1967 to 2000.

P01-27

**Incidence of childhood leukaemia in the vicinity of Finnish nuclear power plants**

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Childhood leukaemia near nuclear installations has been investigated widely in the past decades, but the results have been inconclusive. Radiation exposure for the population appears negligible.

We investigated leukaemia incidence in children living near the two Finnish nuclear power plants (NPPs) using both cohort and case-control analysis.

The residential cohorts defined by censuses in 1980 and 1990 showed no increased risk of childhood leukaemia in the population residing within a 15-km zone from the NPPs compared to the 15–50-km zone.

In the case-control analysis with individual residential histories for 16 children with leukaemia and their 64 matched controls, residential distance from the NPP was not associated with leukaemia.

The results of the cohort and case-control analyses were consistent and neither of them indicated an increased risk of leukaemia. Even though the small sample size and lack of population residing within the 5-km radius limit the strength of the conclusions, the findings are reassuring from the public health perspective.

P01-28

**Radiation doses from global fallout and cancer incidence among reindeer herders and Sami in Northern Finland**

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People in the Arctic regions can be heavily exposed from the global radioactive fallout due to their diet rich in reindeer meat in which radionuclides accumulate. The primary aim of this study was to assess whether the estimated lifetime cumulative radiation doses for the Arctic population from atomic bomb testing have had detectable effects on the incidence of cancer. A cohort of the Arctic population in Finland ( $n = 34,653$ ) was identified through the Population Register Center with grouping by reindeer herding status, ethnicity and radiation exposure. Annual average radiation doses, based on <sup>137</sup>Cs whole-body measurements, were assigned by birth-year, gender and reindeer herder status. Cancer cases of radiation-related cancer types (cancers of the bladder, female breast, colon, esophagus, liver, lung, ovary, stomach, brain and nervous system, bone and thyroid, non-melanoma of the skin, basal cell carcinoma of the skin, and leukemia) during 1971–2005 were identified from the Finnish Cancer Registry. A total of 1,580 cancer cases were observed versus 1,948 expected on the basis of incidence rates in Northern Finland [standardized incidence ratio (SIR) was 0.81 with 95% confidence interval (CI) of 0.77–0.85]. For the reindeer herders SIR was 0.72 (95% CI 0.60–0.85) and for the Sami people SIR was even lower, 0.47 (95% CI 0.37–0.60). No association between the lifetime cumulative radiation exposure from global radioactive fallout and cancer incidence in the Arctic population was found. Potential underestimation and misclassification of the radiation dose may affect the results and the findings should be interpreted with caution.

P01-29

### Health impairments in occupational ionizing gamma exposure

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Work involving the preparation and assay of radiopharmaceuticals is associated with the highest occupational medical staff exposure from gamma emitters (<sup>99m</sup>Tc, <sup>131</sup>I). Our health status surveillance, a 5 years follow-up, of 16 subjects (18.11 ± 13.76 years exposure length, 31.3% easy-smokers) included mandatory national recommendations effect indices: clinical, haematological, cytogenetic micronuclei-MN in peripheral blood. Moreover we performed MN in sputum, oral exfoliated cells, oxidative stress indices (whole blood superoxide dismutase activity – SOD, serum lipoperoxides – Lpox). During follow-up, 18.7% subjects over 12 years <sup>131</sup>I exposure were monitored for occupational thyroidal pathology, other 12.5% for dermic papilloma, 56.3% for cardiovascular disorders or allergic rhinitis. Lymphocytes decreased level correlated inversely with exposure length in 31.2% cases. HGB, HCT modifications were associated with reticulocytes response in 12.5% subjects, but inverse correlated with years of exposure ( $r = -0.42$ ). In 56.3% cases were neutrophil modifications with a 3 years tendency of normal values return at 28.1%. For 6.3% were found numerical and structural blood MN disorders due to workload or no radioprotection rules used. In 36.4% cases MN high level in oral mucous epithelial cells were indirect correlated with exposure length but direct correlated with smoking habit ( $r = 0.58$ ). Sputum type II cytology showed 16.7% ferruginous bodies over 20 years exposure, no correlation with smoking habit. Despite of allowable external exposure limits recorded, chronic exposure increased the SOD activity ( $148.8 \pm 106.6$  U/ml) in 12.5% cases and Lpox level ( $2.4 \pm 1.9$  μmol/l) at 18.7%, having no correlation with tobacco use. We emphasized that continuously clinical and bioassay monitoring in nuclear medicine practices can reveal early changes of radiation induced effects. New proposals on national legislation for improving health surveillance of medical staff will be made.

P01-30

### Spatial correlations of microdosimetric parameters and biological endpoints associated with radon inhalation

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Radon and its progenies can be inhaled and deposited in the airways. Many of the decay products of the radioactive radon isotopes are short lived alpha, beta and gamma active atoms interacting with the epithelial tissue after their deposition and decay in the lung. Some of the radon and thoron decay products are short lived alpha-emitters and can transmit large amount of localized energies to the surrounding cells causing cellular and tissue damages. Since these interactions take place at a microscopic scale, the averaging of radiation dose to the whole body or the whole lung seems not to be fully appropriate. The aim of this study was to reveal the exact spatial correlations of different microdosimetric quantities and biological endpoints in the epithelium following the deposition and decay of short lived radon progenies. For this purpose complex numerical methods were developed. Air and particle transport in reconstructed three dimensional airways was simulated. Particle deposition coordinates were recorded and alpha tracks generated. The cellular architecture of the epithelium was reconstructed and interaction of alpha tracks with the cells modelled. Our results demonstrate that some clusters of cells may receive high local doses even if the average dose is low. For the cells located in the deposition hot spots the probability of multiple hits, inactivation and transformation is at least one order of magnitude higher than the corresponding values assuming uniform surface activities. Present results may be included in future radiation risk assessing models and radiation protection protocols.

P01-31

**Cardiovascular risk after low-dose radiation exposure**

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**Introduction:** There are considerable uncertainties concerning health effects of low doses of ionising radiation on heart. The Life Span Study of the Japanese atomic bomb survivors shows excess radiation-associated risk for cardiac disease even at doses of 0.5 Gy.

**Aim:** We have used both a human endothelial cell line and a mouse model to study proteomic alterations after low-dose irradiation.

**Methods:** The human endothelial cell line Ea.hy926 was irradiated with 0.2 Gy gamma rays with two different dose rates and the cells were harvested 4h and 24h after the irradiation. The proteome changes were analysed using 2 DE-DIGE techniques. Using a C57/Bl6 mouse model functional and proteomic alterations in mitochondria isolated from irradiated and sham-irradiated murine hearts 4 weeks after heart-focused irradiation (0.2 Gy, 2 Gy X ray) were analysed.

**Findings:** In the endothelial cell line, out of more than fifty protein spots that showed significant alterations in their expression 22 proteins were identified. Among the pathways affected by the low-dose ionising radiation are Ran and Rho/Rock pathways, stress response and glycolysis. In the mouse model, no differences between sham- and irradiated cardiac mitochondria were found in swelling, respiratory coupling and production of ATP. However, we could identify significantly increased ROS formation in cardiac mitochondria 4 weeks after the exposure to 2 Gy ionising radiation.

**Conclusions:** The immediate response to low-dose ionising radiation in the human endothelial cell line includes alterations in the expression of small GTPases (or their regulators) such as Ran and RhoA, the expression of which is known to be regulated by the production of reactive oxygen species (ROS). Similarly, we find in the long-term response of irradiated murine heart mitochondria an increased production of endogenous ROS. We conclude that changes in the oxidative stress may be an important factor in the development of radiation-induced cardiac disease.

P01-32

**Modelling and experimental studies on adaptive response**

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The ability of a low “priming” radiation dose to decrease the cell response to a subsequent higher “challenging” dose is termed adaptive response (AR). The main proposed mechanisms to explain AR are: increased efficiency of DNA repair, induction of anti-oxidant enzymes, alteration of cell cycle progression, changes in chromatin conformation. The model proposed by Curtis in 1986 that considers a modulation of the efficiency of DNA repair activity and of the level of anti-oxidant enzymes, starting from the framework of lethal-potentially lethal (LPL) model, was extended with the inclusion of the dynamical variables representing the efficiency of repair, the levels of radiation induced radicals and of anti-oxidant enzymes. In the simulation code particular attention was devoted to the induction of anti-oxidant enzymes as adaptive response mechanism, even if the more relevant mechanism remains the modulation of the repair efficiency, by which the cells processes the initial radiation damage. Furthermore, in order to describe different radiation qualities, the weight of the two factors (i) production of direct damage and (ii) production of free radicals have been made variable in the model. Our model is able to describe the protective effect of a priming dose. Moreover, in agreement with the literature data, the simulations show that the AR happens in a given priming dose and priming dose rate ranges only, and requires at least 4 hours to develop. In order to get more insights on the role of cell-cell communication as factors affecting the AR, experimental studies have been performed using sparse or confluent AG1522 cell monolayer. The results obtained after gamma-irradiation suggest that cell density is a crucial factor for observing an AR. The possibility of an AR induced as bystander effects and as a function of radiation quality is under study.

P01-33

**The  $\alpha$ -particle irradiator at the ISS: a useful tool for low dose/dose rate studies**

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An  $\alpha$ -particle irradiator has been developed for radiobiological studies at the Istituto Superiore di Sanità (ISS), Rome, Italy. It consists in a 20 mm diameter stainless steel chamber that can be equipped with alpha sources of different activities, allowing modulation of dose and dose-rate. In the present configuration the irradiator, equipped with Cm-244 or Am-241 sources, provides a useful facility for irradiation of cultured mammalian cells with  $\alpha$ -particles at dose rate in the range of 1–100 mGy/min, with spatial variations of less than  $\pm 7\%$ . Moreover, for both sources the photon doses calculated at the cell entrance are negligible compared to the  $\alpha$ -particle dose. A further important feature of the irradiator is that the seal necessary to keep the helium gas inside the chamber is provided by the Mylar base of the sample holder. This solution decreases energy degradation and eliminates the problems related to the estimation of the air layer between the exit window and the sample holder. Mylar-based Petri dishes with different irradiation area were designed so that that can house permeable membrane inserts, mimicking the same geometry of commercial cell culture insert companion plates. Due to the limited residual range of  $\alpha$ -particles, this feature is particularly valuable for co-culture experiments aimed at investigating bystander effects. The small size allows the irradiator to be easily positioned into a standard CO<sub>2</sub> incubator, avoiding use of "ad hoc" and separate devices for temperature control and for keeping the cells in the proper air/CO<sub>2</sub> mixture. This important feature makes it possible to carry out long term irradiation and/or post-irradiation incubation of cells in physiological conditions. The irradiator has been already successfully used to continuously irradiate confluent primary human fibroblasts for up to 14 days as well as to investigate cellular and molecular end points in directly hit and in bystander primary human fibroblasts.

P01-34

**Using of radioprotectors and antidotes during the external radiation exposure and radionuclide incorporation**

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We have studied experimentally on mice the compatibility of radioprotectors (indralin and riboxin) and antidote drugs (potassium iodide and ferrocen) during the external gamma ray exposure and incorporation of <sup>131</sup>I and <sup>137</sup>Cs. We have shown that during combined action of both external and internal radiation factor radioprotectors and antidotes do not affect the efficiency of each other. In the absence of antidotes the radioprotectors alterates the exchange kinetics of the radionuclides. Application of the indralin alone increases the concentration of <sup>131</sup>I in the thyroid and kidneys and <sup>137</sup>Cs in the liver. Application of riboxin alone decreases the concentration of <sup>137</sup>Cs in organs and tissues at early times. The accumulation rate and concentration values for radionuclides in different organs depends on the time of radioprotector application.

P01-35

**Low-dose irradiation delays neuronal differentiation during early embryonic brain development****Quintens, Roel; Samari, Nada; Monsieurs, Pieter; Janssen, Ann; Neefs, Mieke; Michaux, Arlette; de Saint-Georges, Louis; Baatout, Sarah; Benotmane, M. Abderrafi**

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Recent interest into the effects of low-dose ionizing irradiation on the human brain has been rather limited partly due to the fact that the adult brain (postmitotic neurons) is very insensitive to radiation damage. However, epidemiological studies on individuals who were exposed to ionizing radiation in utero after the atomic bombings in Hiroshima and Nagasaki, showed an increased incidence of mental retardation and behavioural defects. These defects were most outspoken when the irradiation occurred between weeks 8 and 15 of gestation, which is a critical time for human embryonic neuronal development. This suggests a higher sensitivity of neurons during their early differentiation.

Initial experiments in our laboratory showed that young adult mice that had been irradiated with doses (1 Gy) in utero at day 12 of gestation (E12) and at lesser extent with lower doses (0.2 Gy) at day 11 of gestation (E11) suffered from memory and learning defects as assessed by Morris Water Maze testing. In order to identify possible pathways involved in neurogenesis that could be affected by low-dose irradiation during early neuronal development, we irradiated pregnant mice at day 10 (E10) and 11 of gestation at 0, 0.1 or 0.2 Gy. Three hours after irradiation, embryonic brains were isolated for total RNA extraction and subsequent microarray analysis using the MoGene 1.0 ST Arrays (Affymetrix, USA).

In line with earlier observations, our analysis revealed upregulation of several genes involved in p53-responsive pathways in a dose-dependent way in both E10 and E11 irradiated embryos, indicating that these pathways are important for the response of the embryonic brain to low doses of irradiation. Furthermore, we observed that low doses of irradiation attenuate many functions of the normal physiological changes in gene expression, and in particular functions related to neurogenesis and synaptogenesis. This suggests that normal neuronal development may be delayed by low-dose irradiation. A significant amount of the affected

genes involved in neurogenesis were predicted targets of the neuronal gene silencer RE-1 silencing transcription factor (REST) of which the expression in the embryonic brain decreases during differentiation. Interestingly, expression of REST was increased when E11 brains were irradiated both at 0.1 and 0.2 Gy, while the expression of the REST target genes dose-dependently declined.

Together, our data indicate that the cognitive defects observed in young adult mice that had been irradiated in utero may be related to delayed neuronal differentiation due to a repression of neuronal genes following increased expression of the neuronal silencer REST. The exact mechanism behind the radiation-induced stimulation of REST remains to be elucidated.

*This work is financially supported by the NOTE project EC contract: FI6R-036465.*

P01-36

**EU GENRISK-T project: Thyroid cancer risk in the Balb/c mouse strain after exposure to low doses of X-rays**

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Thyroid cancer is one of the malignancies that are induced by radiation exposure as supported by epidemiological studies of different radiation-exposed groups such as: the survivors of atomic bombing in Japan, Marshall islanders exposed to nuclear test fall out and children undergoing head or neck radiotherapy or accidentally exposed to radiation like in Chernobyl accident. In these two last groups, the age was an important determinant of the radiation-exposure outcome.

Besides the age at the time of exposure, genetic susceptibility is one of the factors that can interfere in the development of thyroid cancer. The aim of the FP6 EU GENRISK-T project is to define the genetic component influencing the risk of developing thyroid cancer after exposures to low dose radiation as there is currently no accurate model of the dose response curve for thyroid cancer at low doses. To shed light on the cause-effect relationship between low radiation exposure, thyroid cancer and genetic background we used a mouse model with low sporadic rate of developing thyroid cancers. Such studies of genetic susceptibility would be impossible to conduct in humans due to the significant incidence of sporadic thyroid cancers and to the presence of "confounding" non-radiation induced tumours.

Balb/c mice were irradiated at 12 weeks of age with either low (25cGy, 50cGy, 100cGy) or high (4Gy) X-ray doses and sacrificed 4 hours, 9 or 18 months post-irradiation. Thyroid cancer was assessed via histopathology examinations to detect any morphological alteration in the thyroid tissue structure. In addition, we used immunohistochemistry to detect the level of some proliferation markers (PCNA and Cyclin-D1) that would be indicative of the proliferation status of the thyroid tissue.

Based on histopathology examinations of thyroid tissue sections from the 9 month mouse group, we found that no mice had developed thyroid tumors even at the highest doses. However, at a dose of 1 Gy, we found two specific cases, one of microfollicular hyperplasia and the other one of acute infiltrate with granulocyte. Regarding the immunolabeling with Cyclin-D1 and PCNA, we found a dose-dependent increase of these molecules significant from 25cGy onwards compared to the controls. Examination of thyroid tissue sections from the remaining mouse groups (4 hours and 18 months) is currently under progress. In parallel, high-throughput microarray technology is currently performed.

*This work is financially supported by the EU Euratom programme (GENRISK-T : contract FP6-36495).*

S02-01

**Current challenges for radiation protection in medical X-ray and molecular imaging**Mattsson, Sören

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The increasing radiation exposure from medical diagnostic procedures is becoming a subject of concern and social interest and is given increased attention by health professionals, authorities and manufacturers. Also patients are now more and more concerned about their exposure situation. New imaging technologies that use x-rays or radioactive materials are continuously developed. These include faster CT-scanners, new interventional techniques, increased use of positron emission tomography (PET), and digital imaging techniques. The techniques are often combined into a single investigation, such as PET/CT and SPECT/CT. As the availability and quality of radiological imaging methods has continued to grow, increases in image quality rather than a reduction in patient dose continues to characterise modern practice. The benefits of the new techniques are so rewarding that a tendency to overuse the technology has occurred. The aim of the presentation is to inform about developing technologies and clinical techniques, and their associated potential radiation risks to patients and staff. The presentation also includes a discussion on tools for optimising investigations and improved dose management, and most importantly, ways to create greater awareness of the physicians prescribing the examinations. It is important that the advances in imaging technology also provide increased medical benefits to large numbers of patients, while maintaining the efforts to keep unnecessary exposure to a minimum. Therefore, persons educated and trained in radiation protection have to be fully involved in planning, dose measurement and optimisation and have to initiate necessary radiation safety training for the medical staff, including those who refer the patients for an investigation. Strict guidelines need to be developed so that referring physicians carefully weigh the benefits against the potential risks and base their decisions on medically relevant data.

S02-02

**Justification of medical exposure in diagnostic imaging – a way forward**Malone, Jim et al.

IAEA

S02-03

**Collective doses from medical exposures: an inter-comparison of the “TOP 20” radiological examinations based on the EC guidelines RP No 154**

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The use of ionizing radiation in diagnostic radiology makes a major contribution to population dose. The introduction of new modalities such as multi-detector computed tomography has tended to increase the doses; it is therefore of concern for the radiation protection authorities to follow trends in the medical use of radiation. An EU-funded project called DOSE DATAMED (2004–2007) was set up to develop harmonized methods for future surveys of population exposure from medical x-rays. The project group was recruited from radiation control authorities or expertise institutes in ten European countries. The guidance was published in 2008 by the European Commission as report No 154 in the Radiation Protection Series. Since then, the network of Heads of European Radiation Control Authorities (HERCA) has appointed a working group (WG6) to test the feasibility of RP154 for ongoing surveys. Some of the countries are performing full national surveys based on the identification and frequency counting of 225 specific x-ray examinations or 70 broader categories of examinations. Others are testing the methodology based on the set of 20 examinations identified as the ones contributing most significantly to collective effective dose. Pitfalls and challenges associated with the different approaches

will be identified. All countries are collecting dose values for at least the “TOP 20” examination types, to establish updated national information on doses representative for current apparatus and scan techniques. In the year 2000, the collective effective dose for the “TOP 20” examinations ranged from 303 to 1421 mSv per 1000 population in Europe. Comparison of the collective effective dose based on the frequency in 2008 and updated dose information from the “TOP 20” examination types will be presented, looking for trends and information from more countries.

S02-04

**Medical exposure of the French population in 2007****Etard, Cécile<sup>1</sup>; Aubert, Bernard<sup>1</sup>; Sinno-Tellier, Sandra<sup>2</sup>**<sup>1</sup>Institut de Radioprotection et de Sécurité Nucléaire, Direction de la radioprotection de l'Homme, FRANCE; <sup>2</sup>Institut de Veille Sanitaire, Département Santé-Environnement, FRANCE

The Institute for Radioprotection and Nuclear Safety and the National Institute for Public Health Surveillance have been collaborating since 2003 to provide updated data on medical exposure of the French population, as requested in the European Directive 97/43. The first report published in 2006 was based on 2002 dataset. This study is related to 2007 dataset.

For private practice, a continuous and representative sample of about 1% of the population has been followed by the National Health Insurance since 2006. All exams (radiology and nuclear medicine) performed to people of this sample by private practitioners are registered. They have been analysed according to the type of exam, age and sex of the patient.

For public practice, as no registration was available, two national surveys have been specifically conducted:

- Reporting questionnaires in 50 representative radiological departments in public hospitals,
- One questionnaire sent to all the 127 public nuclear medicine departments.

In both cases, the total activity of the department in 2007 and dosimetric informations (DAP or administered activity) have been collected and are being analysed.

A mean effective dose has been associated to each type of exam, using the national guidelines in radiology or nuclear medicine, recent French and European studies and data collected through the two surveys.

A new report is foreseen at the end of 2009. Results will be presented as requested in the EC 154 report: annual collective effective dose, annual average per caput dose, breakdowns according to imaging modalities and anatomical regions and analysed by age and sex. Frequencies and effective dose will also be presented for the TOP 20 exams. Number of people exposed to these exams has also been assessed. The results will be compared to previous French data and to European data.

S02-05

**Feasibility study of a simplified method to determine population doses from medical x-ray imaging****Frank, Anders; Almén, Anja; Leitz, Wolfram**

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Medical X-ray imaging has been the largest man made source of population doses for many years, and is rapidly increasing due to an increased use of computed tomography. It is important to obtain information about the contribution from different examinations to these doses in order to select appropriate radiation protection actions. Guidance for assessing population doses is provided in (1), amongst others a simplified method where the collection of data is restricted to a sample of representative hospitals for those 20 x-ray examination categories contributing mostly to the population dose. The purpose of this study was to check the feasibility of this approach. The national coding system was used to identify the 20 categories. From a sample of hospitals (around 20% of the country) frequency data was collected from the radiological information system (RIS). Problems envisaged were differences in the code system between hospitals and that one category could include several codes. This was solved by editing the data manually. The frequencies were scaled up to represent the whole country using information from a complete assessment from 2005. Dose values were collected from national dose surveys and when not available from tabulated values in the guidance. The population dose was calculated to 5500 manSv. The contribution to the population dose from examinations not included in this figure was estimated to be less than 10%. The total uncertainty of the population dose was estimated to 20%. This accuracy could be achieved with a modest workload, using a rather small sample. However, due attention has to be paid to the ambiguities in the coding systems, to the selection of the sample of hospitals and to the methods of extrapolation to a national value.

1. *European Guidance on Estimating Population Doses from Medical X-Ray Procedures, European Commission, Radiation Protection No. 154 (2008).*

S02-06

### Paediatric computed tomography (CT) exposure and radiation induced cancer risk: setting up of a French cohort study

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**Introduction:** The increasing use of computed tomography (CT) scans for paediatric population raises the question of a possible impact of such ionising radiation (IR) exposure on the occurrence of secondary leukaemia and other cancers. We describe the preliminary results of an ongoing large-scale cohort study of cancer risks among children exposed to CT scan in France, performed in collaboration with the “Société Francophone d’Imagerie Pédiatrique et Périnatale” (SFIPP). This study will be included in a trans-national collaborative cohort study for long term follow-up.

**Material and methods:** In 18 paediatric radiology departments, demographic and IR exposure information concerning children less than 5 years, who underwent at least one CT scan between 2000 and 2006, are under collection. Absorbed organ doses are calculated with the “CT-expo” software.

**Results:** Until now, 28,190 children free of cancer or leukaemia at the first CT scan examination have been included. Age at first CT scan exposure was less than 1 year for 42%, 1 to 2 years for 19%, and 13% per year of age up to 4 years old. The mean number of CT examination per child was 1.5 (min 1, max 30) and concerned head in 66% of the cases, thorax in 22%, abdomen and pelvis in 10% and other localisations in 2%. Highest cumulated organ doses were observed for brain and lens during head exposure and mean absorbed doses were 27 mGy (range: 2.8 – 478 mGy) and 30 mGy (0.5 – 620 mGy), respectively.

**Conclusion:** This cohort allows to better characterizing organ doses associated with CT scan exposure in childhood. Relatively high doses to radiosensitive organs (lenses, ovaries, breast, etc...) have been observed, as well as quite large dose ranges according to the protocols used. This underlies the need for optimization of paediatric CT protocols, or even standardization. The follow-up of the cohort will be first based on cancer incidence up to age 15, and on mortality afterward to quantify a possible excess cancer risk.

S02-07

### Does decreasing of setting parameters of the CT at PET/CT devices minimize patient-dose without noteworthy degradation of attenuation correction?

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PET/CT devices almost exclusively use the setting parameters of the CT for the sake of high-quality resolution which is not justified in every case. This poses the question, how far the setting parameters of the CT (particularly voltage and current) can be lowered in order to reduce patient dose while at the same time preserving a clinical useful attenuation correction. This paper presents the results of a series of measurements, which were carried out with a Siemens Biograph 64 PET/CT Scanner and an optimized NEMA PET body phantom that consists on eight hollow acrylic cylinders and several bones (two thighbones, three backbone segments and two pelvic bone parts). First, the CT scanned the phantom varying the voltage (140 kV, 120 kV, 100kV and 80 kV) and using four different current-time-products (ranging from 8 mAs to 138 mAs). Afterwards the phantom was filled with F-18, whereas the cylinders, due to NEMA conditions – received eight times more F-18 than the remaining phantom volume. A PET-scan was performed with and without attenuation correction based on a CT-scan. The results demonstrate that the setting parameters have little to no effect on the quantitative output of the attenuation correction, hence the calculated activity concentration. Therefore a reduction of both current-time-product and voltage are justified for the sake of lowering the effective dose to the patient for medical examinations where a high-quality resolution is not unconditionally necessary. Finally, in order to avoid unnecessary exposure but to keep a useful attenuation correction, guidelines are presented for the adjustment of voltage and current-time-product.

S02-08

**Trigger Levels to prevent tissue reaction in interventional radiology procedures****Trianni, Annalisa<sup>1</sup>; Gasparini, Daniele<sup>2</sup>; Padovani, Renato<sup>3</sup>**<sup>1</sup>Udine University Hospital, Medical Physics, ITALY; <sup>2</sup>Udine University Hospital, Radiology, ITALY; <sup>3</sup>Udine University Hospital, Medical Physics, ITALY

It is well known that the large use of fluoroscopy in interventional radiology procedures may induce unintended patients' skin injuries. For that reason assessment of skin dose for these procedures is getting more and more important. Aim of the study is to investigate the role of cumulative air kerma (CK) as online dose indicator and to evaluate the possibility to define a local CK trigger level which can help operators to identify situations with high probability to exceed a peak skin dose of 2 Gy, the threshold dose for transient skin erythema. Cerebral angiography, aneurysm embolisation and chemoembolisation of liver cancer have been identified as the interventional procedures where high skin doses could be delivered. Dosimetric data (CK, air kerma area product (KAP) and fluoroscopy time) have been collected in a sample of procedures and peak skin dose (PSD) have been measured from dose distributions measured with large area radiochromic films (Gafchromic, IPS, USA) located between table top and patient. PSD varied in very wide range and in a few cases were close to the threshold for main erythema and epilation (6 Gy). The correlations between PSD and CK have been successfully assessed for each procedure type and a trigger level for CK has been derived to alert the interventionalist on the probability to have reached a PSD of 2 Gy. In our center local trigger levels of 5200 mGy and 2500 mGy has been established for brain aneurysm embolisation and chemoembolisation procedures respectively. As suggested by ICRP in the publication No. 85, a follow-up for patients whose estimated peak skin dose was 3 Gy or greater has been implemented as a routine practice.

S02-09

**International project on individual monitoring and radiation exposure levels in interventional cardiology****Padovani, Renato<sup>1</sup>; Czarwinski, Renate<sup>2</sup>; Durán, Ariel<sup>3</sup>; Lefaire, Christian<sup>2</sup>; Le Heron, John<sup>2</sup>; Miller, Donald<sup>4</sup>; Rehani, Madan<sup>2</sup>; Sim, Kui-Hian<sup>5</sup>; Vano, Eliseo<sup>6</sup>**<sup>1</sup>University Hospital Udine, ITALY; <sup>2</sup>IAEA, AUSTRIA; <sup>3</sup>Cardiology Dept., URUGUAY; <sup>4</sup>Uniformed Services University Bethesda, UNITED STATES; <sup>5</sup>Sarawak General Hospital, MALAYSIA; <sup>6</sup>Complutense University Madrid, SPAIN

**Introduction:** Different sources of information show that there are areas where radiation uses can lead to non-trivial occupational exposures. For these areas, the IAEA has launched the Information System on Occupational Exposure in Medicine, Industry and Research (ISEMIR) project, working closely with UNSCEAR. Part of this project, the Working Group on Interventional Cardiology (WGIC) has started a 3-year activity to assess levels of exposure and methods applied for individual monitoring and to propose an international database of occupational exposures in interventional cardiology (IC).

**Materials and methods:** In a first survey, data were collected from: national regulatory bodies, chiefs cardiology and interventional cardiologists.

**Results:** The convenience sample from the survey included nearly 200 cardiologists from 32 countries and 81 regulatory bodies from 55 countries. Concerning IC, there are an average of 2 IC laboratories per IC facility performing about 850 procedures/year with 11 monitored professionals and 400 ± 275 proc./year per cardiologist. Concerning dosimetry: – 72% of cardiologists claim to always use their personal dosimeter, and 36% always two; 26% knew their personal doses; – 57% of regulatory bodies define the number and position of dosimeters for the monitoring of staff. Concerning occupational doses: – less than 40% of regulatory bodies could provide doses; – reported annual median effective dose values (often lower than 1 or even 0.5 mSv) were lower than would have been expected based on validated data from facility-specific studies, indicating that compliance with continuous individual monitoring is often not being achieved in IC.

**Conclusions:** Radiation protection training and certification in radiation protection has a positive effect on the wearing of two dosimeters, the use of protective equipment and the knowledge of personal and patient doses.

S02-10

**Radiation-induced cancer risk from recurrent CT scanning**

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**Purpose:** To estimate the radiation-induced cancer risk from recurrent computed tomography (CT) scanning and associated lifetime attributable risk (LAR).

**Materials and methods:** The cohort comprised 11 968 patients who underwent two or more diagnostic CT's from January 2005 to January 2009. In total 46 019 CT examinations were performed. Each patient's cumulative CT radiation exposure was estimated by summing typical CT effective doses. The Biological Effects of Ionizing Radiation (BEIR) VII methodology was used to estimate LAR on the basis of sex and age at each exposure.

**Results:** In the cohort, the youngest patient was 2 days, the oldest 99 years. The average age was  $55.0 \pm 17.5$  years with a median of 58 years. 2532 (5.5%) examinations were performed on patients of 20 years or younger and 568 (1.2%) on patients of 10 years or younger. 573 (4.8%) patients underwent 10 or more CT examinations, and 163 (1.4%) patients underwent between 15 and 44 CT examinations. 312 (2.6%) patients received an estimated cumulative effective dose of more than 100 mSv, and 107 (0.89%) patients received between 150 and 314 mSv. Of the patients receiving more than 100 mSv, associated LAR had mean and maximum values of 0.14% and 5.7% for cancer incidence and 0.08% and 2.2% for cancer mortality, respectively. 128 (1.1%) patients of the cohort had an estimated LAR for cancer incidence greater than 1%, of which 27 (21%) patients had no cancer history. These values imply that recurrent CT scanning in this cohort may be responsible for 75 radiation-induced cancer and 10 cancer deaths in further life.

**Conclusion:** Recurrent CT scanning added to a significant increase in cancer risk in our cohort which may be a serious problem in long term follow-up of non-cancerous patients or patients who survived their (previous) cancer.

S02-11

**National coordination of Clinical Audits for medical radiological procedures**

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According to the EC directive 97/43/EURATOM the Member States are required to implement clinical audits for medical radiological practices in accordance with national procedures. Correspondingly, the Finnish legislation requires that the radiological units have to implement self-assessments and external clinical audits of their practices. To ensure the quality and consistency of clinical auditing, an Advisory Committee for the coordination, development and follow-up of the clinical audits was established in 2004 by the Ministry of Social Affairs and Health. The committee is a multi-disciplinary group of clinical experts, independent of any auditing organizations. Its tasks include, among other things, evaluating the suitability and coverage of the criteria used in clinical audits and collecting summaries and reviews of the results. The Advisory Committee has issued four recommendations dealing with the competence, experience and independence of the auditors, developments for the second audit round, how to take into consideration the accreditations of nuclear medicine units and the ten points of interest given for clinical audits in the legislation. Two more recommendations are being prepared concerning audit reports and how to take into consideration the new European guideline on clinical audit. Current other activities include efforts to encourage the national scientific and/or professional societies to contribute to the development of the criteria of good practice, and a review of clinical audits in some other countries in order to propose improvements of the Finnish implementation. The Committee has also conducted a survey of the results of the complete first round of audits in Finland and organized a particular seminar on clinical audits. Further information (in Finnish) is available from "[www.clinicalaudit.net](http://www.clinicalaudit.net)". In this paper, the achievements and experiences of the national coordination efforts are discussed in detail.

S02-12

**Radiation protection of patients  
in medical radiology: proposal  
for a worldwide action plan**

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Lacoste, A. C. et al.

FRANCE

P02-01

### TLD postal dose audit of radiotherapy beams calibration: creation of national quality assurance system in Ukraine

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According to IAEA/ICRU requirements for effective radiotherapy and prevention of radiation effects the discrepancy between stated and delivered absorbed dose in tumor should not exceed  $\pm 5\%$ . In Ukraine the metrological control of radiation parameters of radiotherapy units in hospitals are carried out once per 2 years. In hospitals a control of radiation beam calibration are carried out by medical physics using own clinical dosimeters once per quarter or year. But it is necessary to organize the independent control of calibration quality. In 1969 IAEA with WHO established the TLD postal programme to verify the calibration of radiotherapy beams in developing countries. The main purpose of the programme is to provide an independent quality audit of dose delivered by radiotherapy units using TL-dosimetry. Ukraine was included to IAEA programme since 1998. During 1998 – 2008 there were 152 radiation beam checks of 76 radiotherapy units. Although the participation in IAEA/WHO TLD-audit was voluntary and confidential some hospitals (about 25%) never took part in this programme. IAEA/WHO TLD dose audit shows that only 47 – 75% of radiation beams in different years (average value – 64,5%) were within the acceptance limits of  $\pm 5\%$  at first stage of TLD-audit, moreover about 10 – 15.5% of radiotherapy beams had errors of calibration outside  $\pm 10\%$ . After two stages only 69.6 – 89.5% (average value – 77,6 %) of radiotherapy beams were in the acceptance limits of  $\pm 5\%$ . The main reasons of such results were outdated state of radiotherapy units and clinical dosimeters in hospitals, absence of qualified medical physics and using old methodology of absorbed dose estimation in tissues. Thanks to technical and methodological support of IAEA, Ukraine has a possibility to create national system of TLD postal dose audit and provide the control of quality calibration of radiotherapy beams for all hospitals on regular and obligatory basis that will assist in improving quality of radiotherapy.

P02-02

### Making the best use of the radiation in diagnostic radiology – improvement needed

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In the radiological protection community there is an increasing concern about justification. This is partly, due to the remarkable increase in the number of CT examinations in the last 10 years in Europe and in the US, and partly because it is recognized that there is a large potential for averted dose if a substantial part of the examinations is unnecessary. Because of this concern a study was conducted in Sweden in order to investigate the level of unjustified examinations. The study included all patients, in all departments, from large university hospitals to small health care units, examined with a CT scanner during one specific day. There were patients without known disease, patients before, during and after treatment of disease. The evaluation was performed by a group of radiologists and physicians. Some findings; a substantial part of the examinations were unjustified, about 20%. Certain types of examinations had a higher and some a lower level of justification compared to the average number. Examinations of younger patients had a slightly lower level of justification. But as anticipated the observers were not always unanimously in the grading. The first conclusion is obviously, that justification is important and there is a need for the radiation protection community to take active part in the work. Furthermore, it is not fruitful to compare the data in this study with others because the result depends on the methodology and the examinations included. The study also indicates that it is necessary to improve the situation for specific types of examinations. In order to improve the situation much work is needed. One key issue is to develop a system for assessing the cost and the benefit of the procedures. It should be emphasized that risk comprises not only radiation risk. In order to succeed a joint effort involving different professionals is required. This is a challenging task but is essential when striving for making the best use of the radiation.

P02-03

**On the patient dose recording and reporting****Coroianu, Anton<sup>1</sup>; Ghilea, Simion<sup>2</sup>; Rosca Fartat, Gabriela<sup>3</sup>**<sup>1</sup>SC MB TELECOM Ltd, SC Hiperdia SA, ROMANIA;<sup>2</sup>Nuclear Training Center, ROMANIA; <sup>3</sup>Physicist, ROMANIA

Romanian authorities built a regulatory framework for implementing the radiation protection requirements in the field of medical exposures. In this regard, among other actions, it was issued a legal binding document that requires a system for recording and reporting, at national level, the patient doses for each X-ray generator or irradiation source used in diagnostic or treatment. The responsibility for recording the data belongs to the practitioner, and the correctness check is radiological safety officer's duty. Moreover, in case of diagnostic radiology, the patient shall be informed in a written form about the dose he received during the procedure. The aim of this paper is to make an analyze on the appropriateness of parameters required by regulation and on the patient radiation protection benefits and costs in the context of a recognized need for harmonization of quantities, terminology and procedures for dosimetry in diagnostic.

P02-04

**The progress in Minimizing Activity and Dose with Enhanced Image Quality by Radiopharmaceutical Administration project****Hoeschen, Christoph<sup>1</sup>; Mattsson, Sören<sup>2</sup>; Mikuž, Marko<sup>3</sup>; Cantone, Marie Claire<sup>4</sup>; Giussani, Augusto<sup>1</sup>**<sup>1</sup>Helmholtz Zentrum München, German research center for Environmental Health (Neuherberg), Institute of Radiation Protection, GERMANY; <sup>2</sup>Lund University, Malmö University Hospital, Medical Radiation Physics, SWEDEN; <sup>3</sup>Jozef Stefan Institute (Ljubljana), Experimental Particle Physics Department, SLOVENIA; <sup>4</sup>Università degli Studi, Dept. of Physics (Milano), ITALY

The introduction of new and more beneficial diagnostic procedures combining CT and PET or SPECT is related to a rapid growth of medical exposures. The European collaborative project MADEIRA (Minimizing Activity and Dose with Enhanced Image Quality by Radiopharmaceutical Administration) within the 7th EURATOM FP aims to improve 3D nuclear medical imaging in terms of increase of spatial and temporal resolution and also of reduction of the radiation exposure. The project is organized in 5 work packages, which are identified as: WP1 assessment of clinical data, WP2 PET magnifier probe development, WP3 physics-based image processing; WP4 biokinetic and dosimetric modelling; WP5 training and dissemination activities. In particular in WP1 quantitative biokinetic data were collected in patients after administration of <sup>18</sup>F-choline and those data were used to develop detailed compartmental models and to evaluate the internal dose to the patient. Moreover, the biokinetic models were used as a basis to define more efficient protocols for data collection (WP4). The collected tomographic images were used to test different reconstruction algorithms (WP3) including some newly developed ones for which a patent is pending. In addition a special phantom for checking image quality in nuclear medicine imaging was designed and also for this a patent is pending. WP2 deals with the construction of a PET insert probe. The different modules of the probe have been developed and their performances monitored, and the probe prototype is going to be tested in clinical conditions with the use of the developed reconstruction methods. Finally, training and dissemination activities include the organization of two training courses (Milan, November 2008; Malmö November 2009), and the Malmö Conf. on Medical Imaging (June 2009) as well as the tutoring of graduate and doctoral students and young post-doctoral researchers.

P02-05

### A study for the application of prospective approaches for safety assessment in new radiotherapy techniques

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Modern and advanced planning and delivery technologies and techniques, recently introduced in radiation therapy for improving the treatment outcome, call for new challenges in terms of radiological protection of the patient and risk management of potential accidental exposure. The increased complexity related with these technological and process changes, places indeed new demands on quality assurance programmes and new attitudes and approaches of safety culture. A research project aimed to study these aspects has been recently launched by a working group of the European Institute of Oncology (IEO), National Centre of Oncological Hadrontherapy (CNAO) and Physics Department of the State University of Milan. The components of the working group have skills and experience in various areas including radiation therapy, oncology, health physics, dosimetry, radiation protection, statistics, computer science and modelling complex systems. In the first phase of the project, intensity modulated radiation therapy (IMRT) practices are analysed by means of different prospective approaches. Process flow diagrams describing the activities, the instruments and the adopted procedures are properly developed in view of the identification of possible failure modes and the assessment and management of the associated risk. Similar approaches are also considered in the techniques of hadrotherapy and intraoperative radiation therapy (IORT) with mobile electron linear accelerators. In this work the project and the analyses performed are presented.

P02-06

### Radiation doses received by children during CT examinations

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**Introduction:** Computer Tomography revolutionized radiological diagnosis, the number of CT examinations growing quickly. Due to its nature, computer tomography implies higher radiation doses than those in classical radiology. An increased number of examinations, if justified, must be regarded as a benefit for the patient. Monitoring the patients' trend in CT is of particular importance as technology evolves rapidly towards extremely efficient equipments capable of acquiring 4, 8, 16, and 64 slices per rotation. At the same time, reducing examination time led to increasing CT usage as a diagnosis means.

**Material and method:** The present study refers to four departments of radiology, three of them being private. The data regarding the number and type of performed examinations as well as the examination protocols come from the registers of these departments. One of the equipments is single-slice (SSCT) and the others are multi-slice (MSCT), all of them having instruments to compute and display the dose length product (DLP) and the dose index (CTDI), according to the protocol in use. We estimated the effective dose and compared them with the reference values in other studies.

**Results:** The skull and abdomen examinations represented a large majority. The effective dose average varied from one department to another. In comparison to other studies, the average abdominal effective doses were below the values in other studies for SSCT (5.90 mSv compared to 12 mSv), while for MSCT were above them (7.29 mSv compared to 6.59 mSv).

**Conclusions:** The variation of the patients' dose for a particular type of procedure represents a premise for improving the optimisation process of protecting the CT examined patients. In order to diminish doses, it is very important to adjust some parameters such as the multi-ampereage or the number of examined sections depending on the clinical requirements, without compromising the image quality.

P02-07 – Presentation withdrawn

P02-08

**Medical exposure to radiations risk in pediatrics****Dadulescu, Elena<sup>1</sup>; Sorop, Ioana<sup>1</sup>; Mossang, Daniela<sup>1</sup>; Bondari, Dan<sup>2</sup>; Pera, Corina<sup>3</sup>**<sup>1</sup>Public Health Authority of Dolj County, ROMANIA;<sup>2</sup>Faculty of Medicine and Pharmacy University of Craiova, ROMANIA; <sup>3</sup>County Emergency Hospital Resita, ROMANIA

**Introduction:** Radiological examination of children is extremely significant since it stands for the sole and most accurate investigation method. However, one shouldn't neglect the risk of cancer induction that is up to three times higher for children than for adults. This risk is given by the children's anatomic features and their longer life expectation. A special attention is paid to premature children and to those showing clinical complications leading to longer hospitalization periods, thus increasing the number of radiological examinations.

**Material and method:** The study has been conducted in the Pediatrics Sections of Dolj County hospital, Romania, between 2005 and 2008. The focus was on the frequency of radiological examinations and the doses at the entrance surface within the most relevant radiological procedures. The measurements have been carried out using the multi-functional device for testing the quality of radiological systems RMI-242. The effective doses were estimated by using two dosimetric measures: ESD and the conversion coefficients calculated by NRPB using the Monte Carlo method.

**Results:** The values in this study for most of the radiographic examinations are close to the recommended reference levels. However, the pulmonary radiography, which is the most frequently used, constitutes the exception, with a dose average value at the entrance surface of about 3 to 4 times higher than the reference levels.

**Conclusions:** What's worrying is not the dose resulted per type of procedure, but the large number of examinations performed per one hospitalization period, all these leading to cumulative doses, to which it is likely that several others may be added from early childhood. The radiological equipment is outdated and it is not especially made for pediatrics radiology, making it impossible to choose the specific parameters which should lead to very small doses without altering the quality of the radiological image.

P02-09

**The role of radiology technologists in radiation protection of children****Milkovic, Djurdjica<sup>1</sup>; Beck, Natko<sup>2</sup>; Ranogajec-Komor, Maria<sup>3</sup>; Knezevic, Zeljka<sup>3</sup>; Miljanić, Saveta<sup>3</sup>; Rubic, Filip<sup>4</sup>**<sup>1</sup>Children Hospital Srebrnjak, Radiology, CROATIA;<sup>2</sup>Holy Ghost General Hospital, Radiology, CROATIA;<sup>3</sup>Rudjer Boskovic Institute, CROATIA; <sup>4</sup>Children Hospital Srebrnjak, Pediatrics, CROATIA

**Introduction:** Radiation protection depends on many factors. This study deals with the human factor, the radiology technicians. If all technical malfunctions are excluded they are responsible for the patient dose. Depending on their education and experience technicians perform X ray examinations with various end results: image quality, entrance surface dose, patient interaction etc.

**Patients and methods:** The study group of 60 children (for each of three technicians 20 children) was chosen that had a clinical indication for a chest X ray examination (standard PA radiogram). The age of the patients varied between 6 – 12 years, the weight between 20 – 50 kg and the height 110 – 150 cm. All parents were informed about the aim and the experimental details of the study. A Shimadzu X ray machine was used in all cases. Radiophotoluminescent (RPL) and thermoluminescent dosimeters (TLD) were applied at the entrance of the beam in center of the X ray field to measure the entrance surface dose (ESD). The three differently experienced technicians were unaware of the point of the study. Parameters that were noted were the kV, mAs and the size of the field. The radiologists interpreting the radiogram, as well as the scientists interpreting the dose were blinded.

**Results:** The dosimetry results with both dosimetry systems show a good correlation of ESD as a function of mass body index (MBI) between two technicians. Doses were significantly higher for the third one. The ESD values varied between 0.05 – 0.5 mSv.

**Discussion:** This work shows the importance of continues education and good teamwork for dose reduction. In a sequel study after additional education interference with the same three technicians we hope to have results that would show a better dose reduction.

P02-10

### Issues and practices concerning pregnancy and ionising radiation

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A literature review in relation to the irradiation of patients and staff during pregnancy was carried out. A number of publications describing procedures to be followed in the case of a pregnant patient who needs to have a radiological examination and in the case of pregnant staff who work in a department where they could be exposed to radiation were reviewed. A review of existing practices in 13 European countries was carried out by sending a questionnaire to representatives in each country. The questionnaire addressed the following issues: the application of the 10 day rule, patients who are pregnant and need a radiological examination or a nuclear medicine examination, staff and carers who are or may be pregnant and who are working in a radiology department or in a Nuclear medicine department. From the review, it was found that the existing practices with respect to irradiation of patients and staff during pregnancy vary enormously from country to country. There is no harmonisation on this issue at the European level. From the literature review and the review of practices, a number of ethical issues were identified and exposed and a number of conclusions were drawn. This work was undertaken with the support of the European Commission (SENTINEL project contract no. 012909) as part of the sixth Framework Programme.

P02-11

### Quality development and dose optimisation in native pediatric radiography in a maternity hospital

**Parviainen, Teuvo<sup>1</sup>; Vinnurva-Jussila, Tuula<sup>2</sup>;  
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Kättilöopisto is the biggest maternity hospital in Finland. In addition to radiography of newborns and mothers, also the native X-ray examinations of children under 16 years in Helsinki area were earlier centrally taken care by Kättilöopisto hospital. When X-ray imaging was thus increasing, the need for systematic estimating and developing the technology used in the examinations, measuring radiation doses, assessing the clinical image quality and own working methods became current. The hospital started a quality improvement project in 1999 in cooperation with Radiation and Nuclear Safety Authority (STUK). The radiologists and radiographers of the Department of Radiology have participated in the developing work. The aim is to produce an optimal radiodiagnosis with as low X-ray dose as possible following the common good practice.

The methods and results of the development project, changes to radiology practices and factors affecting these changes from the past 10 years are presented. The project has also involved monitoring radiation doses and assessing the clinical image quality in children's X-ray examinations and pelvimetric examinations. Special attention has been paid to radiation doses of newborns and the quality of examinations. Among others, in certain examinations, the radiation dose has been reduced to one third of the earlier dose. The project has proved an excellent starting point for developing good practices. On the basis of the results of the study, objective reference levels of the examinations of the department have been set on picture quality and on radiation dose. The quality development project is still continuing.

P02-12

**Comparison of results of quality control tests of the mammography screening in Mazovia province in 2007 and 2008**Fabiszewska, Ewa; Grabska, Iwona;  
Jankowska, Katarzyna; Bulski, Wojciech

Maria Skłodowska – Curie Memorial Cancer Centre and Institute of Oncology, Medical Physics Department, POLAND

In 2007 and in 2008, quality control tests were performed respectively in 48 and 46 facilities performing mammography screening. For this purpose a comprehensive system and methodology of testing was established.

On the basis of existing legal regulations in Poland, it was decided that as a part of quality control testing the following items should be checked at a facility: equipment, organization of the examinations, correctness of the basic and specialist tests (only in 2007). Additionally a group of tests, so called supervision tests, was listed. One part of the test dealt with physical and technical parameters essential for the quality of mammography images, the other part was used to evaluate the doses absorbed by the examined women. The tests were carried out by the physicists from Mazovia Regional Coordinating Centre. These physicists had to prepare a report according to standard protocol, providing the evaluation of particular tests.

A controlled facility could get maximum score of 84 points in 2007 and 365 points in 2008. An evaluation of the examinations in a facility was rated according to a percentage of scored points: at least 80% – high level, from 79% to 60% – medium acceptable level, below 60% – low non-acceptable level.

In 2007, according to these criteria only 8% of facilities were scored at high level quality of screening examinations, 35% were scored at medium acceptable level, and 56% at non-acceptable level. In 2008, only 7% of facilities were scored at high level quality of screening examinations, 59% were scored at medium acceptable level, and 35% at non-acceptable level.

Obtained results indicate a slight improvement of the quality of mammography screening examinations. However, the quality is still not acceptable and should be further improved in order to be able to contribute to the decrease of breast cancer mortality which is the prime aim of the screening.

P02-13

**Evaluation of dose for routine exposure in mammography screening in Mazovia province in 2007 and 2008**Jankowska, Katarzyna; Grabska, Iwona;  
Fabiszewska, Ewa; Bulski, Wojciech

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There is a significant risk of radiation-induced carcinogenesis associated with x-ray mammography. Therefore determination of average glandular dose is an important part of quality control of mammographic imaging systems. This study presents estimated doses for routine exposure using 45 mm thick PMMA blocks at mammography facilities in Mazovia Province in 2007 and in 2008.

Material for this study constituted data from most of mammography screening facilities in Mazovia Province in 2007 and 2008. The method consists of two parts, i.e. the determination of tube voltage (kV), focal spot charge (mAs), type of anode and additional filter for routine exposure of standard breast. The second part was measurement of entrance surface air kerma (without backscatter) at these parameters. Afterwards, the entrance surface air kerma was calculated at the upper surface of the PMMA. Furthermore the half value layer (HVL) was calculated for tube voltage used during routine examinations. The average glandular dose was calculated according to Dance. Estimated average glandular dose was compared with achievable value for 45 mm thick phantom (i.e. 2 mGy) from "European Guidelines for Quality Assurance in Breast Cancer Screening and Diagnosis".

In 2007, established average glandular doses at all mammography facilities ranged from 1,19 mGy to 4,14 mGy. In 2008, established average glandular doses in all mammography facilities ranged from 1,07 mGy to 3,95 mGy. The average glandular dose exceeded limiting value at 52% mammography facilities in 2007 and at 28% mammography facilities in 2008.

Obtained results of average glandular doses for 45 mm thick phantom reached alarming high values and they depended on wrong setting of technical parameters of mammography equipment.

P02-14

### Doses received by women in screening mammography examinations in Poland in 2007

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**Purpose:** The aim of this study was the estimation of the radiation risk for women undergoing screening mammography examinations. This is the first study of this kind in Poland concerning radiation protection of patients at the national level.

**Methods and material:** Materials for this study are the data from 250 screening mammography facilities in Poland. The following parameters were collected: the breast thickness after compression, the high voltage, the mAs values, material of the anode, additional filters used during the exposition. Data from 44992 expositions were collected. For every mammography facility standard average glandular doses for routine exposures were calculated. Furthermore, average glandular doses for individual mammography examinations, according to the methods proposed by Dance, were calculated. Tolerances were taken from the “European guidelines for quality assurance in breast cancer screening and diagnosis”.

**Results:** Established average glandular doses in 250 mammography facilities in Poland in 2007 range from 0.12 mGy to 14.56 mGy with an average of 1.99 mGy. At only 32 mammography facilities all expositions did not exceed acceptable levels of the average glandular dose. At only 18 mammography facilities all expositions did not exceed achievable levels of the average glandular dose.

**Conclusions:** Average glandular doses obtained for women undergoing mammography screening examinations reach high values and they depend on technical parameters of mammography equipment. In order to reduce the radiation risk for women undergoing screening mammography examinations, the facilities which do not conform to the standards recommended by the European Commission should improve the quality of their examinations or be closed down.

P02-15

### Implementation of quality assurance/ quality control programme in mammography practice at the University Hospital of Osijek

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The radiologist's objective is to obtain accurate diagnostic information from mammography while keeping radiation dose to the breast acceptable. Image quality and patient doses in mammography depend on large number of factors such as film speed and contrast, film processing, tube voltage, breast size and composition, and automatic exposure control. Also, image viewing conditions can considerably influence overall diagnostic accuracy of mammography, especially its sensitivity. Due to number of steps involved in this process, the potential for mistakes increases. Reproducible high-quality images with reasonably low radiation doses are, in general, assured by comprehensive quality assurance / quality control (QA/QC) program (this is also demanded by the Croatian radiation protection law (NN 64/06, NN 125/06). The national audit of mammographic equipment performance, image quality and dose in Croatia was done recently. Results showed large variations in image quality and patient doses and revealed the need to continuously monitor and optimize mammography techniques. Survey pointed out that main problem in the Croatia is the lack of written QA/QC procedures. Consequently, equipment performance, image quality and dose are unstable and activities to improve image quality or to reduce the dose are not evidence based. At the University hospital of Osijek mammography QA/QC programme, based on EC (European Commission) guidelines, was implemented during the year of 2008. After corrections, based on measured data and image quality assessment, technical parameters are now within acceptable levels given by EC guidelines, image quality is improved significantly and rate of rejected images is significantly less than before implementation of the programme.

P02-16

### Cooperation of the Nordic radiation protection authorities in the field of X-ray diagnostics

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The Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) have many similarities as for the status of using radiation in health care and in the regulatory control of radiation practices. Therefore, the importance of co-operation between the Nordic radiation protection authorities has long been recognized and manifests through Working Groups (WG) established for several fields of interest. The Nordic WG for X-ray diagnostics has been operational for over 30 years. The main tasks are to exchange information on the national activities in the field of X-ray diagnostics, to discuss problems for regulatory issues and to undertake joint efforts of research. The results are published as Nordic reports or scientific papers in international journals. In a recent joint project, patient doses in paediatric CT examinations were studied in order to pay attention to the increased need for careful optimization. Comparison of the characteristics of X-ray diagnostics in the Nordic countries indicate that the level of professional resources is somewhat varying. For example, the number of radiologists per number of X-ray examinations is rather constant (about 0,15 radiologists/1000 examination) but the number of physicists in diagnostic radiology varies from about 0 to 13 physicists/million examinations. The annual joint meetings, joint research and other joint activities have ensured effective exchange of information for developing the national regulatory activities and for promoting consistent methods of quality assurance and dosimetry. This paper compares some characteristic features of the use of radiation for X-ray diagnostics in the Nordic countries and the activities of the radiation protection authorities in this field, in particular for the modern X-ray diagnostic practices (multi-slice CT etc) highlighting the importance and achievements of effective cooperation between the authorities.

P02-17

### Diagnostic reference levels for diagnostic x-ray examinations in the Baltic and Nordic countries

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Diagnostic reference levels (DRLs) are important tools for optimisation in diagnostic radiology. The European directive on medical exposures [1] requires member states to promote the establishment and use of DRLs, and thus Denmark, Finland, Sweden and all of the Baltic countries are required to establish DRLs. Individual patient doses should not be compared with the DRL, but average patient doses for a given examination in a hospital are to be compared with the DRL.

Common Nordic DRLs were set in 1996 for 6 conventional examinations [2]. These values are still in use in Iceland, while the other Nordic countries have modified their DRLs based on national surveys etc. Additional DRLs have gradually also been set for CT, mammographic, cardiologic and paediatric examinations. DRLs were first set in Lithuania 5 years ago, and have been modified once, while DRLs have recently been set in Estonia.

The Nordic Working Group on X-ray diagnostics has in cooperation with representatives from Estonia and Lithuania conducted a study of DRLs. The choice of dose quantities measured as well as current and previous values of DRLs are compared among the Nordic and Baltic countries, and the process of revision in the different countries is described.

The trend for radiographic and fluoroscopic examinations is that the dose levels and thus the DRL values have decreased over the years. For CT the dose levels are more constant, but recent values suggest a small decrease.

#### References:

1. Council Directive 97/43/EURATOM of 30 June 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure.
2. Nordic guidance levels for patient doses in diagnostic radiology, Report no. 5 on Nordic Radiation Protection Co-operation, Norwegian Radiation Protection Authority, 1996.

P02-18

### Modification of nuclear medicine diagnostic reference levels in Austria

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**Aim:** Diagnostic reference levels (DRLs) are implemented to optimize diagnostic medical examinations using ionizing radiation. In Austria DRLs were established for the first time 2005 by the Austrian medical radiation protection regulation. In a nation wide survey we asked for daily routine patient details. The aim was to adjust the DRLs in Austria, considering new device developments as well as modified acquisition protocols.

**Materials and methods:** Using pooled data of 5320 patients from the survey, descriptive statistics was done. Frequency, age distribution and mean applied activities were determined, whereby we estimated also an individual effective dose for particular examinations. An extrapolation concerning the cumulative exposure of the population were also taken into consideration.

**Results:** In Austria the most frequent examination was thyroid scintigraphy using <sup>99m</sup>Tc-pertechnetate (23.2%), followed by heart (19.7%), bone (18.7%), renal (8.6%), PET-FDG (7.7%) and lung (7.5%) scintigraphy. About 150000 nuclear medicine procedures in 71 nuclear medicine facilities were performed 2008. An extrapolation revealed 35000 thyroid, 28000 bone, 29500 myocardial 12900 renal, 11500 PET-FDG, 11200 lung and 21900 miscellaneous scintigraphies. Regarding the number of nuclear medicine examinations per 1000 Austrian residents, Austria is located on the fourth place in comparison with 8 other European countries. The average effective dose for a nuclear medicine procedure was 3.9 mSv (range: 0.2 – 22.2 mSv). A mean effective dose of 0.07 mSv per year and resident was estimated. The additive part of the nuclear examinations compared to the total natural effective dose of 3.8 mSv per year could be stated as marginal.

**Conclusion:** Due to our survey results we suggested a modification of the DRLs in 73%. These alterations will be presented and implemented in a revised version of the forthcoming amendment of the Austrian medical radiation protection regulation.

P02-19

### Medical exposure to ionizing radiation in Switzerland – Implementation of national diagnostic reference levels in radiology and nuclear medicine

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The frequency and complexity of medical radiological procedures using ionizing radiation has been increasing continuously over the past years. As a direct consequence also patient doses have been increasing significantly. Since there are no dose limits for patients when applying ionizing radiation in medicine radiation protection is based on two basic principles – justification and optimization. The concept of diagnostic reference levels (DRLs) first introduced in 1996 by the ICRP represents a powerful tool for dose optimization of radiological procedures. In Switzerland, DRLs are implemented in the national legislation. Radiology departments are obliged to compare periodically patient dose to DRLs and to optimize their procedures if necessary. The Federal Office of Public Health (FOPH) provides national DRLs in the field of nuclear medicine (based on a national survey 2004), interventional radiology (IR) and cardiology (based on a national survey 2002) and computed tomography (CT) (partly based on a national survey 1998 and on literature). However, effective optimization of radiological procedures is only feasible if DRLs are periodically adapted to the local practice and the actual state of technology. Therefore, national surveys have been repeated in IR and cardiology in 2007 and in CT in 2007 – 09 to collect actual dose data. These data are statistically analyzed and DRLs will be adapted. Furthermore, in an ongoing project examination parameters in radiography are collected to derive DRLs for the entrance-surface-dose. National DRLs are published in technical bulletins and are available for free download on the FOPH webpage. Periodical audits of the radiology departments and the on-site comparison of local patient doses to national DRLs are most effective for optimizing radiological procedures. To assess the change of patient doses over time for each radiology department the FOPH is establishing a national data base of medical radiological examinations (DAMEX).

P02-20

### The study of patient doses for establishing diagnostic reference levels of exposure in Ukraine

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Medical exposure of patients in diagnostic radiology is the highest source of population artificial irradiation. Optimization of radiation protection in diagnostic radiology should be focused on reducing patients doses obtained from most wide-spread medical examinations while keeping high quality of diagnostic information. International Basic Safety Standards (BSS-115) established guidance levels of patient doses for diagnostic radiography. Different countries can use these values until national diagnostic reference levels are defined. Since 2009 the scientific research of patient doses in diagnostic radiology has started in Ukraine. The main purpose of this work is to evaluate the structure and parameters of X-ray diagnostic examinations, the current state of X-Ray diagnostic units, radiation output of X-ray units in different hospitals, and to measure patient doses for 5 main radiography examinations: chest; cervical spine, thoracic spine, lumbar spine, pelvis (for main projections). The measurements of radiation parameters were carried out for 35 X-ray diagnostic units from 12 large hospitals of 5 Ukrainian regions. The entrance surface doses were measured for more than 600 patients with TL-detectors LiF type MTS-N (Poland). For different types of X-ray units the values of entrance surface doses differ in 20–40 times. For chest X-Ray the average dose was about 0.83 mGy. The maximum average patient doses were observed for thoracic spine diagnostic examinations – 19.7 mGy (AP), 35 mGy (LAT) and for lumbar spine: 18.5 mGy (AP) and 46 mGy (LAT). At present the measurements of patient doses in Ukrainian hospitals are continued. To establish diagnostic reference levels for main radiography examinations the study of patient doses distribution will be done.

P02-21

### Real-time measurement of ovaries dose burden for I-131 treatment patient

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The ovaries dose burden for post-operation thyroid cancer patient undergoing I-131 treatment is estimated by directly measuring ovaries skin entrance dose. Iodine-131 environmental dose rates are determined in real-time basis at 1 meter distance from the patient body to check for the regulatory compliance. Dual digital dosimeters are deployed at the patient's ovaries proximity skin location (OS-1 meter) and at 1 meter distance away from the body surface (EV-1 meter). The OS-1 meter is operated in accumulated mode to totalize the overall dose burden during the I-131 treatment and the EV-1 meter is operated in dose-rate mode to monitor instant environment dose rate read-outs, respectively. Both of the measurements are recorded in hourly basis for up to 4 consecutive days. The times and multiple trips to the bathroom during 4-day period are also been tracked by patient herself. The ovaries dose burden determined by the ovaries skin entrance dose is at a 0.075 rad/mCi (mGy/3.7MBq) value for 4 days accumulated data in this study which is about half of the value from the nuclear medicine reference manual. Iodine effective half-life by using the imaging ROI data is at a 15.4 hours in our case of study, but the whole body iodine clearance half-lives can vary between 6 to 16 hours depending on foods and water taken and how often bathroom trips conducted. The correlation ratios between OS-1 and EV-1 meters read-outs can vary between 22 to 38 from time to time due to I-131 bio-distribution differences during our 4 days of observations. The ovaries dose burden can be measured directly by using real-time digital dosimeter. Real-time environmental dose rate verification, below than 50 micro-Sv/h required, can be used to meet the safety compliance when we are allowed to discharge an I-131 patient.

P02-22

### Evaluation of CT dose and image quality in three states of Brazil

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**Introduction:** The number of CT scanners installed in Brazil has increased exponentially in the last five years. In many radiology departments the multislice technology is now available allowing new clinical applications. However, many departments don't have medical physicists trained and the instrumentation necessary to carry on the quality assurance program. The objective of this work was to perform a dosimetry study of 30 CT scanners located in Brazil and to evaluate the image quality of these equipments.

**Material and methods:** In this work, the volume CT air kerma index ( $C_{VOL}$ ) and the air kerma length product ( $P_{KL}$ ) were estimated for each procedure on the basis of the normalized weighted air kerma indices in CT standard dosimetry phantoms ( $C_W$ ), supplied by the ImPACT group. The scanning parameters for adults and children were collected for head, chest, high-resolution chest, abdomen and pelvis examinations. For each procedure and each institution 15 examinations, randomly selected, were evaluated and the following parameters were registered: tube voltage and current, gantry rotation time, collimation and slice thickness, pitch or increment, scan length and the scanner dose index indication. The image quality was evaluated using the ACR CT accreditation phantom, manufactured by Gammex.

**Results:** The results showed a wide variation of air kerma values for the evaluated institutions. For adults, the  $C_{VOL}$  values for head scans varied between 10 and 60 mGy and the  $P_{KL}$ , from 50 to 500 mGy.cm. For adult chest and abdominal scans, the  $C_{VOL}$  values varied from 5 to 15 mGy, and  $P_{KL}$  values from 100 to 500 mGy.cm. Similar ranges were found for children.

**Conclusions:** Although the  $C_{VOL}$  and  $P_{KL}$  values are compatible to the European reference levels, the image quality did not attend all ACR CT accreditation requirements. Besides, it was verified that adult protocols are used for pediatric patients.

P02-23

### Is the radiation dose received by patients undergoing multiple CT radiofrequency ablations too high?

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**Objective:** Radiofrequency ablation (RFA) of tumors has gained significant interest and acceptance in the last decade due to its potential to produce a large volume of cancer cell death in a controlled fashion. It is successfully used under CT guidance to treat certain tumors of lung, liver, kidney, and bone. The objective of the study was to calculate the effective and skin doses in patients that underwent repeated CT guided radiofrequency ablations (RFA).

**Materials and methods:** The retrospective review included patients having more than 3 RFA ablations during the study period (June 2003-June 2009). The dose length product (DLP), effective dose (E), skin dose profiles, as well as the peak skin dose (PSD) for both the bottom and upper patient skin surface were calculated for each RFA using appropriate methods and software developed during the study. For each patient, the cumulative DLPc and Ec were also calculated from the sum of the respective figures of each individual procedure. To calculate the PSD, the skin dose profiles of each procedure were projected on the same scale using anatomical points for reference and then they were summed up.

**Results:** Five patients were analyzed. Four of these patients had totally 3 RFA and one had 11 RFA during the study period. DLPc, Ec and PSDc range values were 5569–9642 mGy.cm, 83–173 mSv and 774–3364 mGy, respectively. Median E and PSD for each RFA were 35 mSv and 400 mGy. For comparison purposes, a routine abdominal CT imparts approximately 8–10 mSv.

**Conclusions:** DLPc, Ec and PSDc vary greatly even for the same patient. However, the high radiation dose associated with repeated RFA shows the need to monitor in more detail these patients.

P02-24

**Dose-area-product to effective dose in interventional cardiology and radiology**Struelens, Lara<sup>1</sup>; Bacher, Klaus<sup>2</sup>;Zankl, Maria<sup>3</sup>; Vanhavere, Filip<sup>1</sup><sup>1</sup>SCK-CEN, BELGIUM; <sup>2</sup>University of Ghent, BELGIUM;<sup>3</sup>Helmholtz Zentrum München, GERMANY

The implementation of the European Directives introduced a number of new tasks to the radiology departments. It was stated that the determination of radiation doses are an important issue in the framework of radiation protection of the patient. And special attention is given to high-dose procedures, like interventional cardiology (IC) and radiology (IR). Radiological departments are legally obliged to register dose-area-product (DAP) values for every patient undergoing IR and IC procedures. A large national multi-centre project on dose evaluations for IC and IR performed a few years ago, showed that centers with similar average DAP-values, could still result in significant different average effective dose values. Simply register DAP-values is therefore not always the only and most adequate tool for optimization at IC and IR. The additional calculation of effective dose could enable medical physicists to determine and evaluate dose values which will more connect to radiation risk evaluation, if necessary. In the past conversion coefficients (CCs) from DAP to effective dose have been calculated systematically for different anatomical regions and projections for conventional radiological procedures. The use of these published CCs, however are not appropriate for the calculation of effective dose for IC and IR. The irradiated field sizes deviate from those in conventional radiology. Moreover, the requested CCs according to the beam qualities used for these complex procedures are not included in the published conversion tables. In the framework of patient dose optimization, however, there is a need to the availability of systematic tables with CCs who will allow the calculation of the effective dose for the complete offer of IC and IR procedures. In this paper is described how the CCs are calculated for the most common and used radiation fields in IC and IR. The systematic tables with CCs can be obtained at the Federal Agency of Nuclear Control ([www.fanc.fgov.be](http://www.fanc.fgov.be)).

P02-25

**Artifacts found in computed radiography system**

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Computed radiography (CR), scientifically known as photostimulable phosphor radiography, is a digital technology for the acquisition of radiographic images. The technology uses a conventional radiographic acquisition geometry to deposit x-ray energy in a photostimulable phosphor screen with delayed luminescence properties. After irradiation, the screen is stimulated by a scanning laser beam, to release the deposited energy in the form of visible light. The released photostimulated light is captured by a light detector, converted to digital signals, and registered with the location on the screen from which it has been released. The CR systems are replacing the analog systems. However, as in other arrange X-ray images artifacts disrupt and can compromise the exact diagnosis, and should simulate pathological lesions or mask the correct diagnosis. In CR technology artifacts similar to those found in analog systems occur, such as patient related artifacts or operator's errors. However, in addition to these, there are also other artifacts that are system related: Image Plate (IP), like a reader, like a ghost images and problems with the eraser system, to soft copy display or the printers. Some artifacts have still unknown reason. This article shall present some artifacts found in computed radiology and suggests some solutions because the attention of the sources can impact of image quality and rejection and dose in the patients.

P02-26

**Patient dosimetry investigations of a dental panoramic unit and a digital volume tomograph****Hranitzky, Christian<sup>1</sup>; Stadtmann, Hannes<sup>1</sup>; Neuwirth, Johannes<sup>1</sup>; Hefner, Alfred<sup>2</sup>**<sup>1</sup>Seibersdorf Labor GmbH, Radiation Safety and Applications, AUSTRIA; <sup>2</sup>AIT – Austrian Institute of Technology, Environmental Resources and Technologies, AUSTRIA

Patient dosimetry measurement and simulation methods were investigated in dental radiology applications comparing a conventional panoramic x-ray unit and a new digital volume tomograph. Panoramic and new DVT scanners are used for diagnostic imaging of patient's jaw and teeth in dental practice. Free-air and various in-phantom comparisons were carried out in the rotating x-ray fields using standard adult patient examination settings. Air kerma free-air measurements were performed close to the rotation axis revealing difficulties in panoramic fan-beam geometry as compared to the broad cone-beam geometry in DVT. Determination of absorbed dose to water was made at defined positions inside a cylindrical PMMA phantom and inside an anthropomorphic Rando-Alderson head phantom. Measurement results of a 0.125 ccm ionisation chamber free-air and inside the PMMA phantom were compared to LiF:Mg,Cu,P thermoluminescence detector chips. TLD glow-curves were read out on a 3500 Harshaw manual reader with optimized time-temperature-profiles. Distributing TLD chips at selected positions inside the 2.5 cm slices of the head phantom allowed dose measurements for determining organ dose values and resulting effective dose estimates. Reference diagnostic x-ray radiation fields at the Dosimetry Laboratory Seibersdorf were used for quantifying the influence of applied radiation energy spectra up to 120 kV. A set of radiation quality correction factors were determined for ionisation chamber dosimetry as well as for free-air and in-phantom TLD dosimetry. MCNP Monte Carlo simulations with various complexities in geometry were implemented for determining spatial and spectral radiation field distributions inside the head phantoms. A standard planar AP irradiation setup was used for verifying simulated and measured organ dose values. Resulting free-air and in-phantom dose values were up to several mGy whereas effective dose estimates were about 5 µSv and 50 µSv for panoramic and DVT imaging.

P02-27

**Radiation dose in selective nerve root blocks****Tsapaki, Virginia; Maniatis, Petros; Chinofoti, Ioanna; Papadopoulos, Ilias; Triantopoulou, Charikleia**  
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**Objective:** Selective nerve root blocks (SNRB) are useful in the treatment of radicular symptoms, due to the infiltration of large amounts of steroids around a particular nerve root resulting in reduction of pain. Fluoroscopic guidance is usually used to perform these procedures. The objective of this study was to measure the radiation dose received by these patients.

**Materials and methods:** The study included 24 patients undergoing SNRB using a fully digital fluoroscopy X-ray machine Philips Allura FD 20 installed in 2008 in Konstantopoulou Hospital. The following technical parameters were recorded: Kerma Area Product (KAP), cumulative dose (CD), fluoroscopy time (T) and total number of images (F). Patient data recorded were: Age (A), Weight (W) and Height (H).

**Results:** Median values of KAP, CD, T and F were 26.7 Gy $\text{cm}^2$ , 360 mGy, 3.4 min and 123 images, respectively. Ranges of KAP and CD were 1.8–218.4 Gy $\text{cm}^2$  and 24–856 mGy, respectively. No correlation was found between KAP and F (0.12), as well as KAP and T (0.04). Furthermore, no correlation was found between CD and F (0.09) and moderate correlation between CD and T (0.56).

**Conclusions:** Radiation doses vary substantially in SNRB procedures. The fact that they can be repeated to the same patient in certain time intervals calls for more detailed investigation and close monitoring of patients.

P02-28

**Managing radiation dose in interventional radiology****Samara, Eleni-Theano<sup>1</sup>; Bize, Pierre<sup>2</sup>; Binaghi, Stefano<sup>2</sup>; Bochud, François<sup>1</sup>; Verdun, Francis<sup>1</sup>**<sup>1</sup>University Institute for Radiation Physics, CHUV-UNIL, SWITZERLAND; <sup>2</sup>Department of Radiology, CHUV-UNIL, SWITZERLAND

The number of interventional radiology procedures has been shown to increase over time due to their clinical safety and efficacy. Nevertheless, these procedures may be related to elevated patient radiation dose. Stochastic risk management can be improved by monitoring the dose-area product and comparing it to available dose reference levels (DRL). On the other hand, deterministic effects can be managed by monitoring cumulative dose at the intervention reference point ( $D_{IRP}$ ). The objective of this study was to provide interventionists a simple and reliable method to control risks associated with the use of ionizing radiation. Patient data for a seven-month period were collected and analyzed for hepatic embolization and cerebral angiography. Data included dose-area product values, fluoroscopy time, number of images obtained during the procedure and  $D_{IRP}$ . Patient dosimetry was performed by using high-sensitivity MOSFET dosimeters. The SPSS statistical program was employed for data analysis. Maximum skin dose reached 8.9 and 5.5 Gy during hepatic embolization and cerebral angiography, respectively. Good correlation was found between the MOSFET dosimeters and  $D_{IRP}$  during patient study. The 75% percentile of patient dose was calculated and compared with the national DRLs.  $D_{IRP}$  should be recorded during the procedure and included in patient's report file for post-procedure reference. Actions have to be taken towards dose optimization. Patient follow-up has to include check for recognized or suspected radiation injury.

P02-29

**Patient dosimetry during biventricular I.C.D. insertion****Rossi, Pier Luca<sup>1</sup>; Boni, Martino<sup>1</sup>; Corazza, Ivan<sup>1</sup>; Compagnone, Gaetano<sup>2</sup>; Boriani, Giuseppe<sup>1</sup>; Testoni, Giovanni<sup>1</sup>; Zannoli, Romano<sup>1</sup>; Bianchini, David<sup>1</sup>**<sup>1</sup>University of Bologna, ITALY; <sup>2</sup>San'Orsola University Hospital, ITALY

Recent years have seen a great increase in electrophysiological cardiac procedures number (EPs) and radiological systems are constantly improved to obtain good image quality by upgrading technological performance. Even if patient benefits are clear, these procedures expose patients to X-rays for a long fluoroscopic time; the result is progressively higher patient radiation exposure, both in local skin areas (for example, the skin of the back) and in terms of effective dose and related risks. In order to evaluate the mean patient dosimetric parameters, we have analyzed 30 biventricular implantable cardioverter defibrillators (ICD) procedures, measuring DAP (dose area product) during the entire procedure and registering all geometrical and physical data that are necessary to reconstruct, via a MonteCarlo simulation, the dosimetric quantities for ICD therapy. For this reason, for each patient we have collected all X-ray spectrum data (such as kV, mA and time during both fluoroscopy as graphy) related to irradiation geometry (such as focus-to-patient distance, X-ray tube angulations, dimension of X-ray field of view) to obtain a "cumulative dataset" that permit to simulate the intervention. Using a MonteCarlo code, we have evaluated the dose for each patient (both organ dose as effective dose, as "dosimetric indexes" for the procedure) to produce a statistical analysis that can be compared with other interventional therapies (for examples, hemodynamic procedures as stent implantation, angiography, coronarography, etc.) Even if the dose variability between patient data are great, primary due to the complexity of the ICD insertion, our results demonstrate that patient dose indexes for this particular electrophysiology procedure are not significantly different from the X-ray guided hemodynamic therapies.

P02-30

**Cancer risk from medical radiation exposure: prognosis-based lifetime attributable risk approximation (PROLARA)**

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**Purpose:** To evaluate the impact of the reduced life expectancy of patients (compared to a non-patient group with same age distribution) on their nominal risk of developing solid cancer from the diagnostic use of radiation.

**Method:** We define a “prognosis-based lifetime attributable risk modifier” (PROLARM) as the ratio of risks for non-patient and patient, a dimensionless quantity which indicates how strongly the lifetime attributable risk (LAR) is reduced due to the patient’s prognosis. We show that an approximation to this ratio can be calculated (named PROLARA) which depends only on patient’s age at exposure and his/her life expectancy, but is independent of the exact choice of values for the baseline risk of cancer incidence (which varies across populations) and the excess relative risk (ERR) from radiation exposure (which remains controversial in the scientific community). PROLARM and PROLARA were computed for a cohort of  $n = 4285$  female patients with metastatic breast cancer, for which all necessary input data where available.

**Results:** The lifetime risk of solid cancer attributable to radiation is significantly decreased for these patients: PROLARM  $> 20$  for all ages at exposure  $\leq 65$  years. For any reasonable choice of function for ERR, the approximation PROLARA gives a lower estimate of the reduction in risk. The risk for a patient from the above cohort, exposed at age 50, is decreased by a factor of 29 (PROLARM) resp. 27 (PROLARA). In other words, 20 mSv for a patient with metastatic breast cancer correspond risk-wise to less than 1 mSv for a healthy person of the same age.

**Conclusion:** A major portion of the total dose from diagnostic medical exposures does not constitute an additional cancer risk due to the poorer prognosis of patients compared to non-patients of same gender and age. Our new PROLARA concept allows an estimation of the reduction in risk for any pathology when the associated survival is known.

P02-31

**Extracranial radiation doses in children undergoing Gamma Knife radiosurgery**

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It has been long known that patients treated with ionizing radiation carry a risk of developing radiation induced cancer in their lifetimes. Factors contributing to the recently renewed concern about the radiation induced secondary cancer include improved cancer survival rate, younger patients population as well as emerging treatment modalities that can potentially elevate secondary exposures to healthy tissues distant from the target volume. Gamma Knife radiosurgery stereotactically delivers a high single dose of external radiation to a small well-defined intracranial lesions. Due to a large amount of dose delivered in a single fraction (10 – 30 Gy) in stereotactic radiosurgery, dose outside the treatment volume is an important issue. The aim of study was to measure the out-of-field doses during the Leksell Gamma Knife Model C radiosurgery for children. The children population was chosen due to their higher susceptibility to radiation. Also, due to smaller size of their bodies, the larger doses are expected to all out-of-field tissues and organs than for adults for the same irradiation conditions. The purpose was to identify doses delivered to the eye lens, thyroid glands, breasts, sternum, upper abdomen, gonads and knees. According to the phantom measurements of Hasanzadeh et al., Phys. Med, Biol. 51, 4375 – 4383 (2006), the surface dose is comparable to depth dose and we placed dosimeters at the surface of the skin to measure depth (organ) dose. At the every point of the measurement two types of thermoluminescent dosimeters were placed, LiF:Mg,Ti and LiF:Mg,Cu,P and two radiophotoluminescent glass dosimeters (GD-352M). Preliminary results obtained for two children show very good agreement between different dosimetry methods but very different doses at the sites of the particularly organs, for instance for eyes 1.74% (patient A) and 2.02% (patient B) and for thyroid 0.53% (patient B) and 1.2% (patient A). Doses were expressed as percentage of the mean target dose.

P02-32

**A cohort study of childhood cancer following diagnostic X-rays**

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**Introduction:** Ionising radiation is an established cause of cancer, yet little is known about the health effects of doses from diagnostic examinations in children. The risk of childhood cancer was studied in a cohort of 92,957 children who had been examined using diagnostic X-rays in a large German hospital during 1976–2003.

**Material and methods:** Radiation doses were reconstructed using the individual dose area product and other exposure parameters, together with conversion coefficients developed specifically for the medical devices and standards used in the radiology department. Newly diagnosed cancers occurring between 1980 and 2006 were determined through record-linkage to the German Childhood Cancer Registry.

**Results:** The median cumulative effective radiation dose was 7  $\mu$ Sv. 87 incident cases were found in the cohort: 33 leukaemias, 13 lymphoma, 10 central nervous system tumours and 31 other tumours. The standardized incidence ratio (SIR) for all cancers was 0.99 (95% CI: 0.79–1.22). No trend in the incidence of total cancer, leukaemia or solid tumours with increasing radiation dose was observed in the SIR analysis or in the multivariate Poisson regression. Risk did not significantly differ in girls and boys.

**Discussion:** Overall, while no increase in cancer risk with diagnostic radiation was observed, the results are compatible with a broad range of risk estimates.

P02-33

**Modelling electron and photon interactions for applications in brachytherapy**

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One of the main purposes of specific brachytherapy techniques is positioning radiation sources inside or next to the tumour in order to minimize irradiation of surrounding healthy tissues while assuring delivery of high dose levels to the target volume. For example, Ru-106 plaques (Georgopoulos et al. 2003) and I-125 seeds (Thomas et al. 2008, Fuller et al. 2004) are commonly used for eye melanoma and prostate cancer treatments, respectively. Both applications require a precise dose distribution map defining the appropriate radioactive source implantation by minimizing damage to sensitive areas and concentrating dose inside the tumour volume. Following the method we recently published (Muñoz et al. 2008), here we apply energy deposition models at the molecular level for high energy electrons (0–3.5 MeV) and photons (50–100 keV) as a complementary tool for clinical treatment planifications. Briefly, this model consists of a new Monte Carlo simulation programme which as its input parameters uses the interaction probabilities (cross section) and energy loss distribution function we have previously measured or calculated. Special attention is paid to the effect of low energy secondary electrons which are the main responsible for induced damage via molecular dissociations. Detailed energy deposition images and radiation damage evaluation can be derived from the single particle track structures (photon and electrons) predicted by the present model.

P02-34

### Usefulness of specific sensitivity factors of radionuclide calibrators used in nuclear medicine

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In nuclear medicine, the activity of a radionuclide is measured with a radionuclide calibrator that has often an efficiency factor independent of the container type and filling. To determine the effect of the container on the accuracy of the activity injected to the patient, we simulated a commercial radionuclide calibrator and 18 container types representative of the clinical practice. The instrument sensitivity was computed for various container thicknesses and filling levels. Mono-energetic photons and electrons as well as five common radionuclides were considered. The quality of the simulation with gamma-emitting sources was validated by an agreement with measurements better than 4% in four critical situations. Our results show that the measured activity can vary up to a factor 2 depending on the type of container. The filling and wall thicknesses only have a marginal effect for radionuclides of high energy but could induce differences up to 5%. We conclude that dose calibrators used for clinical applications should have efficiency factors specific to a given container type.

P02-35

### Radiation detection in dialysis room for a uremia patient with Y90 microsphere SIRT: initial experience in KMHU, Taiwan

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Y90 microsphere SIRT (selectively intravascular radiation therapy), as radiation embolism becomes an alternative method for advanced hepatic malignant control as hepatic metastasis and primary hepatoma. Y90 with pure beta ionizing radiation is an available therapy radionuclide in clinic. In southern Taiwan, Y90 SIRT in hepatic malignant control is a beginning technique. During past year, we have total six-case procedures. Among them, a uremia patient has colon cancer and massive hepatic metastasis. Due to failure of treatment response to conventional chemotherapy and target therapy, she is advised to receive Y90 microsphere SIRT. Under inform consensus and document approval, the survey procedures including hepatic angiography, abdominal CT and Tc99m MAA shunt study are performed before treatment. Base on metastatic tumor burden and calculated dosimetry, 2.5 GBq of Y90 microsphere is arranged to deliver to hepatic lobe. After successful technique performance, the patient received regular dialysis for medical care in the next day after radiation embolism treatment. First, we arrange independent dialysis space for this special medical condition in our hospital. For environmental exposure dose evaluation, we directly measure X ray from patient by GM counter. There is inhomogeneous radioactivity distribution in patient's body for example: higher in liver, heart and brain. The exposure dose does not exceed 0.15 mR/h in one meter distance from body surface. Initially, contamination of radionuclide Y90 in dialysis equipments is a potential issue. However, there is no significant radioactive residual in dialysis tube as waste storage in nuclear medicine department. In conclusion, dialysis is not a contraindication for Y90 microsphere radiation embolism treatment. In this special medical condition, we suggest arrangement of relatively independent dialysis space and awareness of nursing care as patient with conventional nuclear medicine procedure.

P02-36

**Radiographer students learning dose management of the patients****Henner, Anja**

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**Introduction:** Radiographers have their Bachelor degree in Universities of Applied Sciences in Finland. It takes 3,5 years and is 210 ECTS to be graduated. The students have 75 ECTS (2000 hours) in clinical practice in radiological departments. They start their clinical practice in the end of first year in Health Centres where often only one or two radiographers are working. According to Finnish Radiation and Nuclear safety Authority (STUK) the doses of the patients must be evaluated either as ESD or DAP at least every third year. Every year some doses must be estimated.

**Methods and materials:** The students (N=21) collected patient data during the clinical practice (16 chest, 1 sinus and 4 lumber spine). Each student planned together with the tutoring radiographer and teacher, about what plain examination the material would be most useful to be collected. The staff can use the material as an official part of self-assessment for clinical audits. The students collected data of ten patients: height, weight, sex, kV, mAs, focus to skin distance, added filtration and equipment information with air kerma. At school each student counted for the patients ESD and compared them to the reference levels given by STUK.

**Results:** All patients were in weight 55–85 kg, as recommend. The x-rays were taken with 125–133 kV and 0.1–0.3 mmCu+1 mmAl. The doses varied in chest pa from 0.06 mGy to 0.23 mGy and in lateral 0.08 mGy to 1.3 mGy. The reference levels are 0.2 and 0.8 mGy. In sinuses the lowest dose was 2.28 mGy and highest 2.69 mGy. In lumber spine ap doses varied from 1.1 mGy to 6.5 mGy and in lateral from 2.0 to 8.6 mGy. Referral levels are 6mGy and 15 mGy.

**Conclusion:** Students managed the ESD dose calculation from air kerma very well. All have sent their signature reports with results and remarks to the department where the data was collected. Radiographers in clinical practice use these reports as a part of quality assurance handbook and clinical audit's self-assessment material.

P02-37

**Neutron field analysis for a proton therapy installation****Sandri, Sandro<sup>1</sup>; Benassi, Marcello<sup>2</sup>; Ottaviano, Giuseppe<sup>1</sup>; Picardi, Luigi<sup>1</sup>; Strigari, Lidia<sup>2</sup>**<sup>1</sup>ENEA, ITALY; <sup>2</sup>IPO, ITALY

A proton therapy centre is planned to be sited in Rome, Italy. It will be based on a medium energy proton accelerator and should be associated to a National Health Institute. At least two treatment stations should be realized: a 140 MeV area for shallow tumors therapy and the 200–250 MeV full energy station for deep tumors treatment. Additional experimental areas are foreseen for studying the interactions of low energy, high LET, protons with tissues and the effectiveness of proton therapy on specific pathologies. The project is now in a preliminary design phase. The accelerator is under study, the building layout has to be defined and the preliminary safety solutions are considered as well in this phase. The radiation protection approach requires that all the radiation fields are well known, even those that are not useful for the treatment itself. In this frame the neutron field due to proton interactions in solid, liquid and gaseous materials has to be analyzed during the design phase in order to reduce this component to its minimum extent and to address the radiation protection program. The injector of the proton accelerator has been installed at the ENEA Research Center in Frascati, Rome and will be used to perform the preliminary low proton energy testing and the benchmarks for the simulations needed to assess the neutron field. In the paper the simulation models and the calculation performed with Monte Carlo codes are described. The related results are presented together with the comparison with the low energy benchmarks and the data found in the literature for similar projects. Considerations about workers and patients protection are issued taking into account different technical options and related advantages and disadvantages.

P02-38

### Where is Bulgaria in radiation protection in medicine?

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Medical uses of ionizing radiation are the major man-made source of exposure of the Bulgarian population. The requirements of the International Basic Safety Standards for protection against ionizing radiation and the EURATOM Directive 97/43 were fully harmonized in the Bulgarian legislation and many actions have been undertaken for their practical implementations. In October 2005 new regulation has been enforced for radiation protection at medical exposure. A department for Radiation Protection at Medical Exposure was established at the National Centre of Radiobiology and Radiation Protection in order to lead the practical implementation of the Ordinance. New objective requirements to radiological equipment were set and licensees were obliged to put into operation Quality control program. First Diagnostic Reference doses were given in 2005 based on the limited own experience from the First national survey in conventional performed in 2002 – 2003 within the Bulgarian-German twinning project. Further enlargement of dose surveys and improvement of RP practice at medical use of radiation were realized within the Bulgarian-Finnish Twining project “Strengthening of administrative structures for radiation protection and safety use of ionizing radiation in diagnostics and therapy”. New radiation protection training programs for medical specialist were elaborated including recent knowledge on patient protection. Several national training courses with international lecturers were performed.

P02-39

### A national system on registration and reporting of medical exposure in Romania

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The 97/43/EURATOM Directive was fully transposed into Romanian legislation, starting with the “Norms on radioprotection of the public from medical exposure”, which were jointly approved in 2002 by the minister of health and the president of the nuclear regulatory authority (C.N.C.A.N.) and also by other specific regulations regarding radiation protection of the patient. As in most European countries, the medical exposure is the main man-made radiation exposure of the population in Romania. It is now an alarming increase in use of high radiation dose examinations, such as computed tomography (CT) and of X-rays guided interventions (like coronary angioplasty), with similar doses and sometimes even higher (particularly to the skin). As part of the implementation plan of the 97/43/EURATOM Directive, a national system on registration and reporting of medical exposure was recently developed in Romania. The system is established by two specific regulations of the Ministry of Health, approved by the ministerial orders No.1542/2006 and No.1.003/2008. It refers to all medical radiological procedures: diagnostic radiology, interventional radiology, nuclear medicine and radiotherapy. The system includes three main parts:

- registration (electronic or on files) of basic data (patient data, exposure parameters and individual patient doses, if available), at the level of each user (X-ray machine, nuclear medicine department and/or radiotherapy facility);
- on-line data reporting to the Radiation Hygiene Laboratory (RHL), belonging to the local Direction of Public Health and to the specialized network of the Ministry of Health (quarterly);
- on-line reporting of data, by each RHL, to the Institute of Public Health-Bucharest (annually). The Institute of Public Health – Bucharest has to evaluate all data and to issue in June 2010 a first report on data from 2009.

P02-40

**Analysis of doses in x-ray  
computed tomography****Skrzynski, Witold; Slusarczyk-Kacprzyk, Wioletta;  
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Computed tomography is known to be relatively high dose diagnostic procedure. The need to justify, to optimize, and to evaluate the exposure in tomography examinations is therefore widely accepted. This is especially true for children, who are more sensitive to radiation, and for whom unnecessary overexposure is possible in case of non-optimized scanning protocols. The ALARA principle should, however, be obeyed for all patients.

In this study dose related data were collected for patients examined on several different CT units. The patients included adults and children of various age. The examinations were done either on purpose of diagnosis or for planning of radiation therapy.

Collected data were analyzed in order to establish, whether the parameters of examinations were routinely adjusted accordingly to patient size, especially in case of children. Doses, expressed in terms of  $CTDI_{vol}$  and DLP, were compared with reference levels published by the European Commission and by the NRPB. Effective doses were estimated using conversion factors published by NRPB, and then used for comparison between CT units and groups of patients.

The analysis helped to reveal situations, in which scanning protocols were clearly non-optimized as far as radiological protection of patients is concerned.

P02-41

**Radiographers' safety culture  
in medical use of radiation****Niemi, Antti<sup>1</sup>; Parviainen, Teuvo<sup>2</sup>**<sup>1</sup>Metropolia University of Applied Sciences, FINLAND;<sup>2</sup>STUK – Radiation and Nuclear Safety Authority, Radiation  
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Safety culture is one of the stone basis in medical use of radiation. Safety culture means that organisation and its personnel ways of action and attitudes are so that maintaining and continuous developing of safety is possible. Safety culture in medical use of radiation has been referred mostly theoretically but not empirically. The purpose of this study is to describe and interpret radiographers' safety culture in the medical use of radiation. Another objective is to yield new information and highlight inductively characteristics of safety culture. The data were gathered from two university hospitals and one central hospital. The data consisted of interviews ( $n = 20$ ), fieldwork, articles in a professional journal ( $n = 457$ ) and documents used by a radiographer in his work. Focused ethnographic studies and discourse analysis were drawn on to interpret radiographers' shared meanings of safety culture.

Radiographers' safety culture consisted of four shared meanings: challenges of knowledge and skills structuring safety culture, dimensions of cooperation enabling safety culture, disorientation conditioning safety culture and multidimensional professionalism as the foundation of safety culture. The use of technology was considered an essential part of a radiographer's work, contributing to patient care. The radiographers' varied assignments, their conventional opinions, the work and roles of both head radiographers' and physicians, and their responses to current social challenges in modern working life, all were seen as contributing to cooperation.

Protection against radiation was understood to be an important part of the radiographer's standard activities. Radiographers were confused by the different directions and practices in implementing radiation protection. The results of the study can be used in developing and organizing radiographers' work and education. They may also clarify safety culture as a phenomenon and a concept.

P02-42

### Ethical dilemmas in radiographer's work in diagnostic radiology

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**Purpose:** The purpose is to describe ethical dilemmas in diagnostic radiographer's work. The aim of the study is to create new information since there is comparatively little research focusing on this subject.

**Methods and materials:** Data was collected during spring and summer 2008 and consisted of thematic interviews of diagnostic radiographers (N=8), whose working experience varied from 4 to 31 years. Data was analysed with qualitative inductive content analysis.

**Results:** Ethical dilemmas were found to consider the use of radiation and radiographer's work community. In the use of radiation, implementation of justification and optimisation principles were found to be lacking. There were problems in the safe use of equipments and especially lacks in referrals. There was neither found common safety culture, because the projections, number of them and dose optimisation was insufficient. Also the use of lead shields varied individually and although it was noticed that some colleges didn't use them, there was no discussion about the common practice. Dilemmas in work community consisted of problems among employees and insufficient practice. Background factors of these dilemmas were found to be both dependent on and independent of the employee, resulting in worsened well-being at work and seek for change. Current processing methods of dilemmas were found to be insufficient, and suggestions for better processing methods were made.

**Conclusions:** Daily ethical considerations were described by respondents, but not recognised as ethical dilemmas. Ethics in work as a concept may seem separate and distant, despite the fact that in most cases, ethical dilemmas occur in everyday situations. Recognition of dilemmas is important in order to be able to intervene in them. Respondents repeatedly described powerlessness and inability to intervene in ethical problems. Quite many of those problems can be seen as problems or even lack of safety culture.

P02-43

### Effects of Computed Tomography on paediatric patients: towards an understanding of gene expression profiles and the potential role of radiation induced cytokines

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Computed Tomography (CT) is a diagnostic imaging technique that uses X-rays for assessing a variety of disorders in both adults and children. Within the patient population undergoing CT examination, paediatric patients, following interventional cardiac catheterization CT scans, showed low dose hypersensitivity. A recent study showed an in vivo induction of  $\gamma$ -H2AX foci, caused by interventional X-rays (Beels et al., *Circulation*, 2009). It is suspected that the mechanism behind this hypersensitivity is related to non-targeted or bystander effects.

In collaboration with multiple centres, blood samples will be collected from paediatric patients' pre-CT and post-CT; as well as blood samples from volunteers will be irradiated in vitro, helping us to understand the kinetics of gene expression and track possible differences between in vivo and in vitro radiation effects. Using microarrays, we will be able to investigate global gene expression, thus pointing out differential gene profiles before and after exposure to CT scans. This could lead to an understanding of the biological mechanisms behind the low dose hypersensitivity; on the other hand, we might be able to specify certain early radiation induced biomarkers, thus using it to assess the risk associated with CT exposures.

Bystander effect is the induction of DNA damage response in non-irradiated cells that are neighbouring irradiated cells, and is considered to amplify the effects of radiation by increasing the number of affected cells. Potential players that can promote bystander effect are cytokines; these are signalling molecules that are involved in cellular communication during an immune response. We will use multiplex array assay to determine levels of different cytokines following the radiation induced stress.

*Part of this project is financially supported by the Federal Agency of Nuclear Control (FANC-AFCN), Belgium.*

S03-01

**Radon associated lifetime risk****Laurier, Dominique<sup>1</sup>; Tomasek, Ladislav<sup>2</sup>;  
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Quantification of the risk associated to radon exposure is a major public health issue. Since the 1970s, 13 cohort studies provided results on the exposure-risk relationship in miner populations. Since the 1990s, more than 20 case-control studies evaluated the risk of lung cancer associated to indoor radon exposure in the general population. Nevertheless, due to variations in the study designs, in the characteristics of the studied populations and in factors that modify the exposure-risk relationship (age at exposure, attained age, time since exposure or exposure rate), it is difficult to verify the coherence of published results. Calculation of lifetime excess absolute risks (LEAR) is a way to compare the results of risk coefficients or models derived from different populations when applied to the same scenario of exposure. We present here some LEAR estimates based on the most recent epidemiological results. Different models are applied, derived from both miner studies (BEIR VI, Eldorado, French-Czech models) and indoor studies (European pooling project). The background reference rates are those proposed by the ICRP. Different scenarios of chronic low rate exposure are considered, including those used by the ICRP. Results illustrate the impact of age and time modifiers on the estimated LEAR. Results obtained using different models derived from miner studies are highly coherent. A good agreement is also observed between LEAR estimates obtained from miners and from indoor studies when applied to adapted scenarios. To conclude, calculation of LEAR allows demonstrating a very good coherence in currently available radon associated risk estimates. These results provide support to the elaboration of radiation protection measures regarding radon exposure.

S03-02

**European atlas of natural radiations: status of the indoor and geogenic radon maps****De Cort, Marc<sup>1</sup>; Tollefsen, Tore<sup>1</sup>;  
Bossew, Peter<sup>2</sup>; Friedmann, Harry<sup>3</sup>**

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Based on its political and legal mission, in 2006 the JRC started to design the project of a European atlas of natural radiations. As first step a map of indoor radon was envisaged, given the radiological importance of the related exposure pathway. Since a seminal meeting in Prague, autumn 2006, the indoor Rn map is under way, with contributions from so far (August 2009) 15 countries. Individual measurement data are aggregated into a common grid by the participants. Grid data, which consist of grid cells filled with statistics on individual data, are then further processed by the JRC. In the aggregated dataset, no information on individual houses is available. We present the preliminary results in terms of descriptive statistics and maps, and some further results based on modelling steps, like spatial risk estimate. Indoor radon concentration is controlled by geogenic, climatic and anthropogenic factors. Among the latter are house and room types and living habits. In order to assess the hazard, or potential risk of indoor Rn exposure at a location, independent of anthropogenic factors, one needs a standardized quantity which is only controlled by the geogenic (and possibly average climatic) factors. Since a start-off meeting in Oslo, summer 2008, we are developing a harmonized European Rn index which can be estimated from different input data, as available in participating countries. Among these are indoor Rn concentrations, data on Rn in soil gas, geological classes, geochemical data and external dose rate. Currently algorithms are under discussion to convert such multivariate data, different country by country, into one radon index variable. Future steps of the European atlas of natural radiations may be maps of cosmogenic exposure and geochemical maps of natural radionuclides.

S03-03

### The Austrian Radon Programme – Past and future

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As early as at the beginning of the 20th century radon measurements in water were conducted in Austria whereas radon measurements in air started in 1949. Several thousand measurements of radon in air in workplaces (caves, mines) and homes were conducted until 1972 by Pohl and Pohl-Rüling. Later measurement campaigns took place in Innsbruck, Salzburg, and Vienna but it was not until 1991 that a systematic and coordinated investigation of the radon situation in Austria began.

The main effort was to establish the Austrian radon map in the framework of the Austrian Radon Project (ÖNRAP) with Harry Friedmann as project leader (1992–2004). Other main projects were to test various mitigation techniques (SARAH, Maringer, 1996–1998) and preventive measures. One project dealt with the influence of building characteristics on the radon concentration and the use of a Blower Door to determine the mean radon concentration of a building (RACODE, Ringer, 1997–2001). Substantial efforts were undertaken to determine the radon exposure in kindergartens, schools, and town halls including the mitigation of the buildings with elevated radon levels.

The knowledge and experience gained by the projects led to the issue of three Austrian standards for radon measurement, mitigation and prevention, and to the issue of a radon CD and a radon brochure.

In 2006 the Austrian Centre for Radon was established with the aim to better coordinate the radon efforts. Main tasks at present are the setup of an official radon website and the design and implementation of the Austrian radon database. Other projects deal with the radon exposure in show caves and tourist mines, the investigation of the house to house variation of radon in a community and of the causes of that variability, and the determination of radon levels outdoors.

This paper will present and discuss past and future efforts in Austria to determine the radon exposures in homes and workplaces and to reduce the radon risk of the population.

S03-04

### Norway's new national radon strategy

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Norwegian Radiation Protection Authority, NORWAY

A multidisciplinary working group, including the Norwegian Radiation Protection Authority (NRPA), was initiated in May 2007 by the Norwegian Ministry of Health and Care Services to suggest a coordinated national effort to reduce radon exposure. Their findings were that since radon levels in Norwegian dwellings are log-normally distributed, most of the radon cancers are induced at low levels. They estimated that 70% of the annual lung cancers in Norway induced by radon occur at levels below 200 Bq/m<sup>3</sup>. A successful radon strategy therefore needs to reduce not only high but also moderate radon levels. Radon exposure occurs in all categories of buildings i.e., individual risk comes from the sum of exposures from different buildings; work and leisure. The working group's findings lead to the Norwegian government publishing a new national strategy for radon in July 2009. The strategy seeks to reduce the sum of all exposures and is directed at all categories of buildings. The national strategy aims to achieve radon levels (a) that are as low as practically achievable and (b) that are below given maximum limits. It is divided into the following sections – radon in: land planning, construction of new buildings; existing dwellings, communities with extreme radon problems, public buildings (including schools and kindergartens) and in work places. The NRPA has been appointed by the Norwegian government to coordinate the implementation of the new national radon strategy in the period 2010–2014. Furthermore, the NRPA has changed its recommendations concerning radon, based on scientific evaluation of the current literature and in accordance with the new national strategy. These changes include ALARA and new action and maximum recommended radon levels of 100 Bq/m<sup>3</sup> and 200 Bq/m<sup>3</sup>, respectively. This presentation will present the radon strategy, its justification and the planned implementation.

S03-05

**National measurement database  
in radon research in Finland**Valmari, Tuomas; Mäkeläinen, Ilona;

Arvela, Hannu; Reisbacka, Heikki

STUK – Radiation and Nuclear Safety Authority, Research and  
Environmental Surveillance, FINLAND

STUK has carried out indoor radon measurements in Finnish dwellings since 1980s using alpha-track detectors. Our database contains measurements in 70 000 dwellings in detached houses, 17 000 dwellings in semi-detached and terraced houses and 5 000 flats. Residents are asked to fill in a two-page questionnaire form that contains questions on building characteristics, such as foundation type, ventilation type and radon prevention. Measurement activity is affected by location of residence, as people living in high-radon area are more likely to carry out radon measurements. Representative national and regional average concentrations were estimated by calculating the values in 1 × 1 km cells, and weighting each cell by the dwelling density. The calculated national average radon concentration in dwellings (excluding flats), 137 Bq/m<sup>3</sup>, settles in between the representative values of 145 Bq/m<sup>3</sup> and 121 Bq/m<sup>3</sup> obtained in national random sampling surveys in 1990 and 2006, respectively. Municipal-specific radon map of Finland, as well as curves presenting average radon concentration by construction year, calculated using the dwelling-density weighting method, are presented. Until now, random sampling surveys have been necessary to obtain representative information on radon situation in Finland. The dwelling-density weighting approach opens up an alternative method. The database can be utilised, e.g., in radon prevention and mitigation studies.

S03-06

**A review of the uptake, health benefits  
and cost effectiveness of Smoking  
Cessation and Radon Remediation  
Programmes in Northamptonshire, UK**Denman, Antony<sup>1</sup>; Groves-Kirkby, Christopher<sup>1</sup>;Timson, Karen<sup>2</sup>; Shield, George<sup>2</sup>; Rogers, Stephen<sup>2</sup>;Campbell, Jackie<sup>3</sup>; Phillips, Paul<sup>1</sup><sup>1</sup>The University of Northampton, School of Science and  
Technology, UNITED KINGDOM; <sup>2</sup>NHS Northamptonshire,  
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The greatest risk factor for lung cancer is smoking, the second largest factor being raised radon levels at home. Initiatives to stop smoking and reduce domestic radon levels have met with some success, but in both cases a significant proportion of those affected remain. The two risk factors combine, so that those who smoke and live in a house with high radon levels are at higher risk than if exposed to only one of the two threats. There is the potential for combined public health campaigns to better target those affected. Our group has studied both the smoking cessation and radon remediation programmes in Northamptonshire, UK, considering the costs and health benefits of each, and, using postal questionnaires, recording the demographics of participants. Our analysis suggests that the demographics of the two groups are significantly different. Those who remediate tend to be older, include fewer smokers and have fewer children. In addition, that those who continue to quit at one year were more likely to have children under 18 at home, and live with a parent or partner compared to those who had relapsed after the previous assessment at 4 weeks. The health benefits from stopping smoking are greater than from radon remediation, and the smoking cessation programme costs less per lung cancer averted. The presentation discusses the synergy between the programmes, and argues that there is merit in an integrated approach to these health campaigns, and in particular to extending smoking cessation programmes to include advice on reducing the risks from radon.

S03-07

### A model describing indoor concentrations of thoron and its decay products

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In the past, the radioactive noble gas thoron ( $^{220}\text{Rn}$ ) was thought to occur only in negligible concentrations. But recently, increased thoron concentrations were found in traditional Chinese and Indian mud buildings, where their contribution to the inhalation dose of the dwellers can be in the order of magnitude of the dose from radon ( $^{222}\text{Rn}$ ). Moreover, the WHO's Radon Handbook of 2009 advises dose reductions also with relatively moderate exposures, for which even average additional thoron concentrations can be crucial. Therefore, a model of the occurrence of thoron and its decay products indoors was developed.

The solution of the differential equations which describe the sources and sinks of the nuclides of the thoron decay chain yielded a theoretical relation between the concentrations of the nuclides in the unattached and the attached state, which are important for inhalation dosimetry. Several differences to existing radon models could be identified. Transfer coefficients occurring in the differential equations were determined experimentally. For this purpose various atmospheric conditions were adjusted in a small-scaled traditional Chinese mud dwelling, which had been erected at Helmholtz Zentrum München. Because of the prevalence of mud as a building material in houses with increased thoron concentrations, influences on its exhalation were studied in detail.

To validate the model, model predicted concentrations of thoron and its decay products of real Chinese and Indian mud dwellings were compared to measured concentrations in those rooms. The model makes possible to assess exposures of dwellers to thoron and – combined with a dose model – to calculate their inhalation doses in dependence on their living habits from easily measurable constructional properties of the dwelling. The model predicts significant exposures for residents of buildings with mud construction elements in other countries as well.

S03-08

### First results of measurement of equilibrium factors $F$ and unattached fractions $fp$ of radon progeny in Czech dwellings

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National Radiation Protection Institute, CZECH REPUBLIC

The unattached fraction of radon decay product clusters  $fp$  and equilibrium factor  $F$  are dose relevant parameters in all dozimetric approaches to dose calculation.

In the past, three years weekly continuous measurements of unattached and attached activity of each short-lived radon progeny and air exchange rate were carried out during heating season in thirty occupied typical Czech family houses.

The results indicated statistically significant different weekly averages of equilibrium factor  $F$  and  $fp$  for houses located in towns compared with villages. Due to this fact approximately 10% average increasing of equivalent lung dose rate was calculated in the detriment of towns. Average values of equilibrium factor  $F$  and  $fp$  were found to be 0.40 and 8.6% in case of urban houses and 0.32 and 10.7%, respectively, in case of rural houses.

Based on measurement of mean values of  $fp$  average effective dose conversion coefficients per WLM were estimated to be 15.0 mSv/WLM in case of urban houses and 15.9 mSv/WLM, respectively, in case of rural houses.

The key parameters of the Jacobi-Porstendörfer room model, i.e. attachment rate to aerosol  $X$  and plate-out  $qf$  of unattached radon daughter products were ranged from  $10\text{ h}^{-1}$  to  $60\text{ h}^{-1}$  with the similar means about  $(20-25)\text{ h}^{-1}$ . Air exchange rate was ranged from  $0.1\text{ h}^{-1}$  to  $1\text{ h}^{-1}$  with mean about  $(0.3-0.4)\text{ h}^{-1}$  and it was observed its statistically significant average 30% decreasing during night in comparison with day.

S03-09

**A comparison of one and three month radon measurements in Ireland****Rochford, Heather<sup>1</sup>; Fenton, David<sup>1</sup>;  
Murphy, Patrick<sup>2</sup>; Regan, Laura<sup>3</sup>**<sup>1</sup>Radiological Protection Institute of Ireland, IRELAND;<sup>2</sup>University College Dublin, School of Mathematical Sciences, IRELAND; <sup>3</sup>Dublin City University, School of Chemical Sciences, IRELAND

Indoor radon concentrations are subject to high temporal variation that can make short term measurements of radon unreliable and difficult to interpret. Oscillations in radon concentrations can be smoothed by carrying out long-term measurements using CR-39 alpha track detectors, with a typical measurement period of three months or more. Short term radon measurements can be unreliable when used to predict how average long term radon concentrations within a building compare with the Reference Level. Ideally, the measurements would be carried out over a full year as this would provide the most accurate result. However, householders are often reluctant to wait so long for results and detectors left in place for so long are commonly lost. Furthermore, there is evidence to suggest that the sensitivity of a detector may change over such a long period of time, increasing the uncertainty associated with the result. Currently in Ireland, radon measurements are carried out over a minimum period of three months. This is a compromise between the need for a long exposure period to provide a reliable estimate of the long-term mean radon concentration and the problems associated with year-long measurements. The Radiological Protection Institute of Ireland (RPII) have recommended that radon be included in the conveyancing process but recognise that a 3 month measurement period may create too much of a delay when householders are likely to require a radon result in a shorter timeframe. This project compares the results of one month measurements with three month measurements using CR-39 alpha track detectors. Statistical analysis of the results from 662 homes around Ireland are reported.

S03-10

**Radon hazard evaluation based on measurements of indoor air and gamma measurement surveys in combination with bedrock and drift geology mapping****Rudjord, Anne Liv<sup>1</sup>; Smethurst, Mark<sup>2</sup>; Finne, Ingvild<sup>3</sup>**<sup>1</sup>Norwegian Radiation Authority, NORWAY; <sup>2</sup>Norwegian Geological Surveys, NORWAY; <sup>3</sup>Norwegian Radiation Protection Authority, NORWAY

During the last 10 – 15 years, The Norwegian Radiation Protection Authority has carried out several surveys of radon in indoor air. These data have been useful for the overall evaluation of radon risks at the local level, and they have been used both for estimations of average radon exposure and, to a certain extent, to identify radon-prone areas. According to the new radon strategy (2009) in Norway, the local authorities will need to consider the radon hazard in connection with area planning, and if necessary impose restrictions or local regulations regarding new building constructions in very high risk areas. The Geological Survey of Norway and the Norwegian Radiation Protection Authority have established a combined approach to mapping of radon in Norway, based on direct measurements of radon in indoor air, bedrock and drift geology, and the mapping of uranium/radium in the ground using airborne gamma-measurement surveys. This work resulted in the release of overview radon awareness maps covering the most densely populated areas in Norway around the capital city Oslo. The performance of the hazard evaluations was tested in an area centered around the municipality of Gran, and was shown to be able to enclose most of the high risk areas. Areas already known to be associated with elevated radon hazards were confirmed, and additional potential high risk areas not yet confirmed by indoor radon measurements were identified. The Norwegian Geological Surveys have recently carried out new air-borne gamma measurement surveys in areas south-west of Oslo. Corresponding datasets on indoor radon are available, and includes areas known to be strongly affected by radon. A test of the combined approach in this area will be independent of the earlier studies, and will be used for additional testing and refinement of the method that has been established. The results of this work so far will be presented.

S03-11

**Indoor radon and construction practices of Finnish homes from 20<sup>th</sup> to 21<sup>st</sup> century****Mäkeläinen, Ilona<sup>1</sup>; Valmari, Tuomas<sup>1</sup>; Reisbacka, Heikki<sup>1</sup>; Kinnunen, Topi<sup>2</sup>; Arvela, Hannu<sup>1</sup>**<sup>1</sup>STUK – Radiation and Nuclear Safety Authority, FINLAND;<sup>2</sup>University of Jyväskylä, FINLAND

Indoor radon is the second leading cause of lung cancer in Europe. In order to reduce the exposure to radon, it is necessary to understand the structural features of buildings that affect radon concentrations. These features vary with the year of completion of the building. A population-based random sample study was performed in the homes of 2,882 people. Radon measurements were made using alpha track detectors. Information on the structure of the dwellings was collected using a questionnaire. The weighted national mean of indoor radon concentration in single-family and row houses was 121 Bq/m<sup>3</sup> and in blocks of flats 49 Bq/m<sup>3</sup>. The national mean was 96 Bq/m<sup>3</sup>. The radon concentrations in new single-family and row houses began to rise after the 1960s, and continued to rise until steadying during the 1980s and 1990s, decreasing thereafter to the level of the 1970s. These changes can be explained by changes in building methods. Before 1965, the prevailing house type was one with a basement with no direct entrance into the living area. This solution reduced the radon entry into the living area. Thereafter, a slab-on-ground foundation, which promotes radon-bearing air entering the house, became the most common foundation. A more radon-resistant foundation, crawl space was popular during 1950s. Its popularity decreased thereafter and increased again after 2000. Since the year 2000, mechanical supply and exhaust ventilation has been installed in most new dwellings. This reduces the entry of radon due to smaller pressure differences. In addition, the use of radon prevention techniques in new building has become more common because of new building codes. The changes in the Finnish construction practice from the 20th to the 21st century have had clear consequences, which can be seen in indoor radon concentrations. After a slow awakening to radon awareness in the 1980s, research, guidance and legislation have resulted in the current downward trend in indoor radon concentrations.

S03-12

**Geochemical case study of sediment samples from Olkiluoto, Finland – assessment of radon emission****Breitner, Dániel<sup>1</sup>; Siitari-Kauppi, Marja<sup>2</sup>; Hellmuth, Karl-Heinz<sup>3</sup>; Arvela, Hannu<sup>3</sup>; Ikonen, Jussi<sup>2</sup>; Lehtonen, Marja<sup>4</sup>; Johanson, Bo<sup>4</sup>; Szabó, Csaba<sup>5</sup>**<sup>1</sup>KFKI Atomic Energy Research Institute, Health and Environmental Physics Department, HUNGARY; <sup>2</sup>University of Helsinki, Laboratory of Radiochemistry, FINLAND; <sup>3</sup>STUK – Radiation and Nuclear Safety Authority, FINLAND; <sup>4</sup>Geological Survey of Finland, FINLAND; <sup>5</sup>Eötvös Loránd University, Lithosphere Fluid Research Lab, HUNGARY

In order to define the naturally-occurring radioactive materials that are source of radon in natural environments, a comprehensive analytical (geochemical, physical and chemical) methodology was employed to study sediment samples from overburden glacial formation in Olkiluoto (W Finland). Techniques such as gamma-spectrometry, emanation measurements, sequential chemical extraction, scanning electron microscopy (SEM), electron microprobe analyses (EMPA) and inductively-coupled plasma mass spectrometry (ICP-MS) were used to determine the potential source of radon. Samples are representing a typical Finnish red-ox profile formed on glacial sediments deposited around 9,000 years ago. In Olkiluoto samples activity concentration of <sup>238</sup>U, <sup>226</sup>Ra and <sup>228</sup>Ra show no significant trend in a function of depth secular equilibrium between <sup>238</sup>U and <sup>226</sup>Ra occurred only in the samples collected from the reductive zone. In the oxidized horizon higher radium than uranium activity concentration was measured. In this horizon the <sup>226</sup>Ra/<sup>238</sup>U is 1.4. In Th decay chain secular equilibrium occurred between <sup>232</sup>Th and <sup>228</sup>Ra. Radon productions and emanation factors are very low, varying between 0.01–0.03 Bq/(kg h) and 0.04–0.08, respectively. The uppermost sample collected from the oxidized horizon has the highest radon production and emanation factor. This sample has the highest <sup>226</sup>Ra content (52 Bq/kg), as well. The sequential extraction revealed that in the oxidized zone more exchangeable Ra is present than in the reductive zone. In general, more radium was leached (ca. 20% of the total) easily than uranium and thorium, except in the deepest sample, where 30% of the total uranium was leached easily. Monazite, xenotime, zircons, apatite and U-Th-silicates were identified in the samples as the main sources of uranium, thorium and radium. These minerals were partly weathered in the uppermost horizons and mainly fresh in the deeper ones.

P03-01

**The radon situation in Swedish dwellings based on recent measurements****Hjelte, Ingela; Rönqvist, Tryggve; Ronquist, Birgitta**

Gammadata Mätteknik AB, SWEDEN

Gammadata has been measuring radon levels in Sweden and abroad since the late 1980's and is one of the largest suppliers of CR-39® based radon detectors in Europe. Our extensive database includes several hundreds of thousands of measurements in dwellings, schools, and workplaces. Due to the discussions ensuing after the release of WHO's handbook on indoor radon we have chosen to focus on residential radon levels in this presentation. Using data acquired by us in the last few years we will present results on the radon levels measured in Swedish dwellings and their dependence on several factors such as the type of building, ventilation, and foundation of the measured dwellings.

P03-02

**Radon concentrations in newly built homes in Norway****Finne, Ingvild; Kolstad, Anne Kathrine; Rudjord, Anne Liv**

Norwegian Radiation Protection Authority, NORWAY

Since 1997 requirements on radon in new buildings have been included in building regulations and guidelines in Norway. A large survey of radon in dwellings were carried out in Norway in the period 2000–2001 and the percentage of homes with radon concentration above 200 Bq/m<sup>3</sup> was estimated to 9 % (Strand et al. 2001). These homes were mainly built before the 1997 Building Regulations but little has been known about the effects of the regulations and guidelines on the newly built homes. During the winter season 2008 the Norwegian Radiation Protection carried out a nationwide survey including 750 randomly selected dwellings built in the period 2000–2007 to investigate to what extent radon is still a problem in the new housing stock. The survey showed that the 1997 Building Regulations in force at the time of the survey, and the guidelines supporting it, had very limited effect on the radon concentration in the newly built dwellings. Previous to this study it was assumed that the awareness on radon affected areas could be higher in municipalities strongly affected by this problem. Therefore, another survey was also carried out in seven selected municipalities where extensive radon problems had been found in earlier studies. In two municipalities, 50–60% of the new dwellings had annual mean radon concentrations above 200 Bq/m<sup>3</sup>. In one of the municipalities, all 10 newly built homes had radon concentrations below 200 Bq/m<sup>3</sup>. In the remaining 4 municipalities, the fraction of radon concentrations above 200 Bq/m<sup>3</sup> was in the range 10–30%. The conclusions were that the requirements in the 1997 Building Regulations and supporting guidelines had very little effect on radon concentrations in newly built homes. New building regulations have been adopted after the finishing of this study and will take effect from 1 July 2010.

P03-03

### Short-term measurements of radon concentration in dwellings

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Radon concentrations in dwellings are known to vary from day to day depending on weather conditions and occupant lifestyle. Consequently, short-term measurements (STM) of a few days are generally less representative of the annual mean radon concentration than long-term measurements (LTM) performed over several months. On the other hand, STM may be used as screening techniques for testing radon levels. The aim of this study was to develop a screening method based on STM to provide fast and reliable indications of radon levels in dwellings. Radon concentrations were measured in 184 dwellings in Switzerland over a 3 month period using alpha-track detectors (Radtrak). Together with LTM, STM were performed at 3 time points, i.e. at the beginning, the middle and the end of the 3 month period, using activated charcoal canisters (PicoRad) exposed during one day. A statistical comparative analysis of LTM and STM in those dwellings was performed to derive the screening method. Results obtained with STM overestimated, on average, by 35% those obtained with LTM, with a standard deviation of 65%. This was explained by the reduced ventilation applied during STM. The variability of STM at the three different time points was characterized by a standard deviation of 24%. Based on those results, the following screening method was proposed considering an action threshold of 400 Bq/m<sup>3</sup>: (a) if STM are less than 110 Bq/m<sup>3</sup>, the annual mean radon concentration is below 400 Bq/m<sup>3</sup> with a confidence level of 95%; (b) if STM are above 970 Bq/m<sup>3</sup>, the annual concentration exceeds 400 Bq/m<sup>3</sup> with a confidence level of 95%; (c) if STM range between 110 and 970 Bq/m<sup>3</sup>, LTM are required to determine whether the dwelling is above or below 400 Bq/m<sup>3</sup>. This method was validated for several dwellings. We conclude that STM provide valuable information on radon levels in dwellings to determine if further LTM are necessary. In Switzerland, this STM screening method is primarily used in real estate transactions.

P03-04

### Estimating the health benefits of progeny extraction units as a means of reducing exposure to radon

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Radon exposure to the general public can be reduced by preventing entry of radon gas into buildings using a passive radon-proof membrane or an active sump and pump system. However, a significant majority of the radiation dose delivered is from the decay products of radon rather than from the gas itself. These decay products (also referred to as progeny) are present in indoor air, with an equilibrium factor – a measure of the ratio of progeny to radon gas – of between 0.4 to 0.5. As a result, systems which extract radon progeny from the air by filtering have been promoted as means of reducing exposure to the general population. The European Community Radon Software (ECRS) offers a means of estimating lung-cancer risk associated with an individual's exposure to radon, and includes the possibility of estimating the health risk from different proportions of radon gas and its progeny by varying the value of the Equilibrium Factor. This software was used to estimate the health benefits associated with reduced decay products in differing concentrations of radon gas. The results were compared to health benefits expected if the risk was reduced by the standard method of reducing the radon gas concentration below the Action Level, which in the UK is 200 Bq•m<sup>-3</sup> for domestic properties. These calculations showed that there is the potential for efficient extraction units to provide the necessary dose and risk reduction where initial average radon gas concentrations are up to 800 Bq•m<sup>-3</sup>. However, above 1000 Bq•m<sup>-3</sup>, such systems cannot reduce the health risk sufficiently to reach levels comparable to those resulting from radon gas reduction to below the Action Level.

P03-05

**Indoor radon anomalies and correlation with geodynamic events: A case study in the Etnean area****Vizzini, Fabio<sup>1</sup>; La Delfa, Santo<sup>2</sup>**<sup>1</sup>University of Palermo, Department of Physics and Related Technologies, ITALY; <sup>2</sup>University of Catania, Department of Geological Sciences, ITALY

More than 50% of the total absorbed dose from natural radiation sources is attributed to radon gas and its daughters. In the last decades, an increasing regulatory and scientific interest concern radon indoor monitoring, because radon and its daughters produces a risk of lung cancer, by inhalation of high concentrations for a long time. The indoor radon transportation is due principally by two different mechanisms: diffusion from soil and building materials and convection flow. The diffusion mechanism depends on the radium concentration in soil and building materials, as well as on the diffusion coefficient; convective flows are generated by a pressure difference between the inside and the outside of a building. Many external factors can also influence the diffusion process: rainfall, freezing and increasing atmospheric pressure decrease the exhalation rate, while increasing temperature can increase it.

In 2006, for a period of four months between winter and spring, both in soil and indoor radon gas, and meteorological parameters, have been monitored continuously in two buildings at St. Venerina, situated on the low eastern flank of the volcano. This area is crossed by the Timpe Fault System (TFS), that are composed of faults mainly trending towards NNW-SSE and NW-SE. The indoor radon anomalies have been studied trough statistical methodology and they have been correlated with the geodynamic events of volcano Etna, recorded during the investigated period. Its values seems to show variations not due to local meteorology, diffusion or convection mechanisms, instead the predominant effect seems to be the geodynamics of the Etnean area.

This study is an example that shows how in the active volcano-tectonic areas, the indoor-radon monitoring, based only on seasonality and floor numbers, is not exhaustive to establish the indoor radon levels, and how radon accumulation may depends on several and complex effects, each one able to generate anomalies of its concentration.

P03-06

**Influence of environmental factor on radon emanation coefficient****Hosoda, Masahiro<sup>1</sup>; Sorimachi, Atsuyuki<sup>1</sup>;  
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Radon gas is generated from radium in soil and rocks. Radon emanation coefficient is regarded as an important factor affecting the generation of radon from soil and rocks and it depends on various environmental factors such as soil particle size, temperature and moisture saturation. In this study, radon emanation coefficient of Japanese soil samples is measured by accumulation method. We have examined experimentally the dependency of radon emanation coefficient on different soil particle size (from  $< 106 \mu\text{m}$  to  $> 1000 \mu\text{m}$ ), temperature (5, 25, 40, 55 °C) and moisture saturation (from 0 to 0.9).

P03-07

**Evaluation of radon risk using GIS (Geographic Information System) techniques in the Central Hungarian Region****Boros, Ákos<sup>1</sup>; Szabó, Zsuzsanna<sup>1</sup>; Szabó, Katalin Zs.<sup>1</sup>; Völgyesi, Péter<sup>1</sup>; Horváth, Ákos<sup>2</sup>; Szabó, Csaba<sup>1</sup>**<sup>1</sup>Eötvös University, Lithosphere Fluid Research Lab, HUNGARY;<sup>2</sup>Eötvös University, Atomic Physics, HUNGARY

Central Hungarian Region is the most populated area and cultural, financial and political centre of Hungary. The idea to predict potentially health deteriorating impacts in the area is obvious. Recent radon and thoron studies have been carried out on the region. These researches motivated us to test a new technique of Wattananikorn et al. (2008) for radon potential mapping, based on airborne uranium concentration maps (Tyhomirov, 1965–66). Also, a well studied area with thorium anomaly is known at Nagy-Kopasz hill (Buda Mts., west to Budapest), which provides an opportunity to test this method for thoron concentration distribution of soil gas. On the basis of airborne uranium concentration maps, the soil gas radon concentration can be estimated (Wattananikorn et al., 2008), thus airborne uranium and thorium maps, as well geological and soil maps were processed and analyzed by standard GIS tools. Other factors, for instance, soil permeability and physical types of soils were obtained from the AGROTOPO digital database. The results gained were corrected with land use map and tectonic data. GIS analyses were validated by in situ soil gas radon and thoron measurements and laboratory measurements of exhalation rate of soil samples, as well as radon concentrations in indoor areas. From the calculated soil gas radon concentration we estimated prospective indoor risk values, based on correlation between soil gas and indoor radon concentration data. After an overlay and merge of these data with population maps, the results show different radon risk categories at all settlements in the studied area (Kohli et al., 1997). Kohli, S. et al. (1997). *Computer Methods and Programs in Biomedicine* 53(2): 105–112. Tyhomirov, A. (1965–66). *Airborne radiometric maps, Pilis-Buda Mts.* ELGI Wattananikorn, K. et al. (2008). *Radiation Measurements* 43(1): 85–90.

P03-08

**Deposition and clearance of inhaled radon progenies in the central airways****Balásházy, Imre<sup>1</sup>; Madas, Balázs Gergely<sup>1</sup>;****Kudela, Gábor<sup>2</sup>; Farkas, Árpád<sup>1</sup>**<sup>1</sup>MTA KFKI AEKI, HUNGARY; <sup>2</sup>Eötvös Loránd University, HUNGARY

90% of the lung cancers of former uranium miners developed in the central airways. Current computational fluid dynamics calculations indicate high local primary deposition densities in this region. However, cellular burdens of the radon progenies deposited in the deep regions of the lung and clears up by the mucus layer may contribute to the health effects found in the large central airways. The surface of airway generations increases with airway generation number, thus, it looks a reasonable supposition that the dose contribution of the deeply deposited and up clearing radon progenies may contribute to the health effects in the large airways. In this work, the deposition distribution of inhaled radon progenies was computed by the newest version of the stochastic lung model. A clearance model was constructed to simulate the up clearing fractions of attached and non-attached radon progenies in each bronchial generations. The stochastic lung model was also applied to compute the surface of the airways. Finally, the surface activity densities of the primarily deposited and also the up cleared fractions have been calculated in airway generation level at different breathing patterns and mucus velocities. The main input data of the clearance model are the followings: deposition, velocity of the mucus in each airway generation, length of the airways and the half life of radon progenies. Based on the results, the radiation burden on a unit surface area of the central airways is the highest in the first few generations due to the up clearing, deeply deposited, radon progenies. Comparing the amounts of the primary deposited and the up cleared radon progenies in the large airways one can conclude that the burden of the up cleared fraction is larger than that of the primary deposition with a factor of 2–10. The results demonstrate that a reason of radon induced lung cancer in the central airways may be the dose contributions of the up clearing deeply deposited radon progenies.

P03-09

**Reducing the risk to military personnel from radon gas****Williams, Dean; Langridge, Darren**

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Radon is attributable to approximately 1500 deaths a year in the UK alone. It is a naturally occurring radioactive gas that derives from uranium found in rocks and soils, and is therefore a natural environmental hazard. Employers have a legal obligation to assess the radon health risk for all their employees. Recent improvements in the UK radon data set and developing work on the risk of radon gas has made this a priority issue for the UK Ministry of Defence (MOD). The Defence Science and Technology Laboratory (Dstl) were given the challenging task of developing a strategy to address this issue and to implement a monitoring protocol to cover the whole of the MOD estate (thousands of locations) throughout the UK and overseas. The development of this involved:

- Working with and/or obtaining information from the Health Protection Agency and the Health and Safety Executive.
- Utilising the most up-to-date guidance from the Building Research Establishment (BRE) and academia to understand the most appropriate and effective remediation techniques.

The radon monitoring program is now well under way covering thousands of workplaces, with the aim of protecting the health of military personnel now and in to the future. A number of examples are given, including the unusual example of 'working' in caves, where radon levels may be extremely high. A three year research project has been undertaken assessing the radon doses to military personnel in caves in the North Pennines currently used for adventure training activities. The findings from this work not only aid in protecting the personnel directly involved, but also have the potential to inform risks in future caving activities. The data set collected will be invaluable for future theatres of operation and also potential litigation work. Most importantly, the remediation work undertaken will reduce the health risk to MOD employees across the UK and overseas.

P03-10

**An assessment of radon exposures to CR-39 alpha track detectors during postal transit in Ireland****Rochford, Heather<sup>1</sup>; Fegan, Mary<sup>2</sup>; Fenton, David<sup>2</sup>**<sup>1</sup>Radiological Protection Institute of Ireland, IRELAND;<sup>2</sup>Radiological Protection Institute of Ireland, Radon Advice, IRELAND

In many countries, including Ireland, radon measurements are carried out by sending radon detectors to and from customers through the standard postal system. In Ireland the radon detectors are left in place for at least 3 months before the customer returns them by post. The detectors used are CR-39 alpha track detectors and they are sent in standard A5 envelopes with no radon-proof membranes or seals. To date, this has been done on the assumption that the level of radon detected during postal transit was insignificant compared with the much longer period in situ in the customers' premises. However if a shorter measurement period is chosen, for example one month, the radon exposure recorded by the detectors while in the post could be significant and may give rise to a misleading result. This study investigates the contribution made by levels of radon in the Irish postal system to detectors in transit. Thirty-seven volunteers, located throughout the country were identified for participation in the project. Every county in Ireland was represented, with a focus on high radon areas by choosing two or three volunteers from those counties. Two CR-39 detectors were sent to each volunteer in standard issue envelopes. On receipt of the envelopes, the volunteers immediately posted them back using a provided freepost envelope. Detectors posted close to or during weekends are likely to be in the postal system the longest. For this reason the RPII laboratory always issues detectors before Friday. However there is no control over when customers return them. Results therefore will be presented of a worst case scenario: detectors were posted to volunteers on a Thursday afternoon to ensure the transit time coincided with at least one weekend.

P03-11

**Radon areal distribution in Campania region (Italy) inferred from a geostatistic analysis**

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The territory of Campania region is one the most rich of Radon of Italy and presents prone areas of indoor radon because of the characteristics of the subsoil and of the building materials of local origin which is prevalently volcanic. The national survey on indoor radon classifies this region with a mean concentration higher of 30% than national mean value, but other regional surveys on selected building underline the presence of numerous sites where indoor radon levels are very high. In last fifteen years, our work-group has investigated radon levels within dwellings, schools and workplaces. The principal aim of the present work is to summarize the results of about 700 measurements by using a geostatistic approach which has allowed the realization of a Radon distribution map of the region. Each result is the mean value of an entire year and has been performed by the SSNTDs with LR115 films. Data have been normalized respect to the building material and floor location and, then, located on the map. The lognormal distribution of data has allowed the application of geostatistic techniques using spatial interpolators that not require an uniform distribution of data. The analysis has been performed by the Arcview software which allow the selection of the best variogram and furnishes also the map of the variance of results. Different maps have been extracted from different normalization of data. The maps well describe the real situation according to the experimental results.

P03-12

**Radon mapping strategy in the Republic of Moldova**

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Radon is a chemically inert radioactive gas. It is formed by the natural radioactive decay of uranium in rock, soil, and water. Naturally existing, low levels of uranium occur widely in Earth's crust. Radon is responsible for the majority of the mean public exposure to ionizing radiations. Constant exposure to high concentration of radon gas may cause lung cancer. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as basements. The radon concentrations in a building are dependent on the concentration of radium in subjacent ground and surrounding soil, the geological bed rock, the radioactivity of building materials, the ventilation conditions, the meteorological conditions and human activities, also. The results of radon concentrations monitoring in the air samples which have been collected in different buildings placed on the territory of the Republic of Moldova during the period of time since 1991 till 2008 years are given in the paper. Investigations have related, that the <sup>222</sup>Rn concentrations (92,0...179,1 Bq/m<sup>3</sup>) in most cases do not exceed a maximum permissible level. The establishment of <sup>222</sup>Rn concentrations in the air samples collected from Cricova storage of wine undergrounds, Chisinau underground galleries, and Milestii Mici, some mines from Orhei, traced out the values of concentrations (200...1800 Bq/m<sup>3</sup>) which exceeded the maximum permissible level. Only 2,1% among all investigated houses in territory of Republic of Moldova exceeds the level of 200/Bq/m<sup>3</sup> for radon concentration. The results require the need of radon concentrations monitoring carrying out in dynamics, with the subsequent elaboration of the radon concentrations maps [1].

**Reference:**

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P03-13

**Radon survey in a village close to a former uranium mine (S-W Hungary)**

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The studied former uranium mine is located at the village of Kovagoszolos (S-Hungary). In the area Permian sandstone layers were found to be rich in uranium for mining, which lasted for 40 years. Kovagoszolos has ~350 family houses. At different distances from the surface projection of a mining tunnel radon concentration was measured in 120 houses with passive detector. The average value of the radon concentration is 483 Bq/m<sup>3</sup>. Significantly higher radon concentrations (average 667 Bq/m<sup>3</sup>) were measured in houses within 150 m from the surface projection of the mining tunnel, compared with the houses further than the 300 m belt (average 291 Bq/m<sup>3</sup>). Nine houses were selected for detailed study: short term indoor radon concentration measurement (RAD 7, AlphaGuard); physical (<sup>226</sup>Ra content, radon exhalation) and geochemical study on collected soil samples from house gardens. From the nine studied houses, in four particular ones the radon concentration was above the recommended level. The radium content in all cases was higher than the world average value. In the studied soil samples the finest fraction is dominated, potential radon source minerals were considered as Fe-oxides and hydroxides. Among the four chosen houses in one house an extrem radon anomaly was recognized. The indoor radon concentration was measured for one month (by active and passive detectors). Outdoor the gamma dose rate, soil gas radon concentration, radon exhalation and air radon concentration were also determined in the surrounded area of the house. In the center of detected radon anomaly (an area 5 m in diameter) the radon concentration of the outdoor air was 1660 Bq/m<sup>3</sup>, the gamma dose rate on the soil surface 380 nGy/h, the radon exhalation 20167 mBq/m<sup>2</sup>s and the soil gas radon concentration was > 2000 kBq/m<sup>3</sup>. Based on these results, it is clear that the local geology plays as important role in the development of a radon anomaly as the distance from the surface projection of the mining tunnel.

P03-14

**Radon survey based on home stored CDs/DVDs**

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Since the idea to combine the high radon absorption ability of some polycarbonates, like Makrofol and equivalents, with their track etch properties for measuring <sup>222</sup>Rn was first proposed in 1999, substantial experimental and theoretical work was devoted to implement this method. In particular it was demonstrated that home stored CDs and DVDs (which are made of the same kind of polycarbonate materials), can serve as rather precise retrospective <sup>222</sup>Rn detectors. To evaluate the potential of this method for large scale radon surveys a pilot study was organized. Compact discs and DVDs that were stored for 1–15 years in dwellings were collected and analyzed. Protocols for calibration, including *a posteriori* calibration were developed and practical problems in organizing screenings based on CDs/DVDs were addressed. The results showed that the mean <sup>222</sup>Rn concentrations can be determined with an uncertainty better than 30%. In some dwellings data from integrated <sup>222</sup>Rn measurements made in the past was available. The results obtained by CDs were in good correspondence with these from the previous measurements. We present the technical and organizational details of the gathered experience and give grounds for the conclusion that making large scale surveys based on CDs/DVDs is feasible.

P03-15

### Radon measurement method with passive alpha track detector at STUK, Finland

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In Finland, Radiation and Nuclear Safety Authority (STUK) has performed approximately 5 000–20 000 indoor radon measurement per year. The detector material is polycarbonate and the holder model is STUK's own. After at least two-month measurement in the heating period, the polycarbonate films are electrochemically etched in order to see the alpha tracks. Tracks are calculated with image processing and analysis system. Research and Environmental Surveillance of STUK is an accredited testing laboratory T167 (EN ISO/IEC 17025) by the decision of the Finnish Accreditation Service (FINAS). Airborne radon concentration is one of the accredited fields of testing performed at STUK and verified by FINAS. STUK's Health Risks and Radon safety laboratory also makes comparison measurements every second year with Physikalisch-Technische Bundesanstalt (PTB), the national metrology institute laboratory in Germany. STUK's Health Risks and Radon safety laboratory sends its reference measuring device to PTB for calibration. This is to conserve the measurement standard at STUK.

P03-16

### Results obtained in measurements of Rn-222 with the Romanian Standard System

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The general concept of a Romanian Rn-222 Standard System was presented at IRPA 12 Congress [1]. The results obtained in the absolute standardization of radon extracted from a glass system, containing a Pylon Ra-226 source, by Liquid Scintillation Counting (LSC), was presented at the ICRM2009 Conference [2]. This paper presents the results: (i) Realization of the final metallic system, provided with all the necessary control gauges; (ii) Quantitative extraction of radon from the radium source and quantitative transfer from a vial to another; (iii) Absolute standardization by LSC and relative measurements of radon activity, by using the HPGe gamma spectrometry method and the CENTRONIC IG12/20A ionization chamber, for the assurance of the traceability chain. The final purpose of the work is to calibrate adequately the standard systems, HPGe spectrometer and ionization chamber, for using them in the measurement of the working standards, glass vials containing gas radon, prepared with the standard radon system. These standards will be used for the calibration of equipments of various laboratories involved in radon measurement. A method for modeling of the radon transport in various matrices was also elaborated. One part of it refers to the simulation of the radon detectors containing active charcoal, a particular case of a purely diffusive transport in a medium with constant saturation. It will be validated experimentally, with radon gas standards produced with the standard radon system.

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P03-17

**Estimating lung cancer risk due to radon exposure in the radon-prone areas in Belgium**

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Radon exposure in Belgium is particularly pronounced in the southern part of the country, characterized by a sub-surface of highly deformed and fractured (black) shale, schist and sandstones. A national indoor radon campaign (1995–2000) showed that all of the high radon risk areas (where more than 5% of the measured buildings exceed the Belgian action-level of 400 Bq/m<sup>3</sup>) were situated within the Ardenne massif, affecting a population of 380000. For this reason, detailed information, measurement and prevention campaigns have been organized for the local population and municipal authorities. Whereas the national average radon concentration is about 50 Bq/m<sup>3</sup>, this average increases to 170 Bq/m<sup>3</sup> in the high risk area. Here, 13% of the houses exceed the action level, affecting more than 50000 people, and 4% of the houses exceed 800 Bq/m<sup>3</sup>, affecting more than 15000 people. In 33% of the dwellings, the action-level for new buildings (200 Bq/m<sup>3</sup>) is exceeded. According to the risk estimates from international epidemiological studies, about 24% of the occurring lung-cancers (LC) (49 cases on 201 per year) would be due to radon exposure in the high risk areas. About 40% of the radon-induced LC would occur in the population exposed to more than 400 Bq/m<sup>3</sup> (about 20 LC/y). Comparison of these theoretical values with actual LC statistics of the Belgian Cancer Registry shows a good match between the total number of LC/y in the high risk areas (201 calculated to 203 observed). The correlation between LC occurrence and average radon concentration however is obscured by the high number of influencing factors (migration, age-distribution, life-habits,...) and the relatively limited population. Radon campaigns aim at stimulating house owners and building responsables to mitigate the radon affected buildings and to apply preventive measures in new buildings. In the high risk areas, preventive reduction of radon exposure should lead to a reduction of the LC occurrence with 7%.

P03-18

**New seasonal correction factors for radon measurements in Irish homes**Burke, Orlaith<sup>1</sup>; Long, Stephanie<sup>2</sup>;  
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Indoor radon concentrations have been shown to vary considerably with season. Many countries account for this by applying a correction factor to radon measurements of less than one year. To date, Irish radon measurement services have used correction factors based on data collected during a UK national survey of radon in 2000 homes in the 1980s. In the absence of similar data for Ireland at the time, these were considered suitable for use due to the similarities between the climate, house types and lifestyles in both countries. In order to better estimate the long term radon concentration in Irish homes from measurement results, a dataset comprising measurements from 5640 Irish homes was analysed and used to derive a set of correction factors specifically for Ireland. These were generated by means of Fourier decomposition analysis and the new correction factors compared, using 95% confidence intervals, to those derived in the UK using the same analysis and to those currently in use in Ireland. In both cases, differences were found between 10 of the 12 monthly seasonal correction factors. The results of this analysis will be given along with an overview of the methods used.

P03-19

### Upgrade of the NIRS radon chamber – generation of aerosol-attached radon progeny -

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A condensation monodisperse aerosol generator has been used in NIRS radon-aerosol chamber; aerosol particles are generated by the evaporation–condensation method and supplied into the chamber through the sampling port. Carnauba wax is used as the aerosol material. This study describes the generation and measurement techniques for radon and its progeny, in order to make available an accurate calibration facility for radon concentration and to allow investigations covering fundamental questions of physics with regard to the behavior of radon and its progeny as a function of the environmental parameters. Furthermore, we try to control the monodisperse aerosol with a differential mobility analyzer.

P03-20

### The study of behaviour of radon and its decay products in the low layer of the troposphere

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Radon and its decay products are often used like tracers of dynamic processes in the atmosphere. They are used to study climatic phenomena and to produce climatic models scores of the time. The source of radon in the atmosphere is the bedrock. The transport of radon from soil could be characterized by radon flux; UNSCEAR (2000) presents the estimation of the worldwide average of radon flux  $0.016 \text{ Bq}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ . The value of radon flux in one place isn't in the time constant – it is influenced by three fundamental parameters: the concentration of radon in bedrock, the soil moisture and permeability of soil. Methods of determination of radon flux are very sensitive on interpretation of gained results in the dependence on the atmospheric condition for individual measurement. The concentration of radon and its decay products isn't in the low layers of the atmosphere constant – it is strongly influenced by dynamics of the atmosphere. The main factors which influence the concentration of decay products are dry and wet depositions. Generally it is possible to observe differences between concentrations in the day and in the night and in cold and warm parts of the year. The mean concentration of radon outdoor are about  $10 \text{ Bq}\cdot\text{m}^{-3}$  according to UNSCEAR (2000). The research in this area was supported by project of VaV SUJ200402, investigation of a vertical and horizontal distribution of radon and its decay products in the atmosphere was realized among others.

S04-01

**Dosimetric calculations for uranium miners exposed to radon gas, radon progeny and long-lived radionuclides****Marsh, James<sup>1</sup>; Nosske, Dietmar<sup>2</sup>; Gregoratto, Demetrio<sup>1</sup>; Karcher, Klaus<sup>2</sup>; Blanchardon, Eric<sup>3</sup>; Birchall, Alan<sup>1</sup>; Hofmann, Werner<sup>4</sup>**<sup>1</sup>Health Protection Agency (HPA), UNITED KINGDOM;<sup>2</sup>Bundesamt für Strahlenschutz (BfS), GERMANY; <sup>3</sup>Institut de Radioprotection et de Sécurité Nucléaire (IRSN), FRANCE;<sup>4</sup>University of Salzburg, AUSTRIA

In support of epidemiological studies involving pooling of data for German, French and Czech uranium miner studies, the individual annual doses from the year of first employment to 1999 were required. The annual absorbed doses to regions of the lung, red bone marrow, liver and kidney of each individual miner within the cohorts were calculated. The annual absorbed doses arising from the alpha radiation alone were calculated as well as the absorbed doses arising from the mixture of alpha, beta and gamma radiation. The doses arising from exposure to radon progeny, and to the long-lived radionuclides in the uranium ore dust have been calculated with biokinetic and dosimetric models developed by the International Commission on Radiological Protection. The organ doses arising from the inhalation of radon gas alone have been evaluated using published dose coefficients that were calculated with a specific pharmacokinetic model. The external gamma dose has also been measured and is included in the calculation of the total absorbed dose to specific organs. In this paper the methodology and the parameter values chosen for different exposure scenarios are presented as well as the results of organ dose calculations.

**Acknowledgement:** *This work was partially supported by the European contract Alpha-Risk (FP6-516483).*

S04-02

**Doses of *In Utero* and postnatal exposure to the Techa river offspring cohort****Shagina, Natalia<sup>1</sup>; Tolstykh, Evgenia<sup>1</sup>; Harrison, John<sup>2</sup>; Fell, Tim<sup>2</sup>; Bolch, Wesley<sup>3</sup>; Degteva, Marina<sup>1</sup>**<sup>1</sup>Urals Research Center for Radiation Medicine, RUSSIANFEDERATION; <sup>2</sup>Health Protection Agency, UNITED KINGDOM;<sup>3</sup>University of Florida, UNITED STATES

This paper presents estimates of doses from external exposure and intake of radionuclides for a cohort of about 20,000 offspring, whose parents were exposed in the early 1950s from discharges of liquid radioactive wastes into the Techa River (Southern Urals, Russia). Bone-seeking <sup>90</sup>Sr was the main contributor to the internal haemopoietic tissue doses received *in utero* and during infancy following maternal ingestion of the radionuclide before or during pregnancy and breastfeeding as well as postnatal exposure from direct ingestion. To provide reliable estimates of doses from <sup>90</sup>Sr, biokinetic models developed by the International Commission on Radiological Protection in Publications 88 and 95 were specifically adapted to the Techa River populations to describe strontium transfer to the foetus and breast milk. These models were validated by direct measurements of <sup>90</sup>Sr in the foetal skeleton, breast milk and maternal skeleton. To refine dosimetric model for the *in utero* and infant periods, a series of hybrid computational phantoms were developed for the 10, 20, and 30-week foetus and a newborn, from computed tomography (CT) and magnetic resonance imaging of preserved foetal specimens of similar gestational ages and a 6-day neonatal female cadaver. MicroCT imaging of autopsy specimens of the newborn skeleton allowed consideration of the 3D microstructure of marrow cavities and bone trabeculae across the newborn skeleton. Features of *in utero* haemopoiesis were considered and taken into account in dose estimates. Doses from postnatal exposure were evaluated with the Techa River Dosimetry System TRDS-2009D, taking account of ingestion of <sup>89,90</sup>Sr in breast milk and <sup>137</sup>Cs intake in cows' milk. Improved assessments of *in utero* and postnatal doses will be used in epidemiological studies to evaluate risks from chronic exposures in early life.

*This work has been funded by EC (contract FP6-516478) and the US DoE Office of Health Programs.*

S04-03

**Application of the new ICRP reference computational phantoms to internal dosimetry****Hadid, Lama<sup>1</sup>; Desbrée, Aurélie<sup>1</sup>; Schlattl, Helmut<sup>2</sup>;  
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In nuclear medicine, radiopharmaceuticals are incorporated into the body and distributed through biokinetic processes. Thus, each organ can become a source of radiation delivering a fraction of emitted energy in tissues. Therefore, internal radiation dose must be calculated accurately and realistically. Until now, the absorbed doses were derived from standard mathematical phantoms, in which different regions are defined by complex equations. An alternative class of anatomical models called voxelised phantoms was then developed to offer realistic geometries of the human anatomy. In this context, the International Commission on Radiological Protection (ICRP) has chosen to adopt voxelised models to represent the reference adult. Consequently, the Specific Absorbed Fractions (SAFs), first step allowing the absorbed dose calculations, have to be re-evaluated for the new ICRP reference phantoms.

SAFs were thus evaluated for monoenergetic photon and electron sources using OEDIPE software and MCNPX Monte-Carlo code. The SAFs values were then validated by a comparison with those obtained by the German Center for Environmental Health (Helmholtz Zentrum München) using EGSnrc Monte Carlo code. The results show a general agreement for photons and high-energy electrons with differences lower than 8% between both laboratories. Nevertheless, significant differences were found for electrons at lower energy.

Given these results, the impact of the new ICRP reference phantoms on the absorbed doses per incorporated activity to patients from radiopharmaceuticals was estimated. Absorbed doses were calculated for the [<sup>18</sup>F] FDG and [<sup>99m</sup>Tc] ECD in 25 organs for the new ICRP reference computational phantoms. The dose estimates are overall similar to those of the mathematical phantom except for some particular organs (urinary bladder or uterus) where observed differences can be up to a factor of 2.

S04-04

**The guidelines for internal dose assessment after “malevolent use” incidents presented in TMT Handbook****Etherington, George**

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The main objectives of internal contamination monitoring after a malevolent use incident are to quantify absorbed doses to organs for people who may be subject to deterministic health effects because of very high exposures, and to quantify committed effective doses for people with lower levels of internal contamination. Rapid assessments of monitoring measurements are likely to be needed for two reasons. First, urgent decisions on follow-up actions may have to be taken (e.g. on therapeutic treatment of life-threatening radiation exposures, or on the need for more accurate monitoring to allow decisions on decorporation measures to be made). Second, assessments of internal dose may be needed to support treatment and decorporation measures and to provide information to individuals and others on potential effects on health. The simple action level scheme proposed in TMT Handbook (published in 2009) is described. The action levels are related to dose, but are expressed in terms of measured quantities so that direct comparison with monitoring results can be made, allowing rapid decisions to be made on follow-up actions. The use of the simple “look-up” tables provided in TMT Handbook for quantitative assessment of internal doses is also described. These tables allow the direct determination from monitoring measurements of both committed effective dose and absorbed doses to lungs, red bone marrow and the colon. The biokinetic and dosimetric model parameter values assumed for the calculations of the data contained in these tables are discussed. Dose assessment look-up tables are a potentially useful resource, particularly during the early stages of the response to an incident, but users should be aware of their limitations. The potential uncertainties in assessed dose arising from the use of default values for model parameters such as inhaled particle size, absorption type and gastro-intestinal uptake factor are discussed.

S04-05

**Improving ingestion dose modelling for the ARGOS and RODOS decision support systems: A Nordic initiative**

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Most European countries have integrated either the ARGOS or the RODOS decision support system in their preparedness against nuclear accidents. The ingestion dose module in both of these two systems is based on the ECOSYS model, which was developed shortly after the Chernobyl accident. ECOSYS default parameters are generally applied in dose calculations without much consideration of their applicability and representativeness for the particular case. However, the default values reflect southern Bavarian conditions with respect to for instance dietary habits, food import patterns, farm animal feeding regimes and crop growth seasons, and are far from representative of for instance Nordic conditions. Another problem with the ECOSYS default data is that much of the generic data describing the processes of mobility of contaminants is rather old, and does not reflect the current state of knowledge, e.g., following the host of post-Chernobyl investigations. This affects the quality of parameters such as deposition velocities for different types of particles, leaching rates, fixation rates, desorption rates, resuspension enrichment factors, natural weathering rates, transfer factors and biological half-lives for farm animals. It is also problematic that crop transfer factors have so far not been linked to a soil classification. Many of these shortcomings have been shown to greatly impinge on ingestion doses, and the parameters have therefore been revised by a Nordic work group. This work is now available to the ARGOS and RODOS developers. Examples are given demonstrating the relative importance of both the generic and the location-specific parameter changes.

S04-06

**Ce doped SiO<sub>2</sub> optical fibers for real-time dosimetry of external radiotherapy beams**

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The introduction of new technologies in radiation therapy aimed at improving the dose distribution to the tumour volume, calls for the development of innovative devices able to assure the quality of radiation beams and in-vivo real time dosimetry measurements. This work describes the use of a novel glass composite fiber dosimeter for the characterization of different types of radiotherapy beams. The dosimeter is based on the radioluminescence emission of a small portion of SiO<sub>2</sub> fiber doped with cerium (fibre diameter 100–200 micron), prepared by means of the sol gel and powder in tube techniques. The doped portion is connected by fusion splicing to a commercial optical fiber which is optically coupled to a photomultiplier tube operating in photon counting mode. The signal is processed by a circuitry and software properly designed. In order to subtract the Cerenkov contribution to the signal response a double optical fiber geometry is adopted. The system was tested by using conventional radiotherapy photon and electron beams, as well as stereotactic fields generated by a 6 MV linear accelerator equipped with cone stereotactic collimators. Characterisation measurements were also performed using 138 MeV proton pencil beams at the Center for Proton Therapy of the Paul Scherrer Institute (PSI), using the discrete spot scanning technique. The system showed interesting dosimetric properties in terms of sensitivity, reproducibility, linearity, energy and angular dependence. Moreover, the small dimension of the fibre and the possibility to perform real time measurements of the dose rate, proved to be particularly useful for a reliable evaluation of the output factors of small stereotactic fields and for resolving different scanning sequences of proton pencil beams.

S04-07

**Guidelines for the use of active personal dosimeters in interventional radiology**

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The optimization of the use of active personal dosimeters (APDs) in interventional radiology (IR) is performed by one of the work packages of the ORAMED project, a Collaborative Project (2008–2011) supported by the European Commission within its 7th Framework Program. Due to the specificity of the X-ray fields used in IR (low energies, pulsed fields), the current technology of APDs is inadequate, notably in terms of energy detection threshold and dose rate response. The work presented in this paper consists in establishing guidelines related to the use of APDs in IR. The guidelines are divided in three parts. The first part presents the real radiation field characteristics encountered in IR. The dose rate in the direct field at the level of the table (i.e. above the patient) ranges from 2 to 360 Gy.h<sup>-1</sup>. The dose rate in the scattered beam at the level of the operator ranges from 5.10<sup>-3</sup> to around 10 Gy.h<sup>-1</sup>. Finally, the energy of the scattered spectra ranges from 20 to 100 keV. The second part describes the results of tests performed in laboratory conditions and in hospitals. All APDs present a linear dose response and most of them a satisfactory response at low energies (down to 20 keV). However, some present dose rate and angular responses that do not always fulfil the ISO 61526 standard requirements. Tests in pulsed mode show that limitations of several APDs are mostly due to high dose rates rather than to pulse frequency. This point was confirmed by tests in hospitals. The last part of the guidelines proposes advices in the choice of the APD type and some methods to correct the response of the devices depending on the IR procedure type.

S04-08

**Radiation protection in radiotherapy: primary standard dosimetry of high-energy photon beams in Austria**

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The Austrian absorbed dose to water primary standard is a graphite-calorimeter. It was developed by the Federal Office of Metrology and Surveying (BEV) in cooperation with the Research Centers Seibersdorf. The BEV is the National Metrology Institute (NMI) of Austria. The graphite-calorimeter is a Domen-type calorimeter and in operation since 1983. The realization of the unit absorbed dose to water is based upon absorbed dose to graphite measurements. The absorbed dose conversion is done by two independent methods based on the photon fluence scaling theorem. The graphite-calorimeter was originally designated for determination of absorbed dose to water in Co-60 gamma ray beams. The progress in radiation therapy within the recent years required for extension of the graphite-calorimeter application range to enable primary standard dosimetry of high energy photon beams. The development of the primary standard is based upon Monte Carlo simulations with PENELOPE code and measurements with the graphite-calorimeter and ionization chambers. Furthermore the graphite-calorimeter and its corresponding components had to undergo a refurbishment and modernization process. This paper presents the results of the energy range and application enhancement of the primary standard. The determined correction and conversion factors for high energy photon beams and a detailed uncertainty budget of the primary standard is given. Furthermore the re-evaluated correction factors for Co-60 gamma ray beams are presented. To validate the results the BEV participated the international key comparison for absorbed dose to water in Co-60 gamma radiation at the Bureau International des Poids et Mesures (BIPM). Moreover the BEV planned and coordinates the EURAMET Project 1021 intended for direct comparison of absorbed dose to water primary standards. The accomplishment of the BEV high energy calorimetry project was promoted by the Physico-technical Testing Service (PTP), which is an entity of the BEV.

S04-09

**ETAM – Method for exposure conditions reconstruction****Marinkovic, Olivera<sup>1</sup>; Spasic Jokic, Vesna<sup>2</sup>**<sup>1</sup>Institute of Occupational Health of Serbia, Dosimetry Department, SERBIA; <sup>2</sup>Faculty of Technical science, University Novi Sad, SERBIA

Laboratory for personal dosimetry in the Serbian Institute of Occupational Health, Belgrade, is using LiF TLD nearly twenty years. Equipped with Harshaw TLD Reader Model 6600 (12<sup>th</sup> serial unit), REMSMENU software and Computerised Glow Curve Deconvolution (CGCD – DOS version) has prepared calibration for elapsed time estimation.

Recognizing importance of more information in personal dosimetry practice, Laboratory developed criteria for estimation exposure conditions named ETAM – Exposure Time Assessment Method.

ETAM is based on LiF fading and difference between low temperature peaks half-life. The main values are calculated using CGCD Programme which gives: FOM (Figure of Merit), peak2, peak3 and peak5. Then using laboratory's calibration curves is possible to calculate elapsed time  $T_2$  and  $T_3$ . Ratio peak2/peak5 and peak3/peak5 are linear functions of logarithms of elapsed time  $T_2$  and  $T_3$  respectively. So, even for one LiF crystal estimation is based upon two sets of parameters. One TLD for personal dosimetry usually has two or more LiF crystals.

ETAM recognizes three types of exposure conditions: one-shot exposure (O), repeated exposure (R) and continuous exposure (C).

It is crucial to analyse together all main values. For example: if deconvolution FOM is too high it does not mean that method is inapplicable. Contrary, it could be argument that exposure was not type O.

ETAM criteria is discussed in the paper supported with numerous illustrations from real practice results. Laboratory has about 2000 users monthly. They are working in different exposure conditions, but mainly type C and R.

S04-10

**AmBe tests of a CMOS pixel detector for a future electronic dosimeter****Vanstalle, Marie; Husson, Daniel; Higuieret, Stéphane; Trocmé, Mathieu; Baussan, Eric; Lê, The-Duc; Nourreddine, Abdel-Mjid**

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Operational neutron dosimetry has been mandatory since 1995 for people receiving more than 20mSv per year (international norm IEC 1323). About 60 000 workers are concerned by this policy in Europe, mainly in nuclear power plants or in medical physics. The RaMsEs group (Radioprotection et Mesures Environnementales) is working on a new compact device for operational neutron dosimetry. The electronic part of the detector is made of an integrated active pixel sensor. This device has useful features, including high detection efficiency for charged particles, good radiation resistance, high readout speed and low power consumption. Moreover, because of the thinness of the active layer, these CMOS sensors have low sensitivity to  $\gamma$ -photon background, which is an attractive feature for neutron issues. Our group has recently commissioned an automated facility for neutron irradiations which uses a fast neutron source of AmBe. Experimental measurements have been performed with a 512  $\times$  512 pixel CMOS sensor at several distances and angles to determine the sensor's angular response. These results will be presented together with Monte Carlo simulations performed with MCNPX. Further measurements with an ISO phantom are scheduled to study the albedo effect of neutrons and the  $\gamma$ -transparency.

S04-11Y

**Development of approaches for realistic retrospective evaluation of doses of selected cases of internal contamination**Vrba, Tomas

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The work was focused on estimation of the intake and committed effective dose from internal contamination with americium 241. The various models of americium bio-kinetic were described primarily. Mathematical background of the intake estimation was expressed together with the test of the quality of the model fit to measured data. The maximum likelihood formalism was used as the method of the choice. The uncertainty of the data was estimated in order to obtain reasonable estimate of the intake. The extensive uncertainty analysis of the in vivo measurement of the head and related assessment of the total activity in the skeleton was performed. For that issue was build a voxel phantom of the human head. The most of the factors affecting the measurement of the activity retained in the skull were characterized and its magnitude was quantified. The uncertainties for bioassay quantities, like urine and faeces samples, were estimated also. The intakes and committed effective doses of all followed person were assessed, but the default parameters of the americium model had to be changed. The discrepancy between the model and the data was discussed.

S04-12Y

**Radiation protection dosimetry using recombination chambers at radiotherapy facilities**Gryzinski, Michal

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Radiation protection measurements in radiotherapy departments concern either patients or medical personnel and technical personnel. In some rare cases radiation doses to other persons (carers, comforters and visitors), should also be evaluated. Patient protection involves in-phantom measurements, which are performed first of all for treatment planning but can also be used for determination of dose equivalents in patient's organs outside the treatment field. Occupational radiation protection is based on determination of ambient dose equivalent  $H^*(10)$  at workplaces and on individual monitoring of exposed persons. Usually, free-air ionization chambers are used for X-ray measurements at electron accelerators and neutron rem-meters with appropriate moderators for determination of neutron dose in case of radiotherapy with protons and heavy ions. The paper presents additional possibilities offered by use of recombination chambers and measuring methods based on initial recombination of ions. The main advantage is that the recombination methods can provide information about parameters of radiation quality (radiation quality factor, neutron-to-gamma dose ratio, distribution of absorbed dose versus LET). The paper shows four examples how the chambers can be used at different radiotherapy facilities: 1) Measurements of  $H^*(10)$  and neutron dose along the patient table at 15 MV X-ray therapy (Oncology Centre, Warsaw, Poland). The measurements were performed in the cabin, in the maze, in the control room and in the corridor at the entrance to the maze with slightly opened door; 2) Measurements of  $H^*(10)$  and evaluation of radiation quality factor near a phantom irradiated by 170 MeV protons in the proton therapy treatment room of the Dubna phasotron (Russia) 3) Characterisation of mixed radiation field inside and outside therapy cave for eye proton therapy (60 MeV cyclotron, Kraków, Poland) 4) Measurements of  $H^*(10)$  behind shielding of heavy ion therapy facility (GSI, Darmstadt).

S04-13Y

**Experimental monitoring of  
Ozone production around a  
biomedical cyclotron****Zanibellato, Luca<sup>1</sup>; Cicoria, Gianfranco<sup>2</sup>; Pancaldi, Davide<sup>2</sup>;  
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Intense radiation fields can produce Ozone, due to radiolysis induced process in ambient air. Ozone is the most toxic gas produced by ionizing radiation around a particle accelerator. In PET cyclotron's installations, the most dangerous factor for the worker is clearly radiation, but concurring risk factors should be considered as well. In order to evaluate Ozone production at our installation, we perform a campaign of experimental measurements using ChromAir diffusion badge dosimeters. This is a direct reading, passive, diffusion dosimeter. The device is simple to use, inexpensive, moderately accurate; on the other hand, the device is not influenced nor damaged by the intense radiation fields produced during irradiations; this makes possible to estimate the Ozone generation term not only in working environments, but also inside the cyclotron bunker. Measurements were performed during routine irradiation with our GE PETTrace cyclotron, accelerating H<sup>-</sup> ions at 16.5 MeV on H<sub>2</sub><sup>18</sup>O liquid target for <sup>18</sup>F- target. Diffusion dosimeters were placed inside the cyclotron bunker, in the radiopharmacy laboratory and, in adjacent rooms in which leakage radiation is very limited and outside them facility. Concentration's limits issued by ACGIH were assumed as reference values, the most important being the TLW-TWA, set to 0.1 ppm. In every location inside our laboratories and independently on ventilation condition, the measured Ozone concentration resulted to be less than 0.01 ppm, well behind the TLV. In conclusion, the concentration of Ozone measured in the ambient air inside our PET facility, resulted thus to be very low compared to the TLV and not significantly different compared to what obtained in rooms without presence of radiations and in external air. According to our measurements, Ozone does not represent a significant risk factor for workers around a PET cyclotron; the passive diffusion dosimeter used in our study proved to be an useful tool with adequate sensitivity.

P04-01

### **Reproducibility assessment for a new neutron dose evaluation system**

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The Paul Scherrer Institut (PSI) is investigating a new neutron dose evaluation system manufactured by TASL. This system takes images of the etched tracks in CR-39 detectors by a high magnification microscope, which are then analysed by a software algorithm. Each measured track is characterised by a multitude of separate parameters, which are then used in the neutron exposure algorithm to enable optimum noise discrimination, sensitivity calibration and dose calculation. However, before the system can be used in the routine dosimetry service, it has to be tested for its intrinsic properties, such as reproducibility, linearity, stability etc. In this paper we focus on the reproducibility of the evaluation process. Three sets of detectors, i.e. non-irradiated detectors as well as detectors irradiated with 3 mSv and 6 mSv, were analyzed for reproducibility study throughout the duration of 10 weeks. Interesting behaviour was observed, which will be used as input for potential improvements in the treatment of the detectors and for possible adaptations of the evaluation algorithm by the manufacturer.

P04-02

### **Simulations of radiation fields of a photon and a fast neutron calibration facility**

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At the Karlsruhe Institute of Technology (KIT) (formerly: Forschungszentrum Karlsruhe (FZK)) exists a calibration laboratory for dosimetry and radiation protection purposes. The laboratory provides different radiation fields such as photons stemming from Cs-137 sources and X-ray devices as well as fast neutrons from a Cf-252 source. The reference fields, which are mainly used for calibrations of active and passive radiation protection monitoring instruments, are characterized according to ISO calibration procedures. In order to verify that radiation field qualities are according to international standards not only measurements but also simulations were performed. In this way suitable conditions for research and calibration purposes are guaranteed. Additionally the variability of the fields (including backscattering) which is difficult to impossible to measure can be determined by simulations. The simulations were carried out with the Monte Carlo Codes MCNP5 and PENELOPE2008.

P04-03

**TL and OSL techniques for dosimetry and calibration of  $^{90}\text{Sr} + ^{90}\text{Y}$  clinical applicators****Antonio, Patrícia; Pinto, Teresa; Caldas, Linda**

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The  $^{90}\text{Sr} + ^{90}\text{Y}$  clinical applicators are sources used in brachytherapy in the treatment of superficial injuries of eyes and skin. According to international recommendations, these applicators must be calibrated periodically, and its dosimetry should be performed, to assure their correct use. Thermoluminescent dosimetry (TLD) may be used for the calibration of these sources. However, the optically stimulated luminescence (OSL) technique has been already demonstrated as useful for beta dosimetry. In this work,  $\text{CaSO}_4:\text{Dy}$  pellets, produced by the Dosimetric Materials Laboratory of IPEN, were used as TLDs for the calibration and dosimetry of some clinical applicators. These pellets were exposed to different dermatological applicators and their evaluation was performed using a Harshaw TL system, model 2000 A/B.  $\text{Al}_2\text{O}_3:\text{C}$  dot and nanodot OSL detectors were also exposed to the clinical applicators. The OSL measurements were obtained using a Landauer microStar reader and software. The results obtained from both luminescent techniques were compared, and agreement was achieved.

P04-04

**Air kerma standard and measurement comparison for HDR Ir-192 brachytherapy sources calibrations****Su, Shi-Hwa<sup>1</sup>; Huang, Tzeng-Te<sup>1</sup>; Hsieh, Ming-Tsung<sup>1</sup>; Chang, Bor-Jing<sup>2</sup>**<sup>1</sup>Institute of Nuclear Energy Research, National Radiation Standard Laboratory, TAIWAN; <sup>2</sup>Institute of Nuclear Energy Research, Health Physics Division, TAIWAN

This paper describes the Institute of Nuclear Energy Research (INER, Taiwan) established the reference air kerma rate (RAKR) calibration standard for measurement of the HDR Ir-192 brachytherapy source strength. An bilateral comparison has been made in the RAKR standards for HDR Ir-192 brachytherapy sources at the INER and PTB (Germany) and the measurement difference was within the overall standard uncertainty and showed a good agreement of the two calibration standard systems established at the INER and the PTB. The accuracy in RAKR determination has increased the use of robust well-type chambers designed for brachytherapy. Besides, INER also designed a set of portable measuring device and worked with 20 domestic hospitals to organize an on-site measurement comparison program exploring the status of HDR Ir-192 brachytherapy source strength determination in Taiwan. A comparison result was present the ratios of RAKR with vendor values, as determined by INER and hospitals from the program. The ratios fall in all cases within the  $\pm 3\%$  guaranteed by the vendors for a coverage factor of  $k = 2$  or at 95% confidence level.

P04-05

### **Instadose – Web based system for reading and monitoring dose through Internet access**

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Instadose™ is a small, rugged dosimeter based on patented direct ion storage technology and is NVLAP accredited. This breakthrough technology provides radiation workers with a more precise measurement of radiation dose and includes accurate long-term exposure tracking. A built-in memory chip stores each user's identity via an embedded unique serial code that is assigned to the user. Instadose allows users to have the flexibility to view their radiation dose at any time from any computer with internet access. Readings via a PC are enabled by a USB compatible detector. When a user wishes to obtain a reading they simply log-in to their account, plug-in instadose to a USB port and on the homepage click-on the computer image with the message "Plug in your instadose device now and click here to get an instant reading". The accumulated dose stored on instadose is processed through a proprietary algorithm. This fully automated transfer of data minimizes the chance of human error and misidentification. Once complete a graphical representation of the current dose will load on the screen. Users can also view their cumulative dose level by clicking "View Cumulative Dose." A variety of reports are available for download through AMP (Account Management Program)." The reports include:

- Radiation Exposure Summary Report
- History Detail Report
- Who Has Not Read Their Device.

P04-06

### **Radiation qualities for patient dosimetry in x-ray imaging: from calibrations to clinical use**

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The response of an ideal dosimeter does not have energy dependence and same calibration coefficient can be used for different x-ray spectra. In calibration practice, the energy dependence should be studied by using different radiation qualities. Standard RQR and RQR-M radiation qualities (IEC 61267: 2005), intended to represent the x-ray beam incident on the patient in radiographic, fluoroscopic, dental and mammography examinations, are generally used for calibration in laboratories. They differ from the ones used in patient imaging and they do not cover the total HVL range of clinical use. The calibration coefficients need to be converted to the actual clinical radiation qualities by interpolation using appropriate specifiers of the energy spectrum. For reference class ionization chambers the response depends rather smoothly on the radiation energy, and the half-value layer (HVL) is often sufficient for specifying the radiation quality. However, this may not be the case for dosimeters with a strong energy dependence. In this study, calibration coefficients of different dosimeter types were determined using the standard radiation qualities and several other radiation qualities that are typically used in medical x-ray imaging. The HVL was used as the specifier for the energy distribution of the x-ray beam. The accuracy of air kerma measurements at different radiation qualities was investigated, especially with respect to the interpolations between the radiation qualities used in calibration procedures in order to derive the calibration coefficients for the radiation qualities in clinical practice. KAP meters and semiconductor detectors are examples of dosimeters, which have a strong energy dependence. For accurate measurements, it is not sufficient to make the interpolation based on HVL alone. With KAP meters the difference between calibration coefficients for standard and clinical radiation qualities with same HVL may exceed 15%.

P04-07

**Ambient dose equivalent measurements at IMRT medical accelerator****Tulik, Piotr<sup>1</sup>; Golnik, Natalia<sup>2</sup>; Zebrowska, Edyta<sup>2</sup>; Bulski, Wojciech<sup>3</sup>**<sup>1</sup>Institute of Atomic Energy POLATOM, POLAND; <sup>2</sup>Warsaw University of Technology, Institute of Metrology and Biomedical Engineering, POLAND; <sup>3</sup>Maria Curie Oncology Centre, POLAND

A dose equivalent meter based on a recombination principle has been used for measurements of ambient dose equivalent in mixed (gamma + neutrons) radiation fields outside the irradiation fields of linear medical accelerator. The main detector was a recombination chamber, i.e. tissue-equivalent, high-pressure ionization chamber operating under conditions of local recombination of ions. The second ionization chamber served as a monitor of the beam intensity. The use of recombination chambers makes it possible to determine the total absorbed dose, which is proportional to the saturation current, and recombination index of radiation quality,  $Q_4$ , which can be used as an approximation of the radiation quality factor. Ambient dose equivalent  $H^*(10)$  can be well approximated by the product of the ambient absorbed dose  $D^*(10)$  and  $Q_4$ . The automatically controlled measuring cycle includes determination of the ionization current at four different polarizing voltages, which are sequentially applied to the recombination chamber electrodes. Then, the readings are normalized to the monitor chamber readings and  $Q_4$  values and ambient dose equivalent are calculated taking into account the relationship between the initial recombination of ions and radiation quality factor. Tests were performed at the 15 MV Varian Clinac 2300C/D accelerator and at the accelerator configured for IMRT treatment. The measurements confirmed that the ambient dose equivalent of mixed radiation in clinical conditions could be determined with accuracy of about 20%.

P04-08

**Quality mammography essential in detecting breast cancer****Mossang, Daniela<sup>1</sup>; Dadulescu, Elena<sup>1</sup>; Sorop, Ioana<sup>1</sup>; Pera, Corina<sup>2</sup>; Iacob, Radu<sup>3</sup>**<sup>1</sup>Public Health Authority of Dolj County, ROMANIA; <sup>2</sup>County Emergency Hospital Resita, ROMANIA; <sup>3</sup>Universty Ioan Cuza Iasi, ROMANIA

**Introduction:** Between 1991 and 2007 breast cancer incidence increased 3.4 times with the Romanian women, the trend continuing to grow. Knowing that mammography can detect early breast cancer and that this is the key to successful long-term control of diseases and good prognoses, the present study aims at evaluating the influence of quality control in order to detect small changes in breast tissue.

**Material and method:** There have been assessed five mammography labs (A, B, C, D, E), of which only A had partially implemented the system of quality control. The measurements performed include the evaluation of X-ray units, image receptors, image processors, patient dose and image quality. Mean glandular doses were calculated the way the American College of Radiology does (1999).

**Results:** The assessment pointed out the following differences between labs B, C, D, E, vs. A:

1. the kVp reproducibility was good but the accuracy differs by more than  $\pm 5\%$  from the nominal kVp setting (81.2% in E vs. 1.2% in A);
2. the developer temperature was up to 100C under the value specified by the film manufacturer;
3. the automatic exposure control was not used;
4. the number of visible test objects on the phantom image was unacceptably small in the B, C, D, E;
5. the radiation beams and the mean glandular doses are higher or lower than guidance levels recommended for a high quality mammogram ( $p < 0.001$ ).

**Conclusions:** Quality control does not remove the problems but it can detect them before the clinical results are seriously affected. Mammography is the most exacting radiological examination and that's why it is paramount to apply the quality control in all the labs.

P04-09

**CaSO<sub>4</sub>:Dy TL response for photons energies between 33 keV to 15 MeV**

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In the last decade radiotherapy has been the object of a technological revolution because of the new techniques developed such as Three Dimensional-Conformal Radiation Therapy and Intensity Modulated Radiation Therapy (IMRT). The clinical use of these techniques requires a complete knowledge of the imaging of the volumes to be treated and also the dosimetry of the clinical electron and photons beams that are used in those cases. Thermoluminescence (TL) or thermally stimulated luminescence has been actively developed in the past years due to its reliability, sensitivity and commercial availability and is currently in use with LiF: Mg, Ti (TLD-100) commercial dosimeters in the dosimetric quality assurance of the output of therapy machines which must be verified routinely. This work proposes the use of CaSO<sub>4</sub>:Dy sintered discs as an alternative to LiF commercial dosimeters in the radiation therapy dosimetry of photons beams, studying the photon energy dependence response with energies ranging from 33 keV to 15 MeV using different phantoms such as water filled phantom, a PMMA and a solid water phantom. CaSO<sub>4</sub>:Dy was chosen because is one of the most useful and sensitive thermoluminescent dosimetric material for radiation dosimetry, and in the form of sintered discs are very suitable for applications requiring a large number of measurements. The thermoluminescence dosimetry reader 3500 (Harshaw Model) was employed for the readout of the irradiated dosimeters. Results on reproducibility, radiation dose response and energy dependence show the possibility of their use as an alternative dosimeter of clinical photon beams.

P04-10

**Development and validation of a low dose simulation algorithm for computed tomography**

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**Purpose:** The purpose of this study was to develop and validate software for facilitating observer studies on the effect of radiation exposure on the diagnostic value of computed tomography (CT).

**Methods:** A low dose simulator was developed which adds Gaussian noise to the CT raw data with an automatically derived standard deviation according to the desired dose level. A validation was performed with two phantoms: a cylindrical test object and an anthropomorphic phantom. Images of both were acquired at different dose levels by changing the tube current of the acquisition (500 mA to 20 mA in five steps). Additionally, low dose simulations were performed from 500 mA downwards to 20 mA in the same steps. Noise was measured within the cylindrical test object and in the anthropomorphic phantom. This was performed in actual and simulated images. Finally, noise power spectra (NPS) of actual and simulated images were measured in water.

**Results:** The low dose simulator yielded similar image quality compared with actual low dose acquisitions. Mean difference in noise over all comparisons between actual and simulated images was  $5.7 \pm 4.6\%$  for the cylindrical test object and  $3.3 \pm 2.6\%$  for the anthropomorphic phantom. NPS measurements showed comparable shape and intensity.

**Conclusion:** The developed low dose simulator creates images that accurately represent the image quality of acquisitions at lower dose levels and is suitable for application in clinical studies. The major practical benefit of the algorithm is that it can be retrospectively applied to CT to optimize acquisition protocols in order to reduce the radiation dose.

P04-11

**Basic data for radiotherapy:  
Stopping of protons in liquid water**

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Protons have been used for years in external beam radiotherapy to treat patients with malignant tumours. Obviously, for successful treatments, the knowledge of the absorbed dose to the tumour and to the surrounding tissues is of paramount importance.

In proton radiotherapy, the dosimetry is usually carried out relative to the <sup>60</sup>Co beam, in terms of absorbed dose to water. As this dose is determined with the aid of an air-filled ionisation chamber, the ratio of air and water stopping powers for protons needs to be known with a high accuracy. However, the experimental data are scarce (or non-existent, depending on energy); these stopping powers are usually calculated with the refined Bethe-Bloch formula. Recent investigations in the low-energy region (below a few MeV) by other authors have shed doubts on the accuracy of the widely-used stopping power data for water. In addition to the proton therapy, an accurate knowledge of proton stopping is a prerequisite for a reliable neutron dosimetry. Dosimetry of proton and heavy ion exposure is also of importance in space missions and other branches of radiation dosimetry.

In this contribution we describe the measurement programme for determining the proton, and heavy ion, stopping in liquid water at energies below 30 MeV per nucleon; this is the region where the stopping power models typically have the largest uncertainties. Our method is based on a time-of-flight transmission technique using microchannel plate and semiconductor detectors. The major challenge with thin liquid targets in vacuum is to maintain the target as uniform as required by the desired experimental accuracy. Therefore, a special emphasis is placed on the construction and the characterisation of the liquid target. The methods for target thickness determination using mechanical and optical means are presented, together with preliminary results from the actual stopping power experiment.

P04-12

**Fast neutron detection using  
ALNOR dosimeters with MCP-N  
thermoluminescence pellets**

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The neutrons component was estimated using ALNOR type dosimeters with MCP-N circular pellets of dimension 4,5 mm diameter and 0,9 mm thickness. MCP-N is thermoluminescence material based on LiF with the enrichment 7,5% of <sup>6</sup>Li and 92,5% of <sup>7</sup>Li, doped with Mg, Cu and P. ALNOR type dosimeter have four position to place a pellets, three of them are covered by filters with 1mm thickness, last one is bared. In addition, measurement by FH 40G dose rate measuring unit with FHT 752 SH neutron tracking <sup>3</sup>H probes was performed. Readout of TLD detectors was carried out by RADOS DOSACUS-1 reader for 15s at 300°C. Irradiation was performed at Central Laboratory for Radiological Protection by neutron calibrator OB 26 with <sup>241</sup>Am/Be source at activity 185 GBq and neutron emission 11 × 10<sup>6</sup> n/s (tolerance ±10%) and with neutron energy range 2MeV-10MeV. Before irradiation, set of 40 MCP-N pellets was annealed at 240°C for 10 min then rapidly cooled to room temperature, after that readout was carried out to select group of 20 detectors which count was in range, – average counts from 40 pellets, – standard deviation. There was prepared four dosimeters each with two pellets, one covered and one on bared place. Each dosimeter was irradiated on different distance 0,8; 1,0; 1,2; and 1,4 m from the source. Time of exposure was set to 600s.

Ratio of TL response, covered pellets (TLC) to bared ones (TLB) is adequately 1,12; 1,03; 1,04; 1,06.

P04-13

**Spectrophotometric response of the Fricke gel dosimeter developed at IPEN for clinical electron beams****Cobello Cavinato, Christianne<sup>1</sup>; Sakuraba, Roberto<sup>2</sup>; Cruz, Jose Carlos<sup>3</sup>; Campos, Letícia Lucente<sup>4</sup>**<sup>1</sup>Instituto de Pesquisas Energéticas e Nucleares – IPEN-CNEN/SP, BRAZIL; <sup>2</sup>Hospital Israelita Albert Einstein – HIAE, BRAZIL;<sup>3</sup>Hospital Israelita Albert Einstein, BRAZIL; <sup>4</sup>Instituto de Pesquisas Energéticas e Nucleares, Calibration and Dosimetry, BRAZIL

Gel dosimeters have been largely studied to be applied in three-dimensional (3D) dosimetry in the areas of Gamma Knife® and Intensity Modulated Radiation Therapy (IMRT) radiosurgery using spectrophotometry or Magnetic Resonance Imaging (MRI) evaluation techniques. This work aims to evaluate the performance of the Fricke gel dosimeter developed at IPEN, prepared with 270 Bloom gelatine from porcine skin made in Brazil, conditioned in PMMA cuvettes, for clinical electron beams from a VARIAN® model Clinac 23EX electron accelerator in the energy range from 3 to 15 MeV to depth of maximum dose, using different phantoms such as water filled phantom and solid water and Polymethyl Methacrylate (PMMA) phantoms using spectrophotometric technique. The following parameters were studied: dose rate and angular dependent response, dose response, reproducibility intra and inter batches, color change and response stability in function of storage time under two different conditions:

1. refrigeration and light protected and
2. room temperature and environment light.

P04-14

**Dosimetric properties of agate stones****Teixeira, Maria Inês; Caldas, Linda**

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Control programs in radiation dosimetry play an important role. Radiation processing presents several advantages such as food preservation, sterilisation of pharmaceutical and medical products and treatment of various materials. McLaughlin et al described several kinds of high-dose dosimeters, discussing their advantages and disadvantages. At the Radiation Metrology Laboratory of IPEN, Brazil, different stones have been studied for application in high-dose dosimetry. Amethyst, topaz and jasper have already shown their usefulness for gamma dosimetry, using the thermoluminescent technique (TL). In this work, Brazilian agate was studied in relation to its TL dosimetric properties. Agate is a variety of chalcedony, a form of quartz, in which the color is arranged in bands or concentric zones. The bands may be of different colors or also of a uniform tone. The samples for this study were prepared from four different types of agate stones: yellow, moss green, gray and purple. The agate samples were exposed to gamma radiation of <sup>60</sup>Co (Gamma-Cell system). The TL curves obtained due to absorbed doses of 50 Gy up to 100 kGy exhibit two peaks around 1500C and 2100C. The minimum detection limits, dose-response curves and reproducibility of TL response for all four kinds of agate were obtained in this work. The results indicate the possibility of use of these agate samples as radiation detectors for gamma high-doses, using the TL technique.

P04-15

**Characterization of polycarbonate dosimeter for gamma-radiation dosimetry**Galante, Ana Maria Sisti<sup>1</sup>; Campos, Leticia Lucente<sup>2</sup><sup>1</sup>Institute of Energetic and Nuclear Research, IPEN – CNEN/SP, Brazil., Radiation Metrology Centre, BRAZIL; <sup>2</sup>Institute of Energetic and Nuclear Research, IPEN – CNEN/SP, Brazil., Radiation Metrology Centre, BRAZIL

Gamma radiation causes permanent changes in the physical and chemical polymers structure. Such changes may result in reticulation or in the scission of polymer chains, which are simultaneous and competing processes. A simple and inexpensive dosimeter whose special properties can be determined, quantified and related to absorbed dose was studied in this work. Commercial polycarbonate (PC) is a new type of film detector that suffer yellowing upon radiation exposure. The color change was used as dosimetric property to measure the absorbed doses, but other analyze techniques can be used in neutron and alpha particles detection as nuclear tracks detection. The radiation induced main chain scission of PC and produces phenoxy radical responsible for the yellowing [1,2]. The dosimeter consists of a piece of polycarbonate film of dimensions  $3 \times 1 \text{ cm}^2$  and 3 mm thick. The spectrophotometry was the investigation technique and the absorbance was measure on a spectrophotometer Shimadzu UV-2101PC. PC films were irradiated with gamma doses between 1 and 150 kGy from a <sup>60</sup>Co Gammacell source. Its dosimetric characteristics were studied: pre-and post-irradiation stability, dose – response, environmental conditions influence and dose-rate influence. PC films are easy to prepare, to analyze and inexpensive. The influence of environmental conditions was observed and must be corrected in the studied material. Presents linear behavior in the dose interval studied and indicates that the dosimetric characteristics of polycarbonate dosimeters are suitable to determine high gamma doses.

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2. Sinha, D.; Sahoo, K.L.; Sinha, U. B.; Swu, T.; Chemseddine, A.; Fink, D. *Gamma-induced modifications of polycarbonate polymer. Radiation Effects & Defects in Solids, v. 159, p. 587 – 595, 2004.*

P04-16

**Pellets of oyster shell for high dose dosimetry: Preliminary study**

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Several kinds of silicates have demonstrated their usefulness as radiation detectors for high dose dosimetry. In this work, oyster shell powdered samples were tested for high doses using the thermoluminescence (TL) and thermally stimulated exoelectron emission (TSEE) techniques. Pellets were obtained from the oyster shell powder mixed with Teflon followed by a sinterization process of thermal treatments of 300°C/30min and 400°C/1.5h. The TL glow curves showed two peaks at 110 and 220°C, and in the TSEE case, two peaks at 120 and 180°C. The main dosimetric properties were studied: reproducibility, dose-response curves and lower detection limits. The preliminary results showed the potential use of the studied material as radiation detectors.

P04-17

**Design and assembly of a simple monitor ionization chamber****Yoshizumi, Maíra; Caldas, Linda**

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Transmission ionization chambers are used to monitor the X-ray beam output. These chambers have a large sensitive volume which produces a high response to the incident radiation. This characteristic allows the transmission chamber to be a good radiation monitor as its response is very sensitive. Another characteristic expected for this type of ionization chamber is its invisibility to radiation, i.e., the chamber materials shall not affect the radiation spectra. At the Instituto de Pesquisas Energéticas e Nucleares, Brazil, a new monitor ionization chamber was designed, developed and characterized. This monitor is a parallel-plate type ionization chamber, and it has two sensitive volumes formed by three aluminized polyester foils. The chamber body is made of PMMA disks that are positioned outside the primary radiation beams. The pre-operational tests and the response stability tests were performed. The pre-operational tests, as saturation curve, ion collection efficiency and polarity effect showed very good results. The response stability tests (repeatability and long-term stability) also showed good results, within international recommendations. Besides the good results, this ionization chamber is very simple to manufacture, and all materials used in this project are of low-cost and available commercially.

P04-18

**The use of TL dosimeters in HZE radiation fields****Pugliese, Mariagabriella<sup>1</sup>;****Roca, Vincenzo<sup>1</sup>; Durante, Marco<sup>2</sup>**<sup>1</sup>University of Naples Federico II, Department of Physical Sciences, ITALY; <sup>2</sup>GSI Biophysik, Darmstadt, GERMANY

The problem of radiation protection in space is very important because the exposure of astronauts to the cosmic radiation poses a major risk to space flight. Thermoluminescent dosimeters (TLDs) are largely used to determine the cosmic radiation exposure onboard the International Space Station (ISS) because they are easy to handle, comparatively light-weight, do not require power consumption, and give integral information about dose by post-flight evaluation. To correctly evaluate the exposure dose in space, it is very important to calibrate these dosimeters to HZE beam particles and protons, that are the most important component of the radiation field in the space. To reach this aim, TLD 600 (6LiF:Mg, Ti) and TLD 700 (7LiF:mg, Ti) were exposed to high-energy heavy ions accelerated at the NASA Space Radiation Laboratory (NSRL) at the Brookhaven National Laboratory (Upton, NY): 1 GeV/n protons, 1 GeV/n iron ions and 400MeV/n oxygen ions. TLD were exposed to these beams at different dose values and different dose rates, to evaluate the calibration factors of these dosimeters under different irradiation conditions. The results will be reported.

P04-19

**Intercomparison of various dosimetry systems for routine individual monitoring****Koguchi, Yasuhiro<sup>1</sup>; Yamamoto, Takayoshi<sup>1</sup>;  
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According to the studies of EURADOS ([www.eurados.org](http://www.eurados.org)) in addition to film dosimeters thermoluminescent (TLD) and recently radiophotoluminescent (RPL) dosimeter systems are the most widely used for individual monitoring. The situation in personnel dosimetry is permanently changing. For example in the last years because of introducing RPL dosimetry in Europe, the number of film controlled workers was reduced about 50%. In order to reach a high international standard in the application of these dosimeters for routine individual monitoring, there is a need for inter-comparisons. Therefore an intercomparison was organised with the participation of six dosimetry services from six countries.

The objectives of the study were to compare and to improve laboratory calibrations, to compare the results of different dosimetry systems at the same irradiation conditions. The task of the participating laboratories was to irradiate their own dosimetry system used for routine individual dosimetry together with RPL dosimeters received from Chiyoda Technol Corporation with a dose  $H_p(10) = 0.1$  mSv by narrow spectra X-ray beams of radiation quality N-60. The RPL (GD-450) dosimeters after irradiation were evaluated by Chiyoda Technol Corporation.

The results of this intercomparison indicated that the RPL and the other passive solid state detectors are very suitable for individual monitoring. The establishment of this international intercomparison allowed a broad exchange of experience. As a consequence, the calibration and measuring procedures used in particular laboratories, as well as the quality of the dosimeter systems employed could be improved step by step. We expect that the results of this investigation may encourage the participating services to improve the dosimetry methods and procedures.

P04-20

**Uncertainty of in vivo assessment of actinides activity in human skeleton****Vrba, Tomas**

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In vivo assessment of the actinides activity in the skeleton is valuable source of information on internal contamination of the human subjects. The proper estimation of the overall uncertainty is highly important, however not simple task because there are various sources of uncertainties. Many of them are connected with a measurement but some of them, like skeletal or bone activity distribution need to introduce assumptions about them. The paper tried to estimate total uncertainty, with respect to detectors and geometry of the skull measurement used in the National Radiation Protection Institute in Prague. The combining of the particular uncertainties to the total one was done according two methods; the first one follows simplified approach based on methodology from IDEAS Guidelines and the second one uses Monte Carlo approach.

P04-21

**Quality assurance applied in internal dosimetry for intake estimation in a case study of I-131 ingestion using in-vivo assessment data****Saizu, Mirela Angela<sup>1,2</sup>**<sup>1</sup>NIPNE-HH, Magurele; <sup>2</sup>Faculty of Physics – Politehnica University of Bucharest, ROMANIA

Human Body Monitoring Laboratory from NIPNE-HH, Bucharest, Romania, perform internal contamination Whole Body assessments, respecting its own Quality Assurance System, implemented from the year 2000 and updated in accordance with the requirements of the standard SR EN ISO/CEI 17025:2005.

During routine monitoring of workers, one case of internal exposure revealed to be special due to the fact that it was not an occupational intake, but the result of the ingestion of a capsule of I-131 used in the diagnosis of a thyroid disease. The value of intake was known by the physician that prescribed the diagnosis procedure, but unknown for the Human Body Monitoring Laboratory. There were performed eight thyroid assessments to see the compliance with the expected decay for the I-131 in the thyroid, using a Whole Body Counter equipped with a lead shielded NaI(Tl) detector for the thyroid with an efficiency of  $0.9 \times 10^{-2}$  counts/Bq\*t and MDA of 34 Bq for I-131.

The estimation of the intake and of the dose was made following the steps suggested in the new document, FZKA 7243, General Guidelines for the Estimation of the Committed Effective Dose from Incorporation Monitoring Data for acute ingestion. The thyroid retention predicted values (Bq per Bq intake) following an acute ingestion of I-131 were considered those from the ICRP 78. One measurement data was found to be outlier. The errors of the estimated intake referred to the real value of intake of 2960 kBq, calculated using the first 3 measurements from an interval of 7 days and then, using all 7 valid measurements were as follows: 9.3% and -3.4%, respectively.

The results obtained showed a good compliance of the measurements data with the model considered for the retention of the iodine in the thyroid. This gave us the certitude that the implemented method for the intake and dose estimation is reliable and valid.

P04-22

**Internal dose formation in rural society after the Chernobyl accident****Vlasova, Natalie<sup>1</sup>; Rozhko, Alexander<sup>2</sup>;  
Visenberg, Yulia<sup>2</sup>; Mactkevich, Svetlana<sup>2</sup>**<sup>1</sup>Republican Research Center for Radiation Medicine and Human Ecology, Dose Assessment Department, BELARUS;  
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Dose is formed in person due to the personal psychological, physical and social characteristics and economic status during his practical activities interacting with polluted environment. These actively promotes consumption rate of the contaminated food stuffs, thus the dose is the property of the person.

Every person is a member of a family. Family is the same society, but concerning settlement it is a small one. Moreover, family is a social complex system, including certain individuals being in direct contact for a long time, united by connections and by the nature mutual relations. Every family as a social system determines actions of its individuals and in certain situations acts in relation to environment as a single whole.

The WBC-measurement Data Base for the period of 1989–2008 contains above 2 millions records, which allow studying the internal dose peculiarities.

Provided analysis of internal dose distribution for inhabitants of rural settlements for 10-year period confirmed the hypothesis that every individual and also every family have their own certain place on a dose distribution curve and it is constant in time. In other words the same percentile value of dose distribution corresponds to certain person and certain family. These inhabitants have not only different doses but also different personal, social and economic characteristics.

Finally, the results of the research will allow to predict doses with enough high degree accuracy in certain persons for any year using their own relative doses for one or several years or by known relative doses in members of their families.

This law can be used as a basis for methodological approach to individual doses reconstruction for the subjects for practically any time period of the accident, and that is important for determining of individualized doses for people included into the Belarus State Registry of the Chernobyl affected persons and estimation of individual doses in radiation and epidemiological studies.

P04-23

**Determination of the main pathway of the  $^{131}\text{I}$  intake to the urban residents of Belarus following the Chernobyl accident****Shinkarev, Sergey; Gavrilin, Yuri**Burnasyan Federal Medical Biophysical Centre, RUSSIAN  
FEDERATION

Relationship between ingestion intake with milk and inhalation intake of  $^{131}\text{I}$  for the residents of large cities after the Chernobyl accident depended on the  $^{131}\text{I}$  contamination level of fresh milk distributed in the city trade network. This milk was delivered from different regions with various level of  $^{131}\text{I}$  fallout. The leading contributor to the human intake might be ingestion intake (if milk was delivered from areas with higher or similar level of the  $^{131}\text{I}$  fallout compared to that in the city) or inhalation intake (if milk was delivered from areas with less level of the  $^{131}\text{I}$  fallout compared to that in the city). Selection of a wrong leading route of iodine intake might result in systematic error in individual thyroid dose calculation, which can be as high as a factor of four to five. A method has been developed allowing for objectively determination of the main pathway of the radioiodine intake (inhalation or ingestion with milk) for the residents from one settlement. The idea of the method is as follows. The dependence of the variation with measurement date of the average estimate of the  $^{131}\text{I}$  thyroidal content for adults and for children from the same settlement in case of inhalation radioiodine intake is significantly different from that in case of ingestion intake. Comparison of such dependency derived from actual results of the thyroidal iodine measurements with two theoretical curves allows for making a decision which pathway of two possible radioiodine intakes was the main contributor to the thyroidal exposure for the residents from a given settlement. This method was applied to the results of in vivo thyroid measurements of the residents of two large cities in Belarus (Minsk and Gomel) following the Chernobyl accident. The analysis of those results allowed for derivation of an important conclusion that the intake of  $^{131}\text{I}$  with milk was the main contributor to the thyroidal exposure for the residents of the cities of Minsk and Gomel.

P04-24

**Retrospective and accident dosimetry using chipcards: the Belgian case****Cauwels, Vanessa<sup>1</sup>; Beerten, Koen<sup>2</sup>;****Lievens, Luc<sup>3</sup>; Vanhavere, Filip<sup>1</sup>**<sup>1</sup>SCK-CEN, EHS, BELGIUM; <sup>2</sup>SCK-CEN, BELGIUM;<sup>3</sup>Xios, IWT, BELGIUM

Accident dosimetry aims to determine the absorbed dose of exposed individuals involved in a nuclear accident. In order to achieve this, materials are needed that possess a certain radiation sensitivity and are worn close to the body. Chip cards are the perfect example and have the great advantage that nowadays everyone possesses at least one, in the form of bankcards, SIM-cards, identity-cards, etc. Therefore the possibilities of chip cards as an accident dosimeter are further investigated as a sequel to the research of Göksu (2003) and Woda et al. (in press) to determine whether the results of their research can be adopted for 'Belgian' cards.

Using blue LED optical stimulation, several properties of chip cards that could be traced back to a single manufacturer are investigated. The shape of the OSL-curve and the fading properties are considered. Also the uncertainty on the results and the lowest detectable dose as a function of the integration area are taken into account. The results of this part of the research would enable to determine the most promising part of the OSL-curve for dose determination.

Using these results, further research about the dose-response and possible sensitivity changes are made in order to propose a suitable protocol for the estimation of the absorbed dose.

P04-25

**A numerical statistical method application experience for the interpretation of Ni-60 special monitoring data****Molokanov, Andrey; Bushmanov, Andrey;  
Kukhta, Boris; Yatsenko, Vladimir**Burnazyan Federal Medical and Biophysical Center, Moscow,  
Russia, RUSSIAN FEDERATION

The procedure for assessing doses on the basis of routine monitoring results includes use of standard model parameter values for the dose calculation and at least simple estimation of the associated uncertainty due to uncertainty of the worker exposure conditions, the uncertainty in the time of intake and the uncertainty of the measured bioassay quantity method. If the upper value on assessed dose exceeds the reference limit a special monitoring procedure is required that consist in performing additional bioassay measurements to increase the reliability of the dose assessment by obtaining better information on the model parameter values and by using statistical methods for the calculation of the associated uncertainty. An example of a numerical method application for the interpretation of in vivo and in vitro bioassay measurements of Ni-60 performed during special monitoring of four nuclear power-plant workers is presented to illustrate a possibility of improving the dose assessment. It was shown that from the two compounds used in the ICRP model for cobalt the type S was the best option and the range of AMAD values could be reduced from (0,1 – 20) to (3 – 8) microns. This resulted in the reduction the uncertainty of the dose assessment from (144 – 155) % to (17 – 28) %. It was also shown that absorption type S compound was not slow enough to describe the retention of the radionuclide Co-60 in lungs in the case under study and a slower type like super S was needed.

P04-26

**Comparison of the three most recent biokinetic models for plutonium****Klein, Wolfgang<sup>1</sup>; Breustedt, Bastian<sup>1</sup>; Urban, Manfred<sup>2</sup>**<sup>1</sup>Forschungszentrum Karlsruhe GmbH, Institute for Radiation Research, GERMANY; <sup>2</sup>WAK Karlsruhe, GERMANY

Biokinetic models for the assessment of individual internal doses represent the physiological processes in the human body which affect the internal distribution of the radionuclide of interest. The International Commission on Radiological Protection (ICRP) recommends compartment models which emerge from a development and refinement of originally crude approximations. The three most recent systemic models for plutonium were studied: the ICRP67 model, the model proposed by Luciani and the current model by Leggett, which is supposed to find its way in future ICRP recommendations. The three models represent the physiological processes of a standardized human. The flow from one compartment into another is specified by transfer rates, which may diverge from person to person. The sensitivity of a model regarding changes in one transfer rate was analysed with Monte Carlo simulations. Simulations show that only few transfer rates have an impact on the measurable excretion rates. The influence of a changed transfer rate on the excretion rates is time dependent and can cause a large variation once, while it is without big effects at other times. Significant differences between the three models were observed. For dose assessment with unknown incorporation scenario the intake can be estimated from excretion rates assuming reference assumptions. Incorrect particle diameters, f1-values, solubility, wound categories, ... for inhalation, ingestion and invulneration cases lead to a deviation of the estimated from the real intake. Differences in the prediction capability for unknown incorporation scenarios were studied using excretion data calculated by the three systemic models.

P04-27

**Biokinetic models. Analysis of a numerical technique****Bento, Joana; Oliveira, Augusto; Teles, Pedro**

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Occupational exposure leading to intakes of internally incorporated radionuclides can occur as a result of various activities. This includes work associated with the use of radioactive sources in medicine, scientific research, agriculture and industry, and occupations which involve exposure to enhanced levels of naturally occurring radionuclides. The application of biokinetic models are a fundamental issue in estimation of doses and risks associated with incorporation of radionuclides within the human body. In biokinetic models of radionuclides, there are several techniques available to solve the systems of first-order differential equations. Here we present a straightforward implementation of the difference equations using an available computational spreadsheet like the EXCEL from Microsoft. It was chosen a well known model as a reference, allowing us to check the rigor of the technique. The main scope of this work is to make a detailed computational analysis of the role of all the parameters involved in this methodology. We obtained an accurate insight of the implemented technique, which validates its application in more complex biokinetic models where reference solutions are non-existing or difficult to obtain. In this technique of difference equations there are specific parameters such as time step values and compartment values for each time step that need to be well defined and well understood. Using appropriate algorithms, we developed techniques to optimise those parameters in order to obtain accurate solutions of complex compartment models. Moreover, in the scope of the Internal Dosimetry group activities at the ITN this tool will be of extreme value in order to estimate dose of measured personnel. Finally, another aim of this work is to provide a flexible tool that allows the study of biokinetic models with fast and easy addition or removal of compartments in any given model under analysis.

P04-28

**A methodology for studying cerium biokinetics using stable tracers and Thermal Ionisation Mass Spectroscopy****Keiser, Teresa; Höllriegl, Vera;****Giussani, Augusto; Oeh, Uwe**

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The double tracer technique as introduced in the 60s is a potent method to investigate the biokinetics of elements in humans. The technique was modified and applied over the last years to various elements of interest for radiation protection in order to validate and improve the available biokinetic models of ICRP. One project currently running at Helmholtz Zentrum München aims at studying the biokinetics of cerium in humans using stable, i.e non-radioactive tracers. For this purpose a methodology needs to be developed which enables to measure simultaneously different stable cerium isotopes in human body fluids such as blood and urine Thermal Ionisation Mass Spectroscopy (TIMS) using the instrument "Triton" from Thermo Scientific GmbH, Bremen, Germany. The measurement protocol was developed using cerium standard solutions with different concentrations and different combinations of filament materials. The best results were achieved adopting the double filament configuration and using the tantalum filaments. The optimal current for the ionisation filament is about 4700 mA and for the evaporation filament between 1250 mA, the temperature is around 1700°C. Under these experimental conditions the measured standard ratios agree within 1% with the IUPAC values. For measuring biological samples with TIMS a chemical treatment is necessary because it is not possible to coat the sample holder directly with the sample. A chemical method for eliminating all elements except cerium was therefore established, consisting in two steps: first blood plasma and urine samples are subjected to microwave-assisted acidic pressure digestion, and then cerium is extracted by column chromatography to obtain pure cerium salts, which can be optimally ionised in the TIMS ion source without interfering elements. The methodology was applied to biological samples collected during tracerkinetic studies in humans and preliminary results of urine excretion and plasma clearance of cerium will be presented.

P04-29

### First international intercomparison for Serbian Institute of Occupational Health EURADOS IC 2008

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Laboratory for personal dosimetry in the Serbian Institute of Occupational Health, Belgrade, has taken part for the first time in international intercomparison EURADOS IC 2008. At the same time it was the first international intercomparison for any Serbian dosimetry service.

In this paper is given analyzing of calculation method and results discussion.

P04-30

### Research and applications in laboratory for environmental and personnel dosimetry

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This paper presents the activity of the Laboratory for Environmental and Personnel Dosimetry. This laboratory is a part of the Department of Life and Environmental Science from IFIN-HH. The laboratory has 4 units; each is dealing with a specific activity:

- dosimetric surveying unit which uses thermoluminescent dosimeters for personnel (USD-TL). In USD-TL unit, the personnel monitoring is performed with thermoluminescent dosimetric system SD-TL which uses TL-detector of LiF: Mg, Cu, and P with the measuring range 10<sup>-5</sup>Sv – 100<sup>0</sup>Sv;
- the unit for gamma spectrometrical analyses;
- the unit for measuring the environmental radioactivity where the environmental samples (soil, surface and underground water, vegetal, aerosols and atmospheric sediments) are analyzed from the point of view of the alpha, beta and gamma gross activity. In the same unit, the environmental monitoring is performed also by TL system SDTM type with LiF: Mg, Cu, P detectors;
- the unit for photodosimetric survey.

All these units are working according to the ISO/IEC: 17025:2005 requirements. They are recognized by the, Romanian Nuclear Authority (The Commission for the Control of the Nuclear Activity – CNCAN) and accredited by RENAR (the National Accreditation Body). The R&D activity of the laboratory is focused on the personnel and environment dosimetry:

- the development of survey methods for personnel using in TL dosimetry for the extremities;
- the behavior of the TL detectors in ultra-low radiation background in the salt mines in Romania and intercomparisons of the TL-measuring systems.

P04-31

**Mean energy required to form an ion pair (W value) for various ionizing particles in air****Krajcar Bronić, Ines**

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The mean energy required to form an ion pair (W value) is defined as the mean energy spent by the incident particle of energy E for the formation of an electron – ion pairs after complete dissipation of the initial energy,  $W = E/N$ , where N is the total number of produced electron-ion pairs. For high-energy particles in thin media, when only a fraction of the particle energy (dE) is deposited in a medium, it is necessary to consider the differential w value,  $w = dE/dN$ . For sufficiently high incident energy, W value is approximately constant, and  $w = W$  is a good approximation. Available data on W or w are often fragmented, dispersed, and missing systematic. Several compilations and reviews, such as ICRU Report 31 and IAEA TECDOC 799, provide a basis for assessing the present knowledge of W values for different charged particles in various gases. Most available data exist for electrons. The W value for high-energy electrons (>10 keV) in dry air is well defined,  $33.97 \pm 0.05$  eV, and also a dependence on air humidity has been studied. W and w values for high-energy protons (>20 MeV) have been also carefully analyzed. The value of 34.23 eV, with  $\pm 0.4\%$ , has been recommended. The existing W or w data for heavy ions used in radiotherapy (He, C, Ne, Si, Ar) are fragmentary and most of them are measured for relatively low energies (< 1 MeV/amu) where major variations in energy dependence are observed. There is a lack of experimental data at energies > 1 MeV/amu of interest for radiotherapy. For carbon ions a few sets of experimental data on W exist at low energies and have been recently extended to higher energies. The average W value for C ions at energies > 10 MeV/amu is  $34.7 \pm 0.9$  eV, which is slightly higher than the recommended value ( $34.5 \pm 0.5$  eV) for all ions at energies > 1 MeV/amu. There is a need for new W value measurements for heavy-ions in air at energies > 10 keV/amu, and especially for C ions of several hundreds of MeV/amu that are of interest in carbon-ion therapy.

P04-32

**Comparison of local ion density determined by recombination chambers with biophysical models****Golnik, Natalia<sup>1</sup>; Zielczyński, Mieczysław<sup>2</sup>**<sup>1</sup>Warsaw University of Technology, Institute of Metrology and Biomedical Engineering, POLAND; <sup>2</sup>Institute of Atomic Energy, POLAND

The basic parameter characterizing initial recombination of ions in ionization chambers is local ion density  $\mu$ , defined here as a density of ions averaged over a short segment of an ionising particle track. It can be determined with a recombination chamber, which is tissue equivalent, high-pressure ionization chamber operating under conditions of initial recombination of ions. It was deduced from theoretical models, that the length of the segment mentioned above or the size of cluster of ions in recombination chambers is equivalent to about 70 nm of unit density tissue. For practical reasons, the values of  $\mu$  in the ion recombination models were often approximated by restricted LET, in order to correlate ion collection efficiency in the chamber with radiation quality factor.

In 2004 we published the values of  $\mu$ , measured for low-LET radiations of energies from about 30 keV up to <sup>60</sup>Co gamma rays. More recently, D. Harder and co-authors considered the role of electron track-ends for dicentric formation in human blood lymphocytes and published the curve showing the Monte-Carlo calculated number of correlated track-end groups per unit dose, relative to <sup>60</sup>Co gamma rays. There is striking similarity between this curve and  $\mu(E)$  curve, especially when results of our new measurements, extending the range of E to lower energies are taken into account. The similarity can be easily explained because both phenomena – in the chromosomes and in the gas – depends on the distances between the points of ion formation. In our opinion, expressed also in earlier papers,  $\mu$  is a physical, measurable parameter, associated with track segments of the length similar to important distances within the cell. The paper will present the reconsidered model of  $\mu(E)$  dependence, for low and high-LET radiations, with track-ends taken into account, the set of  $\mu$  values determined for different kinds of radiation and short comparison with biophysical models of dicentric formation.

P04-33

**Energy and angular dependence of radiation monitors in standard X radiation beams****Nonato, Fernanda; Vivolo, Vitor; Caldas, Linda**

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In Brazil, most of the monitoring instruments are calibrated in terms of exposure rate and dose rate in X, gamma and beta radiations, using reference systems calibrated at primary and secondary standard laboratories. In this work, the ionization chambers were calibrated in standard X radiation beams with the objective to study their response in relation to the energy and angular dependence in the operational quantity ambient dose equivalent  $H^*(10)$ , as recommended by the International Organization for Standardization (ISO 4037). For the energy dependence study, the ionization chambers were tested in standard beams, at the distance of 2.5 m from the tube. The X-rays system utilized was a Pantak/Seifert equipment, model MXR-160/22, with effective energies of 48, 65, 83 and 118keV, respectively for the N-60, N-180, N-100 and N-150 radiation qualities. For the angular response of the detectors, a special support was made of PMMA with a goniometer for the monitor rotation. The results obtained were satisfactory, according to the international standards ISO 4037-1 and ISO 4037-3, and to the Brazilian standard ABNT-NBR 10011.

P04-34

**An OSL single-aliquot regenerative-dose (SAR) protocol for low-dose retrospective dosimetry using household salt****Christiansson, Maria<sup>1</sup>; Bernhardsson, Christian<sup>2</sup>; Mattsson, Sören<sup>2</sup>; Rääf, Christopher<sup>2</sup>**<sup>1</sup>Medical Radiation Physics, Malmö, Department of Clinical Sciences, Malmö, Lund University, Malmö University Hospital, SWEDEN; <sup>2</sup>Medical Radiation Physics, Malmö, Department of Clinical Sciences, Malmö, Lund University, Malmö University Hospital, SWEDEN

Using single aliquot protocols when measuring the Optical Stimulated Luminescence (OSL) in materials as quartz and feldspar to measure the absorbed dose is widely used in retrospective dosimetry and geological and archeological dating. In the single-aliquot regenerative-dose (SAR) protocol, a regeneration or calibration dose is given after the OSL in the sample is measured, and the OSL is measured again. Three different regeneration doses are given to the sample to determine the unknown dose. Immediately after each accidental or regenerated dose, a test-dose is given to correct for any changes in sensitivity during the optical stimulation of the sample. The SAR-protocol makes use of the linear relationship between the detected luminescence and the given doses, and has been shown to be robust in determining absorbed doses in the range of 15 mGy to about 100 Gy in heated materials. This study has investigated how the SAR protocol can be applied to low-dose determinations in household salt (NaCl) for absorbed doses down to 1 mGy. Furthermore, investigations if only the first part of the SAR protocol can be used on household salt have been made in an attempt to find a more rapid read-out protocol in case of nuclear emergencies. The OSL was measured using an automated TL/OSL reader equipped with an internal <sup>90</sup>Sr source with an activity adjusted for low dose applications (20 MBq), yielding a dose rate of 0.9 mGy s<sup>-1</sup>. Test irradiations of pure NaCl and household salt were made with the internal source of the reader as well as in the beam of a 7 TBq <sup>60</sup>Co source in a position giving an absorbed dose rate of 21 μGy s<sup>-1</sup>. Preliminary studies show that a simplified SAR protocol, with one regeneration dose, is more accurate on salt in the low-dose ranges than the complete SAR with five regeneration doses.

P04-35

**Uncertainty analysis of internal dosimetry using expert judgment and probabilistic inversion****Hato, Shinji<sup>1</sup>; Homma, Toshimitsu<sup>2</sup>**<sup>1</sup>Company, JAPAN; <sup>2</sup>Institution, JAPAN

In order to analyze uncertainty about model input parameters, each probabilistic distribution of input parameters has to preliminarily be defined. It is rare case that is preliminarily defined each distribution of input parameters which are observable quantity or fitting parameter etc. Then, the method of expert judgment and probabilistic inversion is used to estimate distribution of input parameters. This technique is developed gProbabilistic Accident Consequence Uncertainty Assessment h i2000 jin joint to EU and USNRC. The probabilistic inversion was initially used the method with relative entropy, but is developed and nowadays used the method with iterative proportional fitting (IPF) at 2006. The internal dosimetry model researched in this study is the model recommended by ICRP. This model is consist of respiratory tract model, gastrointestinal model and biokinetic model, and is entered many input parameters which are anatomical and physiological parameters and transfer coefficients etc. It is apparent that their parameters are fluctuated each individual, but the ICRP is recommended dose of reference man. This study goal is that the uncertainty of recommended internal dose is estimated by using expert judgment (2000) and probabilistic inversion based IPF.

P04-36

**Internal and external dosimetry organization in the Joint Research Centre of Ispra****Giuffrida, Daniele<sup>1</sup>; Minchillo, Gianfranco<sup>1</sup>;****Bielewski, Marek<sup>2</sup>; Osimani, Celso<sup>1</sup>**<sup>1</sup>Joint Research Centre, Ispra, European Commission, Radiation Protection Sector, ITALY; <sup>2</sup>Joint Research Centre, Ispra, European Commission, Radiation Protection Sector, POLAND

The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, in order to steer European research on nuclear industry. It hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in past years, namely: two research nuclear reactors, hot cells facilities, radiochemical laboratories, one Cyclotron (still in operation), facilities for studies on fissile material (in operation), and some facilities for the treatment and storage of liquid and solid waste (in operation). The JRC accounts for 21 nuclear licences, 14 Controlled Zones and 12 main Surveilled Zones, on its Ispra Site. The Radiation Protection Sector employs the services of some internal laboratories for the assessment of external and internal doses: the "Dosimetry" Laboratory (for personal and ambient TLDs), the Whole Body Count Laboratory, the Radiotoxicological Laboratory (for analyses on excreta), the Radiation Protection Sector itself (for ambient dose and contamination reporting, and electronic personal dosimeters readings). Some of these Services are open also to the external market, and JRC-Ispra is among the few being able to provide, in Italy, either for internal and external dosimetric services to Customers. The paper will discuss the organization and the structure of the Dosimetry and the Whole Body Count Laboratories, and their functions in the management of daily Radiation Protection tasks at the JRC. Moreover, in order to follow-up and control Personnel radiation doses, the Radiation Protection Sector has developed and put in place, in 2007, the "Unified Dosimetry System", a wide and flexible database centralizing all dosimetric data and making them on-line available to JRC Radiation Protection experts and to the JRC Qualified Expert.

P04-37

**High dose values due to contaminated badges****Copty, Atallah Gabriel<sup>1</sup>; Havlik, Ernst<sup>2</sup>**<sup>1</sup>PTPA Lab. f. Radiation Protection, Magistrate of the City of Vienna (MA 39), AUSTRIA; <sup>2</sup>AKH - General Hospital Vienna, AUSTRIA

In some cases extraordinary high monthly radiation doses have been determined by the PTPA for radiation workers of the Department of Nuclear Medicine of the General Hospital Vienna. These values only could be explained to be caused by contaminations of the cover of the dosimeters (badges). These incidents were the motive for the presented study, with the aim to find out the amount of radioactivity sufficient to produce a monthly dose of 1.67 mSv, derived from the maximum permissible annual dose (20 mSv). For this reason 50 badges (UD-802A) have been contaminated systematically with calibrated radioactive solutions, using a 10 µL-pipette. The drops have been placed on the resin cover above one of the four TL phosphors respectively in order to consider different spots of possible contaminations. The badges have been shielded by lead to avoid irradiating each other. They were stored for one month at most and evaluated afterwards. The procedure was performed with the nuclides F-18, P-32, Tc-99m, In-111, I-123, I-125 and I-131. In order to consider different times of contamination the results of the measurements were converted for 2, 14 and 30 days respectively before the evaluations. As a result just low amounts of radioactivity are causing relative high doses. Due to the radionuclide and – for nuclides of longer half lives in addition due to the moment when a contamination occurred – the values differ significantly. Our study shows, that possible contaminations of the badges can be considered to be the reason for conspicuous high evaluated doses.

P04-38

**Tooth dosimetry for residents of Techa riverside territories****Shishkina, Elena<sup>1</sup>; Ivanov, Denis<sup>2</sup>; Wieser, Albrecht<sup>3</sup>; Fattibene, Paola<sup>4</sup>; Volchkova, Alexandra<sup>1</sup>; Semioshkina, Natalia<sup>5</sup>; Veroneze, Ivan<sup>4</sup>; El-Faramawy, Nabil<sup>3</sup>; Degteva, Marina<sup>1</sup>**<sup>1</sup>URCRM, RUSSIAN FEDERATION; <sup>2</sup>IMP, RUSSIAN FEDERATION; <sup>3</sup>HMGU, GERMANY; <sup>4</sup>ISS, ITALY; <sup>5</sup>HMGU, ITALY

The method of EPR dosimetry with teeth is practically the only method acceptable for retrospective external dose measurement for non-occupational exposure. Application of the method for external dose reconstruction in the Techa River region (Southern Urals, Russia) is complicated by combined character of tooth exposure: internal (mostly due to <sup>90</sup>Sr/<sup>90</sup>Y incorporated in the tooth tissues) and external radiation. The aim of the study was the evaluation of the external doses for Techa riverside residents. The external dose can be assessed by subtraction of the internal dose component from a total EPR-measured dose in the tooth enamel. Therefore the internal dose in the enamel was estimated based on TL contact beta detection of the radionuclides incorporated in the tooth tissues. Thus about 300 teeth obtained from 200 Techa riverside residents, who lived in the different settlements along the river stream, were investigated by EPR. For many of them the parallel TL-measurements of <sup>90</sup>Sr concentration were performed. The presented results of tooth dosimetry are accumulated during 10 years of extensive measurements performed in 3 institutes: IMP (Russia), HMGU (Germany) and ISS (Italy). The obtained results significantly influenced on Techa River Dosimetric System.

S05-01

**Finland's approach to licensing and regulatory control of geological repository for spent nuclear fuel****Varjoranta, Tero<sup>1</sup>; Paltemaa, Risto<sup>2</sup>**

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Finland's program for the disposal of spent nuclear fuel is among the most advanced in the world. The first licensing step, the Decision in Principle, which sealed public acceptance on local and national level, was taken in 2000–2001. Site confirmation studies, the construction of an underground rock characterization facility and the development of the safety case for the facility are ongoing and the program is approaching the next step, the submittal of construction license application, expected in 2012. All this was preceded by more than 30 years of work with a long-term goal. In this review the approach to licensing and regulatory control of the facility are presented.

S05-02

**Sweden's National Radioactive Waste Management Plan****Brewitz, Erica**

Swedish Radiation Safety Authority, SWEDEN

The Swedish Radiation Safety Authority (SSM) has developed a national radioactive waste management plan which covers all types of radioactive waste originating both from outside and within the nuclear fuel cycle (including spent nuclear fuel and nuclear waste). SSM submitted the plan to the Swedish Government in June, 2009. In the plan, SSM has focussed on a few priority areas where the system for radioactive waste management is in need of improvement. These areas are to a large extent connected to the management of radioactive waste from the non nuclear sector, which is not as comprehensive as compared to the waste management in the nuclear sector. Suggestions on measures for improving the waste management are given; these will be presented in detail in the paper, as will the priority areas.

The plan also includes an inventory of all radioactive waste and a description of the streams of radioactive waste from nuclear and non nuclear practices; their origin, treatment and final disposal. In addition, the plan describes the division of responsibilities for the waste management among all parties involved.

For the future, SSM would like to see a gradual development of the national radioactive waste management plan so that priority areas within the nuclear sector also can be elucidated. SSM's suggestion is therefore that the plan is revised every third year. This will allow for the plan to serve as an overall strategy document, an action plan, which focuses on different aspects of the waste management at different points of time, in order to secure a safe radiation environment in the long term.

S05-03

### Optimization of management of radioactive waste generated in research and education centres

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The radioactive waste generated in biological research has low specific activity and it is candidate for clearance from regulatory control. Some issues of the management of this waste could be technically improved. With the aim, it has been initiated a research project with a grant of ENRESA. The objectives are: 1) Characterization of radioactive waste generated; 2) To propose criteria for the management of mixed waste (scintillation vials full of scintillation solution); 3) To suggest clearance values for liquid waste; 4) To propose criteria for the management of uranyl and thorium salts wastes. 1) We suggest to measure the activity of liquid and mixed wastes and to estimate the amount of solid waste. The radiological characterization of selected radiotopic techniques applying this new protocol has begun. Also, we are complying information about chemical characterization of the waste. 2)–3) It has been considered the incineration as the final way for the mixed waste. This waste can be characterized attending their specific activity and it can be applied the clearance levels for solid waste. Therefore, it is necessary to determine the released activity airborne and the activity burnt to ashes. These calculations are being carried out at this moment. Regarding the organic liquid waste, the final way is also the incineration if the radioactive concentration is below the clearance values. However, for the aqueous liquid waste, the final way is the discharge via the sewer system. To determine the maximum discharge concentration, the calculations are being carried out taking into account the water flow of the sewer systems and the Annual Limit on intake for ingestion applying the committed effective dose per unit-intake for the ingested radionuclide. The results obtained allow confirming that it will be possible to obtain a final document to serve as a guide to simplify and to standardize the management procedure of radioactive waste generated in biological research.

S05-04

### Radiation Protection organization and radioactive waste management facilities at the Joint Research Centre of Ispra

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The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, with a mission to focus European research on nuclear industry. It hosts numerous nuclear facilities, some of which are maintained in operation (Cyclotron, laboratories for studies on fissile material, and some facilities for the treatment and storage of liquid and solid waste), whereas others have been shutdown over the past decades (namely, two research nuclear reactors, hot cell facilities, radiochemical laboratories). On its Ispra Site, the JRC holds 21 nuclear licences, and manages 14 Controlled Zones and 12 main Surveilled Zones. This paper will discuss the organization which has been developed over the years to guarantee the highest safety levels in all activities involving exposure to ionising radiation at the JRC-Ispra, with an emphasis on radioactive waste management. JRC's present strategy for waste management will be briefly discussed, and its major facilities will be introduced in detail. The current Radiation Protection Organisation will be reviewed and discussed. Processes discussed will include:

1. Decontamination of surfaces via Abrasive Blasting Unit (ABU);
2. Measurements of materials in the Material Clearance Facility (MCF);
3. Radiological characterisation of waste (active and passive, XDRS and WCF);
4. Radioactive transports and accountancy
5. Interim storage.

S05-05

**The safe decommissioning of two plutonium contaminated facilities at Dounreay****White, Simon; Thompson, Peter**

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The Dounreay site is situated on the north coast of Scotland, mainland United Kingdom, and is operated under contract to the UK's Nuclear Decommissioning Authority (NDA) by Dounreay Site Restoration Limited (DSRL), a wholly-owned subsidiary of UKAEA Limited. Dounreay was instrumental in fast breeder research and fuel reprocessing plant development. The site's business is now one of safe decommissioning and remediation.

This paper discusses the decommissioning of a plutonium criticality test facility and an experimental pulsed column technology solvent extraction facility. There is a detailed discussion of the radiation protection aspects of the decommissioning and the evaluation and implementation of novel, as well as "tried and tested" radiological protection controls within plutonium contaminated environments.

The paper concludes with a review of the radiation protection challenges and successes of the decommissioning techniques used, from a radiological protection perspective, and the lessons learned in successfully completing these challenging decommissioning projects.

S05-06

**Radiation protection issues related to the decommissioning of the DR3 research reactor****Søgaard-Hansen, Jens; Hedemann Jensen, Per**

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The research reactor DR3 was closed in 2000 after 40 years of operation. It was a DIDO type reactor operated at 10 MW thermal power. It was heavy water cooled and heavy water moderated with a graphite reflector. The reactor was used for neutron physics experiments and isotope production. At present the reactor fuel has been removed and most of the peripheral systems have been dismantled. The main construction parts will be decommissioned from 2012 to 2016. The planning of the decommissioning is made by a group of former reactor engineers, mechanical engineers, reactor physicist, technicians and health physicists. A possible scheme of how to decommissioning the reactor has evolved through discussions in the group. Some of the main constructions parts have high contents of activity e.g. up to several TBq of Co-60 and they are posing a major challenge regarding external exposure during dismantling. Graphite dust containing C-14 and primary tritiated heavy water leaked into the graphite and concrete and thus are potential sources of internal exposure. A characterization study of the reactor components together with constructional and operational information is the basis for dose rate calculations related to the coming dismantling operations. The paper describes the major radiation protection issues and how they have influenced the planned decommissioning of the internal parts of the reactor. Examples of calculated dose rates anticipated in some of the critical decommissioning operations will be presented.

S05-07

### Alara aspects in dismantling of the irradiated fuel reprocessing pilot Plant MTR Type ( M1 Plant)

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The irradiated fuel reprocessing plant MTR type was designed to treat fuel elements plate type from reactor JEN-1 (Ciemat). This facility (M-1 Plant) also served to develop fuel reprocessing processes. Dismantling Works, which have been conducted by ENRESA, were carried out by MONCASA-LAINSA (MONLAIN), the most experienced Spanish joint venture in dismantling nuclear facilities. The dismantling of M-1 plant was performed from 2007 until the beginning of 2008. This paper presents the performed dismantling works of the three M-1 Plant main systems:

- Hot Cell M-1
  - Glove Boxes Assembly L-1
  - Radioactive Liquid Waste Storage Cell (F-1).
- The dismantling of these systems required methodical tasks planning, development of specific execution processes, execution of Alara studies and detailed safety plans. Development of specific tools for dismantling tasks, containment auxiliary systems design, namely ventilated tents with local extraction systems and HEPA filters, operation assembly for equipment and components' extraction represent ones of the examples presented in this work. A multidisciplinary team formed by the two companies joint venture, working together on an equipment designed by ENRESA, has carried out a unique work in Spain, executed with efficiency, optimizing resources and wastes, and minimizing the dose in accordance with the Alara criteria.

S05-08

### Protocol for the clearance and release for metal materials from SLAC National Accelerator Laboratory – Application to BaBar Detector Dismantling

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In 2000, the DOE announced a suspension on unrestricted releases of any metals that have been inside a radiological area. SLAC is an electron accelerator facility which has many valuable metal components for off-site reuse or recycling. BaBar is a particle physics detector currently being dismantling for that purpose. Based on the DOE relief process, a protocol for unrestrictive release of non-radioactive metals is developed for BaBar dismantling.

At electron accelerators, surface contamination is very unlikely and volume activation is the main interest. The BaBar protocol can be generalized for other applications at SLAC or other electron accelerators. The SLAC protocol consists of an evaluation to determine the potential radioactivity of metal components based on process knowledge, calculations and measurements, as well as a technical basis for unrestrictive release.

Facility operations (beam or non-beam related) that can potentially contaminate or activate property are evaluated as follows: 1) obtaining process knowledge such as BaBar historical operational models and beam losses, 2) radioactivity calculations using the FLUKA Monte Carlo code, which allows a zoning approach to classify the components as radioactive or not for the purposes of planning, radiological control, and measurements, and 3) gross beta-gamma field survey on all surfaces of every item. Gamma spectroscopy measurements are conducted on pre-determined critical items to compare with FLUKA results.

The technical basis for the protocol consists of determining the detection limits of the measurement methods. Survey procedures and release criteria are developed based on the DOE Order 5400.5, MARSSIM, and ANSI standard N13.12. The SLAC instrument's detection limit is 10 times lower than the N13.12 clearance level for volumetrically activated materials based on the dose of 1 mrem/yr. Only items that have non-detectable radioactivity from both calculations and measurements will be released.

S05-09

**Development of radiochemical analytical method for the determination of radionuclides difficult to measure for decommissioning of nuclear facilities****Hou, Xiaolin**

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The decommissioning of a nuclear facility requires estimating the total inventory of radioactivity in various materials and its variation with time, which has to be carried out by the determination of the radioactivity of various radionuclides presented in the materials. The neutron activation products of components and impurity in the materials, such as  $^3\text{H}$ ,  $^{14}\text{C}$ ,  $^{36}\text{Cl}$ ,  $^{41}\text{Ca}$ ,  $^{60}\text{Co}$ ,  $^{55}\text{Fe}$ ,  $^{63}\text{Ni}$ ,  $^{133}\text{Ba}$ ,  $^{152}\text{Eu}$ ,  $^{154}\text{Eu}$ , and some transuranics, are the main contributors to the total radioactivity. But some fission products, such as  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$ ,  $^{129}\text{I}$ , and  $^{137}\text{Cs}$ , may also exist in the materials due to the contamination of the leaked nuclear fuel. Of these radionuclides, the beta and alpha emitters including  $^3\text{H}$ ,  $^{14}\text{C}$ ,  $^{36}\text{Cl}$ ,  $^{41}\text{Ca}$ ,  $^{55}\text{Fe}$ ,  $^{63}\text{Ni}$ , and some transuranics, have to be determined by radiochemical analysis including a completely separation of individual radionuclides from matrix and other radionuclides before measurement by beta counting, alpha spectrometry or mass spectrometry. This work presents various radiochemical analytical methods developed in the authors laboratory in the recent years for the determination of these radionuclides in various materials for the decommissioning of nuclear facilities, which includes:

1. rapid determination of tritium and  $^{14}\text{C}$  in solid materials, such as graphite, concrete, steel, aluminium, paint, silica gel, soil, and dust;
2. determination of  $^{14}\text{C}$  in high tritium samples, such as heavy water, waste water, and oil;
3. determination of  $^{36}\text{Cl}$  and  $^{129}\text{I}$  in graphite, steel, concrete, waste water, and dust;
4. determination of  $^{41}\text{Ca}$  in concrete;
5. determination of  $^{55}\text{Fe}$  and  $^{63}\text{Ni}$  in graphite, concrete, steel, aluminium, sediment, sand, waste water, seawater, and lichens.

P05-01

### Meaning of site-specific data in dose assessment: case of concentration ratios in boreal forest

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Posiva is implementing a deep repository for spent nuclear fuel in Olkiluoto, Finland. A site-specific safety case is being produced, and data has been acquired for the assessment models. However, neither site or literature data alone are sufficient for the safety case; a balanced combination is needed. The case of the concentration ratios from soil to plants in boreal forest, dominant ecosystem at the site, is discussed in this contribution.

Combining literature data with site data is not straightforward. Our approach is based on updating probability density functions (pdf). First, an *a priori* distribution is established from site-applicable literature data to contribute to the width of the distribution. Then, the pdf is updated with individual, site-relevant literature data taking into account the number of samples as a weight. Finally, the distribution is updated with the site data. In the weighting, also additional weighting factors of confidence or relevance for which quantitative measures have been established can be used. Repeating the procedure for different groupings of data, e.g. plant types, reveals whether the grouping is statistically reasonable.

The meaning of the site data is pronounced where the site data alone is not sufficient and where the literature data would have not been adequate: few site data do not necessarily reveal the entire width of the distribution, and the literature data may not span to the extremes in the site data.

Furthermore, the national forest soil inventory methodology applied required development of a concept to calculate concentration ratios from multi-layer soil data where the rooting depth is taken into account, as opposed to the conventional method of average concentration in soil core to a fixed depth. Examples of concentration ratios specific to soil layers are presented.

P05-02

### A graded approach to dose assessment in the Posiva safety case

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Posiva Oy is responsible for implementing a final disposal programme in Finland for spent nuclear fuel. The next step of the nuclear licensing is by the end of 2012 submit a construction licence application for a KBS-3 type of repository at the Olkiluoto site. Currently, a safety case is produced to support this application, were a preliminary version was completed in 2009. A three-tiered graded approach was developed and applied in the dose assessment. Tier 1 and 2 are generic screening evaluations, and Tier 3 is based on site-specific state-of-the-art radionuclide transport modelling and dose assessment. The main aim of the screening evaluation is to reduce the number of radionuclides needed to be considered in Tier 3, which is especially valuable for long-term assessments that are associated with large uncertainties. This approach assures that the level of detail of the assessment is appropriate to the magnitude of the potential radiological consequences, and strengthens the confidence in the assessment and the demonstration of compliance with regulatory criteria. Tier 1 derives defensible and extremely cautious Risk Quotients, assuming that all radionuclides released from the geosphere expose one person, or a penalizing species for other biota, without any dispersion in the biosphere. Tier 2 derives defensible and cautious Risk Quotients, based on a generic model including three sub-models, a terrestrial, an aquatic, and a well. The screening evaluation was applied to the geosphere releases derived in the interim safety case. The result shows that 24 of the 35 radionuclides in the geosphere releases can be screened out. Especially noticeable is that no radionuclides in the naturally occurring decay chains need to be propagated to Tier 3. This paper presents the methodology of the graded approach, the screening models, and the results from the screening evaluation in the preliminary safety case.

P05-03

### On a simple method for proving clearance conditions for radioactive waste

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Radioactive waste is one of the main problems of nuclear power. Any unusable material (waste) occurring in a part of a nuclear power plant is considered radioactive waste. An important part of these wastes have very low radioactivity, it may be excluded from the system of the radioactive waste regulation. Exclusion of a material from the regulation of radioactive waste is based primarily on a series of measurements to demonstrate the radioactive elements in the material are under the exclusion limits set by law. This paper presents a methodology including a series of relatively simple measurements which prevents time and human resources consuming radiochemical separation procedures. The basic idea is the fact that it is not necessary to know the exact amount of radioactivity, it is sufficient to demonstrate it is under a certain value (clearance limit). It is not necessary a complete characterization of the waste to demonstrate it meets the criteria for unconditional release. In a CANDU type radioactive waste may occur difficult to measure alpha active elements as  $^{234/235/238}\text{U}$ ,  $^{238/239/240}\text{Pu}$  and  $^{241}\text{Am}$ ; beta active elements as  $^{14}\text{C}$ ,  $^{63}\text{Ni}$ ,  $^{99}\text{Tc}$ ,  $^{90}\text{Sr}$  and  $^{90}\text{Y}$  and easy to measure gamma emitting nuclides as  $^{54}\text{Mn}$ ,  $^{60}\text{Co}$ ,  $^{95}\text{Zr}/^{95}\text{Nb}$ ,  $^{106}\text{Ru}$ ,  $^{110\text{m}}\text{Ag}$ ,  $^{134}\text{Cs}$ ,  $^{137}\text{Cs}$ ,  $^{144}\text{Ce}$ ,  $^{152}\text{Eu}$  and  $^3\text{H}$  ( $^3\text{H}$  is considered easy to measure, the LSC technique is quite easy to apply). Determining the gross alpha and beta activity, high resolution gamma spectrometry and LSC counting can reach a well-founded conclusion the material meets all conditions for the release from the radioactive waste regulation system. The method consists of 12 stages, the theoretical basis for each stage will be presented separately. It will present the conditions under which these measurements are made and the basic properties of the equipment (background, efficiency, detection limits, stability, etc.). We will insist particularly on the need of the long-term stability of the installations used for the measurements.

P05-04

### A comprehensive overview of the disposal of large components

**Meissner, Frank; Bauerfeind, Matthias**

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During the decommissioning of nuclear power plants large metallic components like steam generators or reactor pressure vessels are playing a relevant role. Depending of their radiological properties a disposal or a further use is possible. To fulfill the requirements of the intended products, different strategies are used. These strategies are following the basic conditions like the radiological or the site situation. A relevant aspect is the possible clearance of the waste material which can be achieved after decay storage where necessary. Based on these premises different strategies are resulting. Some of these strategies are already used in practice. For example, large components can be deconstructed on site with the objective of a final storage. Other strategies are pursuing the goal of the clearance of at least a part of the large components. This can typically be achieved by an after treatment of the fragmented or entire large components, eventually including decay storage. It is within the scope of this article to show up different strategies from a point of view of practical application of dismantling. The strategies will be compared concerning their relevant advantages and disadvantages like the legal situation or radiological protection.

P05-05

### **Recovery from old intermediate level liquor spillage in redundant magnox waste Silo**

**Brown, Andrew; Doyle, Ken**

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A Silo at Sellafield has been used to store historic intermediate level waste from irradiated magnox fuel decanning operations undertaken from 1964 until 1991. This material is stored under water in 22 separate compartments.

In 1999, there was an event on one compartment that resulted in a liquor spill on the main silo operations floor with contact dose rates estimated at approximately 2 Sv/h in contact and general waist height dose rates of tens of mSv/h.

Retrieval of the contents from all of the Silo compartments in the building is one on the UK's most important nuclear risk reduction activities. In order to do this, it has been necessary to decontaminate and shield the affected area as far as reasonably practicable so that Silo emptying equipment can be deployed.

Detailed evaluation of the spillage was performed over the course of several years, until equipment was identified capable of removing an acceptable layer of the silo operations floor while maintaining its structural strength. Deployment of this equipment will be covered along with the ALARP processes used to identify an acceptable level of shielding for the floor area, taking account of expected future operations.

The presentation will describe the significant radiation and contamination challenges and the ALARP techniques undertaken during the course of the work. Photographs and radiological images will be used to illustrate how the project progressed through the phases of work, include a summary of the immediate follow up to the event.

A summary of the lessons learnt through this project will be presented. This will review the capability of dose prediction, suitability of the contamination control arrangements and utilisation of "radscan" imagery in an operational environment.

P05-06

### **Efficient and environmentally sound management of radioactive waste streams from maintenance, upgrade and decommissioning**

**Stenmark, Anders**

Studsvik Nuclear AB, SWEDEN

Power generation of today struggle with many challenges and as the effects of global warming become obvious many countries seek alternatives to fossil fuel. The increasing interest in nuclear technology is based on its many advantages but the technology also offers challenges in how to cope with prolonged lifetime support and sustainable waste routes.

Studsvik have been processing Low Level Waste (LLW) at its licensed facility in Studsvik, Sweden since the mid-1970s. The facility has historically processed metallic and combustible waste and can today demonstrate a well defined, cost effective and robust waste volume reduction route for both the Swedish and the international nuclear industry.

S06-01

**Determination and quantification of NORM radionuclides**

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In this paper we describe results which were realized as part of a research project performed in collaboration with the Belgian Federal Agency for Nuclear Control and the Customs Department of the Port of Antwerp. The project is funded by EFRO and the ministry of the Flemish community. One of the major goals of this project is the detection of NORM radionuclides in a shipping container using a NaI detector coupled to a Multi Channel Analyzer. Furthermore, detection is followed by an estimation of the activity and activity concentration of each found radionuclide. At first, we used a general purpose spectrum analysis tool. We developed an analysis sequence taking into account the container geometry and the mass of the load within the container. A second step is to make the tool useful for non specialized workers in NORM industries. We automated the interaction between the detector and our software. Next we implemented a user-friendly interface which makes it possible to derive the spectrum automatically from the MCA into our software, which performs the analysis and which reports the nuclides found together with the corresponding estimations of the activity. In addition, we implemented and applied spectrum analysis algorithms customized for the detection and quantification of NORM radionuclides. These algorithms will be discussed in the paper. To calibrate and/or screen aforementioned techniques, reference samples were taken and analyzed by a certified institution. The tool was connected to the Antwerp Customs Department's database containing a large number of spectra which were recorded during physical inspections of containers. As a result, also to intercompare, the described techniques could be executed on a lot of spectra. Optimization of the methods is important as new European regulations of NORM radionuclides will be proposed and a cost-efficient, user-friendly tool to determine the activity concentration of NORM material can aid to implement the new directives.

S06-02

**Exposure of workers in France due to naturally occurring radioactive materials (NORM)**

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Handling or storage of raw materials which contain naturally occurring radionuclides can lead to a significant increase of the exposure of workers. French authorities take this matter into account with a specific regulation, the Ministerial order of May 25, 2005. This imposes on operators to assess the effective doses received by workers. Based on data presented by operators in the ninety studies received by IRSN and French authorities, the aim of this presentation is to summarise the results which concern nine different industrial activities.

Most of the studies take into account external exposure and internal exposure by dust inhalation. Some also consider doses due to inhalation of radon. When data were available, exposure due to natural background was subtracted from the doses reported by operators. Data relative to exposure to radon have been considered specifically.

Effective doses reported by operators range from less than 1  $\mu\text{Sv}/\text{yr}$  to 82  $\text{mSv}/\text{yr}$ . For example, dose ranges for different industrial activities are presented hereafter:

- Coal combustion: <1  $\mu\text{Sv}/\text{yr}$  to 0.4  $\text{mSv}/\text{yr}$ ;
- Ore processing for production of metals: 0.05 to 6  $\text{mSv}/\text{yr}$ ;
- Processing of material involving thorium: <1  $\mu\text{Sv}/\text{yr}$  to 82  $\text{mSv}/\text{yr}$ ;
- Production of zircon and smelting and metallurgy which involves it: <1  $\mu\text{Sv}/\text{yr}$  to 2.3  $\text{mSv}/\text{yr}$ .

Based on the feedback gained by IRSN and French authorities from the studies conducted by operators, the following conclusions can be drawn:

- assessments are still expected for some industries;
- about 10% of calculated doses are greater than the limit of 1  $\text{mSv}$  per year for the public and need a further examination;
- external and internal exposure are in the same order of magnitude;
- the highest doses are found in facilities which produce materials involving thorium;
- some types of industrial facilities currently not concerned by the French ministerial order, e.g. paper manufacturing, are concerned by NORM and TENORM issue and could be added to the list of industrial facilities.

S06-03

### Radiological baseline study on the planned Sokli phosphate mine in Finnish Lapland

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The results of a radiological baseline study on the planned Sokli phosphate mine in Finland are presented.

Sokli is located in Savukoski municipality, Finnish Lapland, close to the border with Russia. The mineral deposit is associated with a carbonatite massif some 360 million years old, with a land surface diameter of 5 – 6 km. In addition to the phosphorus minerals, the carbonatite massif contains other ores, such as iron, niobium and vermiculite minerals. Plans for the Sokli mine project include opencast ore extraction and treatment, crushing and grinding of the ore, beneficiation, dewatering and storage of the products, tailing storage, water treatment and auxiliary activities. The planned production is 2.0 million tonnes of phosphorous concentrate. The amount of ore mined will be 4 – 10 Mt/a depending on the mining and milling strategy in the area.

From the radiation protection point of view, the Sokli carbonatite massif contains considerable amounts of natural radioactive substances, e.g. thorium and uranium and their decay products. These substances are especially rich in the niobium ore. In connection with the Environmental Impact Assessment, the Radiation and Nuclear Safety Authority (STUK) carried out a radiological baseline study at the site of the planned Sokli phosphate mine. In the baseline study the activity concentrations were studied in ecosystems at the Sokli site, as well as in the immediate vicinity where the mine may have some radiological impact. The objective of the study was to obtain a detailed understanding of the radiation levels at and in the vicinity of the Sokli mining site. The baseline study can be used in the future to assess the possible impacts on the environment of the natural radionuclides released during the mining process.

S06-04

### Naturally occurring radionuclides in drinking water – An overview of the problem in Sweden

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In Sweden, uranium rich soils and bedrocks can give rise to high concentrations of naturally occurring radionuclide (NORM) in groundwater. If the extracted water is then used as domestic water supply, an appreciable radiation dose can be received. Radionuclides that are of interest, originate principally from the decay series of uranium (<sup>238</sup>U) and include radon (<sup>222</sup>Rn), radium (<sup>226</sup>Ra), polonium (<sup>210</sup>Po), lead (<sup>210</sup>Pb) and <sup>238</sup>U itself if the latter is present in high concentration (> 100 µg/l). A recent country wide mapping of about 700 drilled wells reveal that geological criterion cannot alone explain concentration variations of radionuclides in groundwater. 8% of the studied wells, located outside regions containing uranium rich bedrocks, had a radon concentration exceeding the recommended action level of 1000 Bq/l in water. A proper understanding of the factors guiding the mobilisation and transport of decay products of <sup>238</sup>U in the subsurface is a prerequisite to make accurate risk prediction. There are about 250 000 drilled wells that are used permanently in Sweden and between 5000 – 10000 wells get constructed every year. The concentrations of radionuclides except for radon are seldom analysed. The National Board of Health and Welfare in Sweden recommends radon measurements in drinking water coming from private wells. Results of water analyses, if or when performed are not communicated to a centralised database that can be used by various national authorities but efforts are ongoing to build such a system. Knowledge regarding the extent to which private well owners check the quality of their water with regards to radionuclide and take appropriate remediation measures is poor. An ongoing survey regarding remediation measures is hoped to provide additional information on the issue.

S06-05

**NORM in the petroleum and geothermal industries: evolution of the French radioprotection legislation****Lafortune, Stéphane<sup>1</sup>; Pinte, Jean-Claude<sup>1</sup>; Sada, Martine<sup>2</sup>**<sup>1</sup>INERIS (French National Institute for Industrial Environment and Risks), Ground and Underground Risks Division, FRANCE;<sup>2</sup>French Ministry of Ecology, Energy, Sustainable Development and Sea, FRANCE

Fluids produced from oil or gasfields and aquifers are naturally radioactive due to the presence of potassium-40 and isotopes from decay chains of uranium-238 and thorium-232 in these reservoirs. Thus, natural radionuclides can be carried away towards surface when petroleum or geothermal reservoirs are drilled and produced. These radionuclides can precipitate in deposits forming in process equipment, which can then be unusually radioactive, expose workers to hazardous materials and create waste disposal problems. Workers can also be exposed to high concentrations of radon. Due to their natural origin, these accumulations of radionuclides in equipment are called Naturally Occurring Radioactive Materials (NORM). They are also known as TENORM, because they are technologically enhanced.

In closed systems, exposition to gamma radiations penetrating equipment to the external surface can be reduced by restricting and controlling access to appropriate areas. But personnel may come into direct contact with NORM during maintenance and cleaning operations, when opening equipment and vessels.

In France, hygiene and safety rules concerning the protection of workers in the petroleum and geothermal industries are formulated in a specific legislation related to extraction and mining. Presently, both petroleum and geothermal industries are not included in the list of activities which have to follow radioprotection measures given by this legislation. French authorities are currently planning to update the list by including these two activities. There is a real need to realize a state-of-the-art of the exposition level of French workers and to match the dose limits to those given by the Labor and Public Health Codes.

This paper will present the origin of NORM and radon contamination in the petroleum and geothermal industries and discuss the French legislation evolution for the radioprotection of personnel working in these two industries.

S06-06

**Ukrainian experience of public exposure to NORM in building materials****Pavlenko, Tetyana<sup>1</sup>; German, Olga<sup>2</sup>;****Los', Ivan<sup>1</sup>; Aksyonov, Nikolay<sup>1</sup>**<sup>1</sup>Marzeev Institute of Hygiene and Human Ecology, AMSU, UKRAINE; <sup>2</sup>Swedish Radiation Safety Authority, SWEDEN

This article provides an overview of the monitoring results of NORM content in building materials. Totally, 22 open cast mines producing crushed rock were examined including 10 sand pits and 4 clay pits. Ca 800 samples of raw mineral material were measured. The effective dose of external exposure of the population caused by the building material was estimated. It was also found out that 12% of the open pit mines do not correspond to the regulatory criteria and material produced there should not be used for building of dwellings. According to our estimation an average weighted effective dose to the population in Ukraine, due to the occurrence of NORM in dwellings is 0,23 mSv/a. Key words: building materials, effective dose.

S06-07

**The International Association of Oil & Gas Producers (OGP) naturally occurring radioactive material management (NORM) guidelines****Mously, Khalid<sup>1</sup>; Cowie, Michael<sup>1</sup>; Campbell, John<sup>2</sup>**<sup>1</sup>Saudi Aramco, Environmental Protection Department, SAUDI ARABIA; <sup>2</sup>International Association of Oil & Gas Producers (OGP), BRITISH INDIAN OCEAN TERRITORY

It has been established that Naturally Occurring Radioactive Materials (NORM) may accumulate in the oil/gas production process. This can create a radiation hazard for workers, the general public and the environment if adequate controls are not established. Regulations and guidelines on radiation protection in general and NORM in particular have been issued by various National and International entities, however these are not specific to the Oil & Gas industry, and do not provide clear and concise guidance to enable NORM to be managed effectively. The International Association of Oil and Gas Producers (OGP) established a task force, headed by Saudi Aramco, to develop NORM Management Guidelines. This task was completed after research, review and thorough consideration of most available NORM regulations, and the industry's current best practices in NORM management. The OGP guidelines offer a simple and logical method of managing NORM impacted operations that are flexible enough to be implemented across the industry. This paper outlines major aspects of OGP NORM management guidelines and elaborates on key issues related to the management of NORM in the Oil & Gas Industry, in particular on NORM monitoring, control of NORM contaminated equipment, managing NORM waste handling and disposal, and worker protection, awareness and training.

P06-01

**Technologically enhanced NORM and heavy metals in iron and steel industry****Khater, Ashraf<sup>1</sup>; Bakr, Wafaa<sup>2</sup>**<sup>1</sup>King Saud University, SAUDI ARABIA;<sup>2</sup>Atomic energy Authority, EGYPT

Iron and steel industry was ranked as the largest industrial source of toxic environmental contamination in USA. About 2–4 tones of various solid wastes (slag, sludge, dusts and scales) are generated per ton of steel produced. These wastes contain a notable concentration of Naturally Occurring Radioactive Materials – NORM and heavy elements that could be a source of environmental contamination and occupational exposure. Composite samples of different iron and steel industry's wastes were collected from four iron and steel factories. Natural radionuclides ( $^{238}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ ,  $^{210}\text{Pb}$ ,  $^{210}\text{Po}$ ) and trace elements (e.g. Cd, Cu, Pb and Zn) were measured using gamma-ray spectrometry, alpha particle spectrometry and ICP-MS analytical techniques. There is a wide range of variation in the concentration of natural radionuclides and other elements that depends on their concentration in the process input materials and thermal treatment process. Occupational dose due to dusts inhalation was calculated. According to the assumed scenario, the occupational exposure is much lower than the reference dose limit. The environmental impact due to wastes storage and/or usage should be considered generally and case by case.

P06-02

**NORM and trace elements fractionation in phosphate rock beneficiation processes: potential hazards and useful applications****Khater, Ashraf**

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Beneficiation processes (mainly crushing, washing, magnetic separation and wet screening) of phosphate ore rock aims at increasing the phosphate content percentage. It starts with the ore rock and end with wet rock, and different rejects or processes by-products. By-products have potential hazards due to their content of Naturally Occurring Radioactive Materials – NORM especially uranium-238 series and heavy metals, e.g. Cd, Cu, Pb and Zn. They have also potential industrial and agricultural useful applications due its physical and chemical properties such as their relative high content of clay and iron. Representative samples of ore and wet phosphate rocks and beneficiation processes by-products (clay and dolomite rocks, wet screening, magnetic separation and slim) were collected. Natural radionuclides ( $^{238}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ ,  $^{210}\text{Pb}$ ,  $^{210}\text{Po}$ ) and trace elements (e.g. Cd, Cu, Pb and Zn) were measured using gamma-ray spectrometry, alpha particle spectrometry and ICP-MS analytical techniques. Potential hazards due to beneficiation processes and their by-products were discussed from both the radiological and chemical point of views. Radiologically, internal hazards index, external hazard index, representative level index, gamma absorbed dose rate and occupational dose equivalent due to inhalation were calculated. Chemically, input of toxic heavy metals (radioactive or stable) to the environment due to by-products dump and/or usage were estimated and their hazardous aspects were discussed. Some of the by-products could have potential useful applications such as clay rock and slim for agricultural soil reclamation. The aspects of these useful applications were discussed.

P06-03

### **NORM in clay deposits: potential hazards and useful applications**

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Clay deposits are very important industrial mineral resource that have different significant industrial and agricultural applications. As any other natural material, clay deposits contain notable concentration of Naturally Occurring Radioactive Materials – NORM such as uranium-238 series, thorium-232 series and potassium-40. Clay deposits have potential hazards as well as potential useful applications. This work aims at measuring the activity concentration of some natural radionuclides to investigate their potential hazards and the useful applications of clay deposits. Twenty two composite clay samples were collected from three different regions (Al-Riyadh, Al-Kharj, jedha). The activity concentrations, in Bq/kg, of <sup>238</sup>U, <sup>232</sup>Th, <sup>40</sup>K were measured using gamma-ray spectrometry based on hyper pure germanium detector. Physical and chemical properties (pH, EC, CEC, particle sizes, soluble cations and soluble anions) of clay samples were measured. The aspects of useful applications of clay deposits were mentioned. To estimate the potential hazards of clay deposit mining and application, radium equivalent activity, internal hazards index, external hazard index, representative level index, gamma absorbed dose rate and occupational dose equivalent due to inhalation were calculated. The correlations between natural radionuclides activity concentration and Physical and chemical properties of clay samples were discussed.

P06-04

### **Distribution pattern of NORM on Red Sea shore sediments in relation to non-nuclear industries**

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The Red Sea is a deep semi-enclosed and narrow basin that has an intensive non-industrial activities on and near its shore. Oil exploration, phosphate mining and trading, navigation activities and intensive touristic activities are consider as non-nuclear pollution sources that could impose a serious radiological and ecological impacts on the Red Sea marine environment. Both oil and phosphate related activities could increase the concentration of Naturally Occurring Radioactive Materials – NORM such as uranium-238 series, thorium-232 series and potassium-40. Forty representative shore sediment samples were collected from the Egyptian Red Sea shore, from Shuqeir to Marsa Alam City region. Activity concentration of <sup>238</sup>U, <sup>232</sup>Th, <sup>40</sup>K, <sup>210</sup>Pb and <sup>210</sup>Po were measured using gamma-ray spectrometry, alpha particle spectrometry and ICP-MS analytical techniques. Previous study showed the possible impact of industrial activities on the activity concentration of NORM in shore sediment. This study will investigate such relation and the distribution pattern of NORM in more details.

P06-05

**NORM and heavy metals partitioning during water treatment processes****Khater, Ashraf**

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Water samples were collected from underground water purification plant to study the variation in Naturally Occurring Radioactive Material (NORM) e.g., U, Th and K, and heavy metals e.g., Cd, Pb, Hg, Cu, and Zn concentration through the treatment processes and its relation to physical and chemical properties of water. Samples represent the different treatment processes (input, output, after filtration, sludge tank, reverse osmosis permit and reject, and waste water ponds). NORM and heavy metals concentration in the collected samples were measured using ICP-MS. Their concentrations in water samples show a wide range of variation that depend mainly the water treatment processes and the chemical properties of water samples. Water physical and chemical properties, i.e. pH, EC, major cations (Ca, Mg and K) and major anions ( $\text{CO}_3$ ,  $\text{HCO}_3$ , Cl and  $\text{SO}_4$ ) were determined. The effect of water treatment processes on NORM concentration; dose assessment due to water drinking (before and after treatment) and the radio-ecological risk assessment were discussed.

P06-06

**Soil-to-plant transfer factors of  $^{210}\text{Pb}$  and  $^{210}\text{Po}$  in boreal forests****Vaaramaa, Kaisa<sup>1</sup>; Aro, Lasse<sup>2</sup>; Solatie, Dina<sup>3</sup>**<sup>1</sup>University of Helsinki, Laboratory of Radiochemistry, Department of Chemistry, FINLAND; <sup>2</sup>Finnish Forest

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The general goal in this project was to obtain overview on  $^{210}\text{Po}$  and  $^{210}\text{Pb}$  behaviour and mobility in the environment. Binding and mobility of  $^{210}\text{Po}$  and  $^{210}\text{Pb}$  in forest soil and transfer of polonium and lead from soil to plants were considered. The main study areas were located in Scots pine forests in southern Finland (62°9'N, 22°52'E) and in northern Finland (66°21'N, 26°44'E). The soil samples were collected and separated into different soil horizons (litter, organic and mineral soil layers). Vertical distribution and concentrations of  $^{210}\text{Pb}$  and  $^{210}\text{Po}$  in soils were determined. Wild berry samples and edible mushrooms were collected at the sampling sites. Activity concentrations of  $^{210}\text{Po}$  and  $^{210}\text{Pb}$  were analysed from roots and rhizomes of the berry samples as well as from berries (i.e. fruits), leaves and stems separately. Mushrooms were divided into caps and stipes and each part was analysed separately. The mean  $^{210}\text{Po}/^{210}\text{Pb}$  ratio was 0.9 in the organic soil layer in the southern and the northern Finland sites. The activity ratios of  $^{210}\text{Po}/^{210}\text{Pb}$  in the wild berry and mushroom samples were mainly higher than one, indicating elevated concentrations of polonium in the samples. In mushrooms the concentrations of  $^{210}\text{Pb}$  and  $^{210}\text{Po}$  were higher than in fruits of the wild berries. Soil-to-plant transfer factors for lead and polonium will be discussed. The research results gained in this project will enable an assessment of the mobility of  $^{210}\text{Po}$  and  $^{210}\text{Pb}$  in the environment and in the food chains and estimation of ensuing radiation doses to humans.

P06-07

### **Radiological assay techniques associated with TENORM industry**

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In recent years there has been an increasing awareness of the radiological impact of non-nuclear industries that extract and/or process ores and minerals containing naturally occurring radioactive materials (NORM). Actions were undertaken to find and characterize the main industrial activities involving NORM and to assess the impact of these activities on the nearby public. The main concern was on past activities in phosphate fertilizers industry and the associated by-products disposal as well as the activities in oil and gas production and processing industry. Phosphogypsum is the main by-product generated during the phosphoric acid production process (wet process), and phosphate slag is the principal by-product generated from the production of elemental phosphorus (thermal process). During the wet process, a selective separation and concentration occurs for radionuclides which are naturally associated with the phosphate ores. In oil and gas production and processing equipment some elevated TENORM contamination might occur due to the physical processes to which the extraction fluids are exposed. Some radium and radium daughter compounds are slightly soluble in water and may become mobilized when this production water is brought to the surface. The paper presents the methodology used in some particular cases to deal with NORM characterization as a regulatory requirement for non-nuclear practitioners to improve their radiological safety and to achieve an adequate level of knowledge as concerns the risks associated with NORM industry.

P06-08

### **NORM management in the oil & gas industry – Saudi Aramco experience**

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It has been established that Naturally Occurring Radioactive Materials (NORM) may accumulate at various locations along the oil/gas production process. Components such as wellheads, separation vessels, pumps, and other processing equipment can become NORM contaminated, and NORM can accumulate in the form of sludge, scale, scrapings and other waste media. This can create a potential radiation hazard to workers, general public and the environment if certain controls are not established. Saudi Aramco has developed NORM management guidelines and is implementing a comprehensive strategy to address all aspects of NORM management which aim towards enhancing: NORM monitoring, Control of NORM contaminated equipment, Control of NORM waste and disposal, Workers protection, awareness, and training. The benefits of shared knowledge, best practice and, experience across the oil & gas industry are seen as key to the establishment of common guidance. This paper presentation outlines Saudi Aramco's experience in the development of a NORM management strategy and its goals of establishing common guidance throughout the oil and gas industry.

P06-09

### The needs and feasibility of land reclamation of areas affected by enhanced natural radioactivity

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The majority of efforts devoted for disposal of radioactive materials are focused on those originating from nuclear industry. Far less attention has been paid to environmental burden of waste with natural radioactivity enhanced by non-nuclear industry (TENORM). Such waste differs significantly from classical nuclear ones and the radiation risk is often associated with risk caused by other pollutants. Contrary to the nuclear waste that's strictly controlled it has been a common practice to put TENORM into heaps, where they can reach thousands of cube meters or tonnes, without any protection. Exposure to meteorological conditions sets some chemical or physical processes in motion, leading to the selective transfer and accumulation of radionuclides and disequilibrium in decay series. As a result of the inconclusive European law, that leaves the decision where risk caused by TENORM is significant under each member state's competences, non-nuclear industry of concern is hardly ever aware of environmental problems caused by natural radioactivity or they would expect negative consequences in case of implementing radiation protection measures. This results in the substantial understatement of the detriment to the environment originating from TENORM. EU member states apart each other try to regulate this problem case by case but the risk caused by TENORM is rarely taken into account when the treatment of such waste is planned. The feasibility of different methods of land reclamation was discussed including hard land reclamation, bioremediation and phytotechnology. An approach based on dilution of TENORM with inert materials was considered. Contrary to the nuclear waste, where dilution is totally forbidden, natural radioactivity, which is present in small amounts elsewhere, is a case where such approach to decrease risk sounds rationally. In extraction industry huge amount of gangue is present so that such approach is well-founded also from economic point of view.

P06-10

### Uranium and heavy metals in narghile (shisha, hookah) moassel

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Cigarette smoke is a source of some trace and heavy metals but also the smoking mixtures used in narghile. Some cigarette filters retain significant quantities of cadmium, lead, magnesium, iron, and other metals. However, data on narghile (hookah, shisha, water-pipe) are scarce. So, the objective of the present study was to investigate the contents of the main and widely used smoking product: moassel. Ten representative samples of 3 different moassel brands were collected from the local market of Cairo city-Egypt and Riyadh City- Saudi Arabia. Uranium and heavy metals (e.g., Cd, Cu, Pb and Zn) were assessed using ICP-MS. Among the 10 representative samples of the 3 different moassel brands, The results indicate the existence of a wide range of variations in uranium and other element concentrations that could be because of non standard manufacture processes. The concentration levels were compared to the results of other studies and that of cigarette tobacco. Our study shows that, as far as trace elements are concerned, harm can be reduced. Public health officials could include in the national prevention plans the use of smokeless tobacco, particularly when addressing heavy narghile smokers. However, it must be clear that there are important differences between smokeless products. On one hand, some of them, like the Sudanese "tumbak", contain high levels of carcinogenic nitrosamines and we fear that Arabian shamma might be of a similar nature. On the other hand, a moist snuff like the Swedish SNUS, is, in the view of prominent international experts, highly recommendable all the more that it is also very low in carcinogenic substances. We therefore encourage its use all the more that this harm reduction product is culturally adapted to the Arab world context and other similarly sanitary and socio-cultural ones.

P06-11

**External gamma radiation produced by materials: proposal of an evaluation model. Application case study to NORM**

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External gamma exposure to natural radiations is due to a series of isotopes gamma emitting, contained in all building materials. Beginning from the set up of a calculation model to estimate the emission in a closed environment, it was possible to derive the effective dose in the environment. The case of materials generally rich of natural radioisotopes was investigated. From an inverse process, starting from the examination of the radiation field it is possible to estimate the extension of an activated surface. A case of contamination and activation surface in a general context as the inner part of nuclear plant or a radioactive facilities was evaluated. This method, moreover, is also applicable to NORM.

S07-01

**The Safety Culture as a part of radiation protection in medical imaging**

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**Introduction:** The safety culture means individual awareness of the importance of safety, competence, commitment, motivation, supervision and responsibility, concerning also attitudes of the staff at all levels. The enhancement of patient safety involves a wide range of actions in the recruitment, training and retention of health care professionals, performance improvement, environmental safety and risk management, equipment safety, safe clinical practice and safe environment of care.

**Materials and methods:** To find out the features of the radiation safety culture, several studies in different areas were analyzed concerning radiation safety officers in diagnostic departments and patient doses.

**Results:** Regulatory and organizational environment, management styles, workers and attitudes as well as technology characteristics were the main factors affecting the safety culture. The dose study of pediatric reflux patients showed that about 6.9 examinations/patient were made up to the age of 16 years. Accepting the higher noise but still reliable diagnosis the dose could be decrease by up to 80 percent. In the study of newborn premature babies showed that they are exposed a lot (even 64 images during first living months). Most of the examinations were chest and abdomen examinations. The study of pregnant woman examinations showed that there was no common practice on how to exclude the possibility of pregnancy and the dose to a foetus was not estimated either before or after the pelvic x-ray examination.

**Conclusions:** Optimization of image quality and patient dose allows the patient dose to be decreased by more than 50% in many patient groups. Digital imaging gives possibility to degree dose and still has image quality good enough. The attitudes and fear of change are the biggest barriers to reach the good safety culture. The next step is the establishment of safety culture, which takes into account the attitudes, behaviour and other human factors, which have effect on safety.

S07-02

**The role and responsibilities of the medical physicist as a radiation protection adviser in the healthcare environment**

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In the European Member States, the use of ionising radiation in the healthcare environment is regulated by the transposition in to national legislation of Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionising radiation in relation to medical exposures. EFOMP noted the definition of the Medical Physics Expert and the involvement of this expert in radiotherapeutic, diagnostic nuclear medicine and other radiological practices in this Directive. EFOMP has for many years sought to harmonise and promote the best practice of medical physics in Europe and has in this respect issued Policy Statement No. 9 in response to the above directive. The EFOMP strategy is directed towards the recognition of the European Medical Physicist and for this purpose the Federation's approach has been to encourage registration schemes (on a voluntary basis) where no regulated scheme (as imposed by law) exists. EFOMP recognised that the most appropriate way to achieve harmonisation of standards across the whole of Europe was to express the duties and competencies expected of the Medical Physics Expert (MPE) set out in the 1997 Directive, in very practical terms. A framework of five levels of competency that covers the whole career structure of the medical physicist was developed including the duties of the MPE. A system for recognised Continuing Professional Development is recommended by EFOMP and has been described in a Policy Statement. This paper aims to present EFOMP's efforts to harmonise the education, training and competences of the Medical Physicist in Europe and thus to meet the role and responsibilities of the MPE as specified in the above directive.

S07-03

**Computer based radiological protection course for workers in the health care sector****Busoni, Simone<sup>1</sup>; Fulcheri, Christian<sup>2</sup>; Gori, Cesare<sup>1</sup>**<sup>1</sup>Azienda Ospedaliero-Universitaria Careggi, Health Physics, ITALY; <sup>2</sup>Università degli Studi di Firenze, Health Physics Specialization School, ITALY

Radiological protection aspects in the health care sector are a primary concern with respect to worker safety due to the very different kind of occupational activities existing in health care and large number of people usually involved with ionising radiation (I.R.), for instance in a large hospital.

The Government of the Tuscany Region (Italy) has promoted the realisation of a computer based radiological protection training course for all I.R. workers of the National Health Service within the Tuscany region.

The main challenge of the project is to provide the basic safety information in such a complex field, where people with very different education levels and duties work together. The goal of the project is to fulfill the specific educational requirements of Directive 96/29/EURATOM as introduced in the Italian legislation.

The course is devoted to provide radioprotection training to all people working in the medical environment, with special attention to workers without high level of education in the I.R. field (physicians outside the radiology area, surgery room staff, nurses in nuclear medicine or radiotherapy, laboratory technologists, etc.).

The course is composed of four sections dealing with the general aspects (basic radiological physics, biological effects of I.R., national regulatory system, dosimetry, radioprotection principles) while four other sections deal with sector specific radioprotection aspects in radiology, nuclear medicine, radiotherapy and laboratory. A special chapter, summarising all aspects treated in the course, is devoted to workers with lower educational level and no-background in the field of physics, radioprotection and current legislation. Each section comprises a multiple choice test, a glossary and a bibliography. The course is developed with an open source content management system, and a web site interface as user interface. First feedback and tests results collected within hospital workers will be reported.

S07-04

**e-Learning in DAP-measuring****Varonen, Heidi<sup>1</sup>; Kurtti, Juha<sup>1</sup>; Parviainen, Teuvo<sup>2</sup>; Halonen, Noora<sup>1</sup>; SR08S1, Radiography students<sup>1</sup>; Grönroos, Eija<sup>1</sup>**<sup>1</sup>Metropolia University of Applied Sciences, FINLAND; <sup>2</sup>STUK – Radiation and Nuclear Safety Authority, FINLAND

According to studies lower limits for radiation dose setting can be established for computed radiography (CR) systems to produce diagnostic quality images than the standard values used for film/screen systems. This is especially important in examinations performed for the children. Flat panel Detectors (so called direct radiography, DR) gives even more possibilities for dose reduction and still having at least as good image quality as with CR. One of the most important quality assurance procedures is to evaluate the doses delivered to patients who undergo x-ray examination. The DAP-meter is a real-time patient dose monitoring system for auditing patient doses. Technical data from each exposure and for every examination type can be collected. Radiography students and lecturers of Metropolia University of Applied Sciences produced an e-based learning module about DAP-measuring in co-operation with Metropolia degree programme in multimedia technology and Finnish Radiation Protection Authority. In this presentation the contents and pedagogical solutions of this module are presented. Also the development process of this learning module is depicted. The educational module consist of articles to be read, different kinds of tasks to be solved e.g crossword about central concepts of dose-area product-meter (DAP). The group also made a film that shows how to measure patient doses with DAP when using digital radiography (DR) technology.

S07-05

**e-Learning philosophy and structure for a Nordic education project in evidence based radiography**

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Helsinki Metropolia University of Applied Sciences has initiated a Nordic project to increase competence of radiographers by evidence-based training in quality in radiographic imaging. The members of this project are radiography lecturers, principal lecturers and physicists from universities in Finland, Norway and Sweden. The goals of the project are to produce curricula and learning materials using internet solutions for ground-, master and PhD-level web-based education and finally to implement the education and evaluate the training program and the materials produced. The main contents will be evidence-based digital imaging, dose optimization and quality assurance of digital imaging systems. The main principle for the education project is that the way of training as well as the contents will be evidence-based. In accordance with this the members of the project group apply evidence-based way of working in planning the education and in the contents. To give the students understanding, knowledge and tools for working evidence-based, the training program will start with an introduction to evidence based knowledge and its use in radiography, which is elementary in the whole education. The training program applies various web-based methods depending on the subject and the expected learning outcomes. In some cases the method used will be group activities like lectures by videoconference, face to face meetings on the web and discussions in groups synchronously or asynchronously via Wiki-based IT-solutions. Some subjects will be suitable for individual studies by self-paced e-learning online e.g. when searching articles or offline e.g. in learning dose area product measuring or other procedures. Students from the participating universities are even involved in the project from the very beginning e.g. by writing thesis for the needs of the project.

S07-06

**Developing a radiation protection culture at school**

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Since September 2007, actions have been undertaken in several schools in cooperation with experts from the Institute of Radiation Protection and Nuclear Safety (IRSN), the Nuclear Protection Evaluation Centre (CEPN) and a centre for scientific culture (Pavillon des Sciences – Franche Comté) in order to develop a radiation protection culture. The aims are to provide school-students with scientific and social bases on radiation protection in order to be better prepared for dealing with societal issues, to promote a scientific and technical culture, and to allow the students to better understand the «world» of radiation protection.

Each year, this approach includes two steps:

One part is dedicated to training during the school-year; each school works on different topics chosen according to local concerns (e.g. radon in dwelling, medical radiation protection, radioactivity in the environment, radiobiology...). In order to facilitate the development of this culture, practical aspects are favoured, notably with experiences and visits to laboratories, hospitals, ... Special attention is given to multi-disciplinary approach including physics, chemistry, biology, philosophy, geography, economy... This task is lead by school teachers in cooperation with experts.

The other part consists in participating to a «student workshop» allowing them to present their work and exchanging with other students and experts. In 2008, the first workshop was held in Montbéliard (France) and the second one, involving French as well as German, Ukrainian and Belarussian schools, was held in Poitiers (France) in 2009. More than 100 participants attended these workshops, and the next one is planned in Paris in March 2010.

This paper will detail the actions developed during the last years and will discuss the lessons drawn on the way to address radiation protection with young people combining scientific issues and social concerns.

S07-07

### How to share with children the basic Knowledge about radioactivity and nuclear risks?

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This paper will present the strategy of IRSN to increase the basic Knowledge of young of children about radioactivity and nuclear risks in partnership with associations. 58 reactors are built on the French territory but a review performed by M Vrousos in 2004 highlighted that French people have a very poor Knowledge about radioactivity and nuclear risk. This was confirmed by the Euro-barometer surveys. The consequences of such a low background Knowledge should be that in case of nuclear event (example Tricastin 2008) or nuclear accident, the behaviours of concerned people and French consumers create strong social and economical effects. In order to diffuse a better knowledge Institut for radioprotection and nuclear safety (IRSN) and the Formation of trainers for major risks and environment (IFFO RME) decided to have a partnership to develop tools for teachers and children. The Gafforisk fan was the first tool, with the objective to give fundamental knowledge about natural radioactivity, nuclear reaction, accident fallout, crisis management with a special emphasis on behaviour recommendation in case of nuclear crisis. The tool was developed in a mobile exhibition which can be used by local information commission, for example during crisis exercise. The paper will present in detailed the strategy, the partnerships the different tools and their use.

S07-08

### European ALARA Network: – Evolution, operation and key activities

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The new ICRP recommendations (ICRP 103), and in particular the detailed treatment of optimisation in the ICRP Publication 101, define optimisation of protection as a source-related process aimed at keeping the likelihood of incurred exposures, the number of people exposed and the magnitude of their individual doses as low as reasonably achievable, also below constraints, taking into account economic and societal factors. The implementation of the optimisation of protection into practice is supported by the ALARA principle. The term ALARA is an acronym for “As Low As Reasonably Achievable”. In essence, the ALARA principle requires that radiation exposure of man and environment be kept as low as reasonably achievable (also below constraints) when using ionising radiation. Practical implementation and further development of the ALARA principle has been achieved for many years now by the successful cooperation of experts from different European organisations; first as pioneers by establishing the European ALARA Network and then by enthusiastically supporting the activities of the network itself. This contribution presents the evolution, operation and key activities of the European ALARA Network (EAN) in the last years; the successful cooperation of experts from different professional backgrounds, advocating the ALARA principle in a range of radiation protection areas, and contributing to its further development by trading experience and networking. The interaction between the EAN and international organisations, which support the ALARA principle by including relevant activities in their work programmes, is described, as well as the cooperation between EAN and other networks to identify the role of ALARA in the process of improving radiation protection culture.

S07-09

**ENETRAP II: development of European reference training schemes for RPE's and RPO's**

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Radiation protection (RP) is a major issue in the industrial applications of ionising radiation, both nuclear and non-nuclear, as well as in other areas such as the medical and research area. As is the case with all nuclear expertise, there is a trend of a decreasing number of experts in RP due to various reasons. On the other hand, current activities in the nuclear domain are expanding: the nuclear industry faces a so-called "renaissance", high-tech medical examinations based on ionising radiation are increasingly used, and research and non-nuclear industry also make use of a vast number of applications of radioactivity.

Today's challenge involves measures to make the work in RP more attractive for young people and to provide attractive career opportunities, and to support young students and professionals in their need to gain and maintain high-level RP knowledge and skills.

The ENETRAP II project aims at meeting this challenge, through the development and implementation of a high-quality European standard for initial education and continuous professional development for Radiation Protection Experts (RPEs) and Radiation Protection Officers (RPOs), and a methodology for mutual recognition of these professionals on the basis of available EU instruments. It is envisaged that the outcome of this project will be instrumental for the cooperation between regulators, training providers and customers (nuclear industry, medical sector, research and non-nuclear industry) in reaching harmonization of the requirements for, and the education and training of RPEs and RPOs within Europe, and will stimulate building competence and career development in RP to meet the demands of the future. Another goal of the project is the introduction of a European RP training passport.

S07-10

**A Training Programme for Regulatory Inspectors under ISO 17020**

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The Radiological Protection Institute of Ireland (RPII) is the competent authority for all matters pertaining to ionising radiation in Ireland. In fulfilment of its statutory responsibilities it oversees a regulatory programme (licensing, inspection, enforcement and the provision of technical guidance and advice) for all users of sources of ionising radiation.

In December 2008 the RPII was awarded accreditation to ISO 17020: General Criteria for the Operation of Various Types of Bodies Performing Inspection by the Irish National Accreditation Board (INAB). In achieving this award the RPII became the first regulatory authority in Europe engaged in radiation protection inspections to be accreditation for its inspection services under this standard. The RPII's quality manual and quality procedures describe in detail how its inspection programmes are planned, carried out and reviewed as well as setting out training requirements for inspectors.

This presentation will describe in detail the formal training programme that was developed for a new inspector who joined the medical section of the RPII's Regulatory Services Division in Oct 2007. The programme was developed in accordance with the requirements of the ISO standard and audited by technical assessors from INAB. The programme clearly identifies all aspects of training that a new member of staff has to undertake, both technical and non-technical, in order to be warranted as an inspector/authorised officer.

In addition to the development of a formal training programme for new inspectors, the ISO standard also required the RPII to develop a formal programme for assessing the on going competency of existing inspectors. This is achieved through a programme of inspection witnessing of individual inspectors by their technical managers. Inspectors are deemed competent to continue to undertake inspections provided that their technical manager is satisfied with their knowledge and performance of the witnessed inspector.

S07-11

### A European survey addressing needs for safety culture training

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Nuclear Safety Culture is a topic of paramount importance for nuclear operators as well as those working with radiology and radiotherapy. Safety culture is a combination of individual and group beliefs, values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment and the proficiency of an organization's safety management. Implementation of safety culture requires continuous and multilateral efforts involving not only technical but also human and social aspects. Many principles of safety culture are generally applicable, and could be disseminated through seminars on best practices, case studies, feedback studies, pilot sessions, etc. Such dissemination would contribute to harmonisation according to high standards, and it would promote the mutual recognition of training throughout Europe.

A consortium of 19 partners working together in a 4 year project, TRASNUSAFE, will develop and test relevant training schemes on Nuclear Safety Culture, based on an evaluation of the training needs in a European context. Special attention will be given to the links between the ALARA principle currently used in the radiation protection community and the safety culture of the nuclear industry. Two user groups, involved throughout the entire development process, will contribute to the training schedule by providing their input and feedback and by participating in the training modules.

Training needs will be assessed throughout Europe using a questionnaire to be separately developed and validated prior to the assessment. The actual assessment of training needs will make use of web based surveys, e-mails and regular mails, telephone conversations with correspondents, as well as seminars and site visits.

This paper will focus on the training needs analysis. It will explain the methodology and will give a report of the first results.

S07-12

### Managing medical exposure through education

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Nuclear physics is providing medicine investigation and treatment methods of a priceless value. During over one hundred years, radiological equipment become more and more performing from the point of view of easy handling and rapid answer, quality of radiation beams and, not the last, radiation protection of operators and patients.

Physicians' enthusiasm due to these possibilities and society concern for individual health risk to transform these achievements from friends to enemies of health due to their excessive utilization.

It is important to estimate supplementary cancers expected by irrelevant computer tomography examinations but it should be more adequate to develop measures and methods for preventing transformation of these potential figures into real ones.

In this context, education could be used as a mean to present both sides of these special applications involving individuals, on one hand by public information and on the other hand by improving physicians' education.

Public education could begin even from elementary school by graduate introduction of the necessary notions to understand the specific aspects of radiation biologic effects. It could continue through mass media communication and by physicians at their surgeries.

This paper proposes to present a guide dedicated to patients including benefits and risks of radiological examinations, in order to involve them in the medical act. Being aware of radiological examinations specific aspects, people would participate more active to the implementation of individual monitoring systems.

As a result of the international actions already initiated, it is presumed that prescribes would become more restrictive when recommending radiological examinations and radiologists and non-radiologists physicians would become more aware to comply with the regulatory requirements on justification of each examination.

P07-01

**Improving radiation protection culture: Social representations, attitudes towards risks and stakeholders involvement**
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The culture in RP is an integral part of the safety and prevention culture and it includes the complex of all those risk-based approaches chosen to set the standards and the philosophy governing those standards. The level of ambition against risk has evolved during the time on the basis of new information about the effects of radiation and considering changes of attitude towards risk. The concern on environmental protection is an emblematic example. Often it has been asked if really RP has been and continues to be a model with the capability to also influence the protection against risks of different nature than radiation, as regards to the proposed approaches in risk assessment and evaluation. In this paper the authors are proposing a multidimensional approach to the study of the RP culture by carrying out: 1) a comparative analysis of the various and different approaches which, during the past years, have been adopted in managing the technological risk both in the RP area and in other areas of technological and scientific knowledge; 2) the historical reconstruction of the evolution of the collective imagination about the possible risks connected with nuclear radiations. In the context of the modern societies, in fact, a wide range of factors of socio-cultural, ethic and political nature contribute to determine the social representations on which the attitudes to accept or to reject the technological innovation and its related risks are founded. We are convinced that by deepening the nature of the close connections of the co-evolution between the collective imagination about radiations and the different approaches to the governance of the technological risk, starting from the inclusion of different stakeholders, by also taking into consideration the lessons learned from experiences in other fields of activities, it will be possible to define useful cognitive tools aimed to strength the RP culture.

P07-02

**The EUTERP Platform: Towards a European approach for harmonisation in education and training for radiation protection professionals**
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In Europe, a common vision for maintaining competences in radiation protection is emerging, focussing on a common denominator for qualification of radiation protection experts (RPEs) and radiation protection officers (RPOs), and for mutual recognition and mobility of these professionals across the European Union and related countries. Started as an initiative of the European Commission the European Platform on Training and Education in Radiation Protection (EUTERP Platform) has been transformed into a legal entity under Dutch law. The Platform facilitates a permanent dialogue between all involved parties by the use of its website ([www.euterp.eu](http://www.euterp.eu)), by issuing newsletters and by organising workshops. From the workshops several recommendations based on common agreement among the participants - were given to the EC, IAEA, IRPA and national authorities including proposals for definitions of the RPE and the RPO. Currently, the possible consequences for national legislation and E&T activities and guidance needed in relation to this proposed definitions of RPE and RPO that will be implemented in the Euratom BSS are the main focus of the EUTERP Platform. The role of EUTERP concentrates on the objectives to strengthen and harmonise education and training, and to facilitate the development of mechanisms of mutual recognition, based on a common approach. EUTERP will be provided with input from the ENETRAP II project. With these results it will: develop guidance on a methodology to compare the quality of training courses and training material; develop guidance on a standardized methodology of assessing the recognition of RP professionals as a basis for future mutual recognition, based on a description of roles and duties, education, training and work experience; develop guidance for a formal recognition process of the competences of RPEs and RPOs. EUTERP aims for being a European body on harmonisation of criteria and qualifications for and mutual recognition of RP professionals.

P07-03

### **Enetrapp II WP5: Develop and apply mechanisms for the evaluation of training material, events and providers**

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To maintain a high level of competency in Europe regarding radiation protection and to facilitate harmonisation and (mutual) recognition of Radiation Protection Experts (RPEs) and Officers (RPOs) quality assurance and quality control might play an important role. The ENETRAPP II project aims at developing European high-quality 'reference standards' and good practices for E&T in RP. In work package 5 (WP5) the quality issue is addressed. Therefore WP5 deals with the development and application of mechanisms for the evaluation of training material, training events and training providers by means of a transparent and objective methodology. The results can be used by regulatory authorities to benchmark their national radiation protection training programme and will be communicated to other networks, e.g. EUTERP. The presentation is about two key tasks in WP 5. The first key task is the development of a comparison method to compare existing training material with existing standards. WP5 has been started with an inventory of topics, items and subjects that need to be addressed in the education and training of the RPE and RPOs. The inventory has started with the subjects addressed in the syllabus EG133, the IAEA syllabus, the European Master's degree in RP syllabus, the existing tables of subjects for E&T in RP and similar tables used in different countries. At the conference a presentation is given about the comparison of an existing training book with EG133, which led to the concept of the first comparison table. The presentation will also address the development of a quality assurance protocol that is another key item in WP5. For the comparison of training providers an inventory will be carried out about the elements of quality assurance. This inventory will take into account requirements by regulations and international standards, e.g. ISO 17024 and topics addressed by stakeholders. A first concept of the elements of quality assurance will be presented at the conference.

P07-04

### **About implementation of EU requirements on education and training**

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The Council Directives require that each Member State shall take the necessary measures with regard to teaching, education and vocational in radiation protection. Moreover, it is foreseen that each Member State shall fulfill the requirements on establishment of an appropriate curricula and recognition system of competences in radiation protection and the undertaking is obliged to provide appropriate radiation protection training and information programmes for their personnel. In order to establish a harmonized framework and to avoid overlapping with national regulation, EU strategy on establishment of a common infrastructure for education and training in radiation protection throughout the European Union should be built. It should be defined the European agreement on the qualifications for training and education and requirements for mutual recognition of the competencies. Following the EU directions, each Member State should revise the national strategy in order to establish the national training needs, the system for credentialing radiation protection programs, national policy on the selection and training of trainers and to comply with the EU mutual recognition system. Participation in EUTERP and ENETRAPP meetings on this subject represents a good opportunity for sustaining these proposals.

P07-05

**European Medical ALARA Network (EMAN): Supporting the ALARA principle in the medical field****Almén, Anja**

Swedish Radiation Safety Authority, SWEDEN

The main objective of this project is to establish a sustainable European Medical ALARA Network (EMAN) where different stakeholders within the medical sector will have the opportunity to discuss and to exchange information on different topics relating to the implementation of the ALARA principle in the medical field. This network will also support the European Commission (EC) in its activities in this field. In addition, EMAN will aim to:

- Disseminate up-to-date information about literature, studies, research and good practices relating to the ALARA principle in the medical sector,
- Identify and communicate to the EC needs for development and update of European Union guidance,
- In particular cover the areas of education and training as well as continuous quality improvement as requested in the Directive 97/43 EURATOM
- Formulate proposals to the EC on harmonization issues,
- Propose to the EC solutions of identified issues at the European level,
- Establish co-operation with appropriate international organizations and associations.

To fulfil these objectives, EMAN will especially rely on:

- Three Working Groups, where three specific topics, all deserving special attention, will be widely discussed by professionals of the medical area: on optimisation of patient and occupational exposures in CT procedures, on optimization of patient and occupational exposure in interventional radiology, on radiological safety for patients and personnel in activities using X-ray equipment outside the X-ray departments,
- A website to widely diffuse the information gathered and the work done by the network and to facilitate the exchange of information within the members of the network,
- A final workshop to present and discuss the work performed in the scope of the network and of the three working groups and to propose recommendations to the EC for improving the optimisation of radiation protection in the medical sector. This contribution will present structure and activities of EMAN

P07-06

**Thinking about stakeholders and safety culture in the ionizing radiation medical field****Téllez de Cepeda, Marina;** Huerga, Carlos; Ordonez, Jorge;

Sende, Jose Antonio; Huertas, Concepción; Serrada,

Antonio; Corredoira, Eva; Plaza, Rafael; Vidal, Jesús

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This work deals with:

1. The need to have a well built radiation protection technical organization not only from de scientific point of view but from that of organization and the stakeholder perception.
2. The importance of knowing how to relate and communicate to: Regulators Organization Directors Exposed and not exposed workers Patients People; media; judges and lawyers.
3. The need to improve and maintain the safety culture.

**Conclusions:**

- A deep built radiation protection organization system maintained and actualized is needed.
- The radiation protection experts must have a continuous training related to technical radiation protection aspects and how to communicate to stakeholders.
- The safety culture must be a part of the quality assurance program with a systematic incidents review and the measures taken to minimized errors.

P07-07

### Better evidence-based quality in radiographic imaging by e-Learning?

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Change from the film/screen radiography imaging systems to digital imaging has brought imaging departments in front of vast challenges in many respects. First of all general guidelines and working models for performing the imaging process with the new technique optimising the radiation dose and image quality of radiographs are needed. The second challenge derived from the first one is to update the competence of the staff working in imaging units and to educate the new health care personnel who are in the middle of their studies to match the needs of the new technique. The project purpose is to increase the competence of staff working in imaging units by evidence based education in digital imaging and dose optimisation according to the principles of ICRP and DIMOND 3 in three Scandinavian countries: Finland, Sweden and Norway. Specific objectives are to:

- Plan and implement Scandinavian evidence-based course plan in digital imaging and dose optimisation and the materials needed on the basis of national and international regulations about the subject in 1st, 2nd and 3rd cycle education degree and life long learning.
- Product materials for the education
- Evaluate the evidence-based course plan in quality of digital imaging and the materials produced.

The project management group consists of radiography lecturers, principal lecturers and physicists of College University of Gjøvik – Norway, Karolinska Institutet – Sweden, University of Oulu – Finland, Oulu University of Applied Sciences – Finland and Helsinki Metropolia University of Applied Sciences – Finland. Also students of these organizations are involved in the project from very beginning. The project has been planned to be realized between autumn 2008 and spring 2011. In the presentation the main results of the project till summer 2010 are presented.

P07-08

### Monte Carlo based PCXMC-program as a tool of learning dose optimisation in plain radiography

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**Introduction:** Effective dose can be defined for X-rays as the sum of the weighted average absorbed doses in all the tissues and organs of the body. ICRP has produced a list of tissue weighting factors for a number of organs and tissues. The calculation of effective dose is based on the Monte Carlo technique described in NRPB-R186 or direct organ dose measurements. PCXMC is a widespread and well tested Monte Carlo program for calculating patients' organ doses and the effective dose in medical X-ray examinations. The anatomical data is based on the mathematical hermaphrodite phantom models of Cristy, which describe patients of six different ages: newborn, 1, 5, 10, 15 -year-old and adult patients.

**Material and methods:** The PCXMC program is introduced to students by 2 hours lesson. After that the students practice by themselves to calculate the doses according the given examples. They calculate first dose to an adult person. After that only one parameter at time is changed. Students evaluate the effect of change to whole body dose and organ doses organ by organ. The changed parameters are: kV, filtration, field size, projection (ap /pa), age and focus to skin distance.

**Results:** Students have found very useful to analyse the doses. E.g. in chest ap / pa it is easy to find the benefit in pa projection both in organ doses and as a whole body dose. PCXMC evaluates also the risk to the patient due the x-ray examination. It is amazing to find out how small changes can effect so much to the patient's dose.

**Conclusion:** The students have found out the benefits of PCXMC in dose optimisation. It is easy to point out, what kind of changes have to be done and how much the changes help to decrease the dose. Also the meaning of critical organs clarifies. Students analyse their findings and compare them to the results of scientific articles published during the last years.

P07-09

**Radiation protection of the staff in operating theatres****Henner, Anja**

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**Purpose:** The universal features of the safety culture are individual awareness of the importance of safety, knowledge of competence, commitment, motivation, supervision and responsibility. In Finland nurses and medical doctors are allowed to use the c-arm in operating theatres and emergency rooms. The purpose of this study is to point the key factors affecting to the radiation protection and safe use of mobile c-arm in operating theatres and emergency.

**Methods and materials:** About 40 courses (1,5 ects) concerning the safe use of mobile c-arms have been given to nursing staff all over Finland. The course consist of 5 areas given in EU legislation: Fundamentals of Radiation Physics and Radiation Biology, Radiation Protection Provisions, Radiation Safety Measures at the Workplace and Procedures Involving Exposure to radiation. In demonstration all features of that c-arm are shown step by step. In the end of the course there is a written exam and more than 1300 answers have been analysed for this research.

**Results:** About 80% of the participants passed the test in first exam and only 1% needed third exam. Mostly participants are nurses but also some medical doctors and other staff. According to this study the most difficult areas are the basic concepts: radiation and it's features, effects of radiation at the molecular, cellular and tissue levels, deterministic and stochastic effects of radiation and their identification, radiation user's organization, dose motoring and categories A and B and what they mean in everyday work, controlled and supervised areas and monitoring of radiation exposure of workers. The operational radiation protection is quite well known.

**Conclusion:** During the courses there has been discussion about factors influencing the interpretation of fluoroscopic images procedures exposing children and pregnant women to radiation. The nursing staff is very willing to involve to good safety culture. More hands on training is needed to the nursing staff.

P07-10

**Radiation protection training in the Joint Research Centre of Ispra****Giuffrida, Daniele<sup>1</sup>; Vanetti, Silvia<sup>1</sup>; Osimani, Celso<sup>2</sup>**<sup>1</sup>Joint Research Centre, Ispra, European Commission, Radiation Protection Sector, ITALY; <sup>2</sup>Joint Research Centre, Ispra, European Commission, Nuclear Decommissioning Unit, ITALY

The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, in order to steer European research on nuclear industry. It hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in past years, namely: two research nuclear reactors, hot cells facilities, radiochemical laboratories, one Cyclotron (still in operation), facilities for studies on fissile material (in operation), and some facilities for the treatment and storage of liquid and solid waste (in operation). The JRC accounts for 21 nuclear licences, 14 Controlled Zones and 12 main Surveilled Zones, on its Ispra Site. The Radiation Protection Sector has developed, during the last years, a new approach for training in Radiation Protection: this includes an improvement and extension of the traditional classroom-based training to Exposed Workers, and:

1. the generation of new training modules on radiation and radiation risks, specifically addressed to non-exposed Personnel;
2. on-the-job training to newcomers and Radiation Protection Officers;
3. development and operation of mock-up facilities for specialized training (glove boxes, high contamination areas, etc.).

Evaluation of training effectiveness has also been modified and enhanced. Moreover, the need for a more comprehensive set of "education and training" actions in the field of Radiation Protection is becoming a priority, in Italy, due to the reduced availability of competent Technicians in the Radiation Protection market. The JRC-Ispra is currently studying the possibility to re-evaluate its training offer to the market, in order to further improve, according to its mission, the dissemination of technical and scientific knowledge in this field.

P07-11

### Teaching of radiation protection in Estonia and use of web tools

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After regaining independence the first radiation protection courses were taught at the University of Tartu. These were addressed mostly to the students of environmental physics. During the following years the scope has widened and at present the topics covered at the university are addressed for several specialities. From late nineties a radiation protection course is taught also in the Türi colleague of the University of Tartu, where many environmental specialists are educated. Taking into account that in Türi lecturers usually are available only during the lecture course, it was decided to develop a web-based tool to have a better interaction with students and to provide the learning environment with additional information. This web-based course was finished in 2009 and is available for students. For a decade there have been courses available for the users of radiation sources. Most of the first courses have been organized in the framework of international co-operation projects, but later the courses have been presented by local trainers. whereat present, basic radiation protection education for the operators is provided by local experts. The Radiation Safety Department of Environmental Board facilitates translation and publication of several radiation protection related publications and uses its web pages as tools for providing the corresponding information. Taking into account that in the accepted energy policy of Estonia the development of nuclear option is listed as one of the possible future scenarios, there is a great need for education in nuclear safety. University of Tartu and Tallinn Technology University will start the preparation of the master course on nuclear safety. The first students are supposed to be admitted in autumn 2011.

P07-12

### Radiation protection education and training activities at the Belgian Nuclear Research Centre SCK•CEN

Coeck, Michèle

SCK•CEN, BELGIUM

The scientific world of radiological protection (RP) is in constant motion, triggered by new research as well as by developments and events in the daily industrial and medical sectors. In addition, national and international regulatory policies try to streamline and guide daily practice along procedures that guarantee the protection of workers and public and that at the same time also ensure optimisation of all peaceful uses of applications of radioactivity. Harmonisation and coordination are in this sense of utmost importance, also with regard to education and training (E&T). Within this spirit, the international school for Radiological Protection (isRP) of SCK•CEN organises courses on a wide variety of RP topics and aims to play a role in relevant national and international policy. Our activities are situated on three tracks:

1. Coordination and organisation of E&T programmes: isRP activities deal with all aspects of RP and are directed to the private, medical and industrial nuclear sector, national and international policy organisations, the political and academic world and the general public. Courses are also organised in cooperation with academic and other institutes.
2. Research on transdisciplinary aspects of E&T: Understanding the benefits and risks of radioactivity requires technical insight and training, but also notice of the context and a sense for the social and philosophical aspects of the situation. The research of isRP concentrates on how to integrate this transdisciplinary approach in E&T programmes for professionals, students and pupils.
3. Policy support with regard to applied E&T on a national and international level: The implementation of a coherent approach to E&T in RP becomes crucial in a world of dynamic markets and increasing workers' mobility. Through networking and participation in international programmes, isRP contributes to a better harmonisation of education, training practice and skills recognition on a national and international level.

P07-13

**Nuclear Training Centre experience in radiation protection culture****Avadanei, Niculina Camelia<sup>1</sup>; Rosca Fartat, Gabriela<sup>2</sup>; Grigorescu, Enric Leon<sup>1</sup>**<sup>1</sup>"Horia Hulubei" National Institute of Physics and Nuclear Engineering, Nuclear Training Centre, ROMANIA; <sup>2</sup>Romanian Radiation Protection Society, ROMANIA

This paper aims to present Nuclear Training Centre (CPSDN) Romanian experience in education and training in order to achieve the required competences in radiation protection with a view to future recognition within the EU countries.

Carrying further education and training activity started with almost 50 years ago by the Institute of Atomic Physics and University of Bucharest-Faculty of Mathematics and Physics, CPSDN organized over 750 programs and trained more than 18500 participants.

For each of these programs, CPSDN take into account the following objectives:

- provide adequate training for workers, for radiation safety officers and specialists
- comply with the authorities regulatory requirements
- develop syllabus for general education, specialized training courses and upgrading programs in compliance with CE RP 116 and IAEA recommendations for the groups of professionals that have been identified
- contribute to the national radiation protection infrastructure
- establish the necessary mechanism and to provide appropriate administrative support, qualified and experienced trainers, practical demonstrations and exercises
- cooperate with national organizations developing activities in the field, for example the Romanian Radiation Protection Society, University of Physics, research institutes, main stakeholders.

Being concern by the continuously improvement of its services, CPSDN applied for TUV-CERT certification for the quality management system according to ISO 9001/2000, in 2007.

P07-14

**ENVIRAD-SPLASH: The study of the radon to understand the radioactivity and to know the environment****De Cicco, Filomena<sup>1</sup>; Balzano, Emilio<sup>2</sup>; Di Liberto, Francesco<sup>2</sup>; Pugliese, Mariagabriella<sup>2</sup>; Roca, Vincenzo<sup>2</sup>; Sabbarese, Carlo<sup>3</sup>**<sup>1</sup>Seconda Università di Napoli and INFN, ITALY; <sup>2</sup>Università di Napoli Federico II and INFN, Scienze Fisiche, ITALY; <sup>3</sup>Seconda Università di Napoli and INFN, Scienze Ambientali, ITALY

The work describes the collaboration among many Italian research groups that pursue since seven years the objectives to make students of secondary schools aware of the problematic of the radioactivity and of the ionising radiations, introducing them, when possible, in real research activities. For reach this goal, many approaches were adopted around the main path starting with the measurement of indoor radon concentrations and continuing considering most complex themes. The project obtained very good results from many points of view, and each year many schools that carried out their activity want to insert in the experience new students and new schools joined to the project. This implied a continuous increase of the students that approach themselves these problems and, through this contact, the world of the research and of the university; Meetings and conferences have been regularly organized, in which the students communicate to a wide public their experience; and often students, teacher or researcher are invited in several contexts to describe the developed activity. Year by year the number of proven techniques increased and from the indoor measurements carried out with passive techniques, it has been passed to the dose measurements, to the analysis of materials, to the comparison of more techniques, to the use of active instrumentation which is often home made. Starting from 2008, the study of the artificial radioactivity in environmental samples, originated by radioactive fallout, began. These results were possible thanks to the commitment of research groups involved. A further increase of the schools involved would entail too great an effort to sustain. To avoid that, are being prepared various kinds of materials that can help schools continue to use this useful method of investigation of science topics, usually treated just in schools, but by shifting the focus of the operation on them.

P07-15

**Rn-222 concentration measurements at Italian schools: a way to educate, train and disseminate radiation protection culture among young students****Groppi, Flavia<sup>1</sup>; Manenti, Simone<sup>1</sup>; Gini, Luigi<sup>2</sup>; Bazzocchi, Anna<sup>3</sup>; Bonardi, Mauro L.<sup>1</sup>**

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In Italy the "nuclear issue" was for a long time a taboo. A lack of information will lead to unwarranted fears, which will distort the risks we take in everyday life. In other words the subjective perception (sensation) of the risk doesn't correspond very often to the objective and real risk of human activity. In particular, our perception of radioactivity is often misleading because of the lack of accurate information. A way to approach this theme to make the public more trusting of nuclear issues is to discuss radioactivity and ionizing radiation starting from young students. An experimental activity that involves secondary school students has been developed. The approach is to have students engaged in activities that will allow them to understand how natural radioactivity is a part of our everyday environment.

On this basis started a project that gave students and teachers of the Italian secondary school system the opportunity to discuss and to experiment with nuclear related experiences. The students were provided basic but correct information and with the added benefit of being able to experiment. The core idea is that: a) to provide the students a furnished laboratory at their school so that they can measure the natural component of the radioactivity that surround us. In this exercise the measurement of the <sup>222</sup>Rn concentration is particularly well suited b) to show the different types of radiations including ionizing radiations and how they each relate to the other; c) to demonstrate how easily ionizing radiations can be measured; d) and to prove the fun a student can derive from discovery and detection of ionizing radiation in the environment.

One other interesting outcome has been that the measurements have been made in accordance to Italian radiation protection law. Therefore, the data collected could be used to determine the radon concentration mapping of the school buildings.

P07-16

**RadiaX – Radiac simulation for first responders****Gårdestig, Magnus; Halse, Tore; Pettersson, Håkan**  
Linköping University, Department of Medical and Health Sciences, Radiation Physics, SWEDEN

A computer-game has been developed to help train first responders to correctly and efficiently handle situations involving radiation. This virtually eliminates the need for expensive and time-consuming exercises, while providing a safe, versatile environment and immediate feedback. This feedback is difficult to accomplish in traditional training and is consequently often neglected or incomplete. In addition, a computer simulation allows for more accessibility, adaptability and reproducibility than what any physical training facility can offer, especially with a limited budget.

The game is a modification of an existing computer game of the type "first-person shooter". The game simulates existing radiation intensimeters and a variety of radiation sources. Introductory exercises educate the gamer/trainee on the functionality and properties of different instruments as well as on basic radiation physics, e.g., the inverse-square law and shielding. Alarm levels and their sounds are authentically reproduced, which is not a likely option in real life exercises for safety reasons. Environments are constructed to simulate different scenarios; urban, rural, indoors and outdoors. Radiation sources of various isotopes and activity are placed at desired locations according to chosen scenarios or simulated actual events. This can complement actual exercises given to first responders. Radiation measurement is found well suited for simulation since no tactile simulation is needed. The focus is on achieving high fidelity of the instruments and their response to radiation fields.

The game can easily be widely distributed to the individual first responder, thus eliminating the need for various levels of instructors. The target groups are fire fighters, police forces, customs staff, medical personnel as well as radiation protection experts. The game can serve both as an educational tool for classes in radiation protection and for debriefing when recapitulating real incidents.

P07-17

**Radiological emergency exercises facing the collaboration issue between different response authorities**Östlund, Karl<sup>1</sup>; Finck, Robert<sup>2</sup>; Samuelsson, Christer<sup>1</sup><sup>1</sup>Lund University, Medical Radiation Physics, SWEDEN; <sup>2</sup>Swedish Radiation Safety Authority, Dept. of Radiation Protection, SWEDEN

In Sweden, two large radiation emergency exercises with international participation were held in 2001 (Barents Rescue) and in 2006 (DEMOEX). Experiences from these exercises showed that conducting “close reality” emergency situations utilizing real radioactive sources was very valuable in the training of radiation experts and first responders. In the years 2007 – 2009 this concept of combined training was further developed in a set of smaller-scale exercises called Lärmät. The concept was to break down the large scale scenarios to pieces and learn its radiation protection difficulties in detail. This showed to be a successful and appreciated way of conducting exercises for Swedish specialists. The radiation specialist, however, will never have free hands to handle the situation in case of a malevolent act involving radioactive material. The situation would involve combined actions of several authorities. Therefore, Sweden’s combined radiological emergency response has an urgent need for exercises where authorities work closely together across authority borders. This issue was specially addressed in the exercise Lärmät 09. Teams were put together from radiation protection specialists, rescue services, police, the National Laboratory of Forensic Science, The National Board of Health and Welfare and the Swedish Customs. The idea was to let people from each profession present their view (in each different scenario) of the situation in order to solve it safe and not destroying potential evidence. In Lärmät 09 six different scenarios were built with real sources and inspired from real radiation accidents. The radiation doses to the participants were kept low by radiation protection planning and technical arrangements. This paper presents the Lärmät 09 scenarios and lessons learned from this joint “close reality” exercise.

P07-18

**New education technique using radiation sources fabricated from chemical fertilizers**Kawano, Takao

National Institute for Fusion Science, JAPAN

Many materials on the Earth contain naturally occurring radioisotopes such as  $^{40}\text{K}$ ,  $^{232}\text{Th}$ , and  $^{238}\text{U}$ . It is inenarrable that people living in the world are irradiated at every moment with natural radiations emitted from the materials. However there are many people who do not know the existence of naturally occurring radioisotopes and radiations. Consequently, appropriate radiation education must be very important. Chemical fertilizers containing potassium are often used in educational courses on radiation. Because, naturally occurring potassium consist of three isotopes:  $^{39}\text{K}$ ,  $^{40}\text{K}$ , and  $^{41}\text{K}$ , and  $^{40}\text{K}$  emits a 1.33 MeV beta particle and a 1.46 MeV gamma ray. In our previous study, a compression and formation method was developed and applied for fabricating disk-shaped radiation sources from commercially available chemical fertilizers. It was found that thus fabricated radiation sources (fertilizer radiation sources) were effective educational tools. In the present study, a new education technique was developed using radiation sources fabricated from several brands of chemical fertilizers with different component fraction. A relationship between the radiation count rates of the fertilizer radiation sources and the potassium fractions of the fertilizers was examined and found to be linear, meaning the radiation count rates directly depended on the potassium fractions. It is concluded that this education technique using several fertilizer radiation sources is useful to understand that the substance emitting radiations in chemical fertilizers is potassium-40. It is also found that the radiation sources fabricated with chemical fertilizers can be safely and easily handled in educational radiation courses.

P07-19

**Organisation of pilot modules of the newly developed European Radiation Protection Training Scheme ERPTS**Moebius, Siegard

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The ENETRAP II Project (European Network on Education and Training in Radiation Protection) aims at harmonizing the Education and Training in Radiological Protection RP e.g. by reaching harmonization of the requirements of RP experts and officers within Europe. These "Reference Standards will reflect the needs of the RPE and the RPO in all sectors where ionising radiation is applied. Therefore a remodelled modular European Radiation Protection Course has been developed in the ENETRAP first phase project. One major goal of the present project is to monitor the effectiveness of the proposed methodologies by organising pilot sessions of selected training events within Work package 8. The courses are designed for radiation protection professionals such as Radiation Protection Experts (RPE) and Radiation Protection Officers (RPO) according to the agreed standards and include On-the-Job OJT Training as key element. Domains to be chosen are occupational radiation protection in Nuclear Power Plants, Radioisotope Training in Non-nuclear industry and Research, and Specificities of Waste Management and Decommissioning. In this paper the outcome of the pilot sessions as far as available is evaluated and the results summarised. Preliminary improvements are recommended for further performance.

S08-01

**Work management to optimise occupational radiological protection at nuclear power plants**

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The operation and maintenance of nuclear power plants imply the occupational exposure of workers. Experience has shown that the optimisation of occupational radiation protection necessitates a coherent and comprehensive work management approach. This approach stresses the importance of managing jobs completely from planning to follow-up using a multi-disciplinary team approach which involves all relevant stakeholders. In order to provide guidance to the nuclear community on the best practices of work management, the Information System on Occupational Exposure (ISOE), sponsored by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, established an international expert working group to update a report on this topic, previously issued in 1997. This recognises that while work management is no longer a new concept, continued efforts are needed to ensure that good performance, outcomes and trends are maintained in the face of current and future challenges. The report, "Work Management to Optimise Occupational Radiological Protection at Nuclear Power Plants", was published in 2009. It provides practical guidance based on the operational experience within the ISOE programme in the key areas of work management to optimise occupational radiation protection, including:

- Regulatory aspects;
- ALARA management policy;
- Worker involvement and performance;
- Work planning and scheduling;
- Work preparation;
- Work implementation;
- Work assessment and feedback; and
- Ensuring continuous improvement.

The specific aspects of work management applicable to each of these areas are illustrated by practical examples and case studies arising from ISOE experience. The objective of the paper is to summarize and describe the key messages of the report.

S08-02

**Challenges on the radiation protection optimization of medical staff in interventional radiology and nuclear medicine: the ORAMED project**

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The development of an up-to-date radiation protection system for medical staff working with radiations requires data on field (type of radiation, energies, scattering materials...), exposure (time, activities, position of operator...) and protective devices (barriers, glasses, gloves and aprons) which are only partially available in the radiation protection routine practice. Local high exposures in interventional radiology (IR) and nuclear medicine (NM) are due to the closeness of medical staff to the direct and scattered field, in the first case, and to the direct handling of radionuclides, in the second. Many studies in IR have shown that the doses can vary a lot, even for the same type of procedure. The routine monitoring of the extremities (hands, forearms and legs) is difficult to be performed thus only data for whole body, fingers and wrists are reported. Moreover, eye lens dose is rarely estimated, even if there is some evidence that cataract is an increasing effect in exposed population. In NM the main topic is the skin dose, but is generally unknown which part of the hand receives highest doses and which is the dose distribution in the hand itself. Indeed, the use of unsealed sources with high activities and beta emitters in therapeutic NM can worsen the situation for the involved personnel. These aspects are studied within the ORAMED (Optimization of Radiation protection of MEDical staff) project, funded by EU-EURATOM FP7, studies in which a series of European laboratories and hospitals participate. The project is subdivided in 5 work packages: extremity and eye lens dosimetry in IR and cardiology (WP1); development of practical eye lens dosimetry in IR (WP2); optimisation of the use of active personal dosimeters in IR (WP3); extremity dosimetry in NM (WP4); and training and dissemination (WP5). In the present work the state of the art of the main tasks performed in WP1, WP2 and WP4 is briefly summarized.

S08-03

**Increased extremity doses for staff in the preparation and administration of beta-emitters and PET nuclides in nuclear medicine****Stritt, Nicolas; Linder, Reto-Peter**

Swiss Federal Office of Public Health, Division of Radiological Protection, SWITZERLAND

Due to the continuous increase in extremity doses in nuclear medicine departments, the Swiss Federal Office of Public Health (SFOPH), in its capacity as the supervisory and regulatory authority dealing with ionising radiation, has investigated the reasons for this and introduced measures aimed at their reduction. Since the mid-90s, the SFOPH has observed a continuous increase in extremity doses of persons occupationally exposed to radiation in nuclear medicine departments. Whereas only a few persons in the 50 facilities had accumulated an extremity dose greater than 25mSv/year in 1996, ten years later there were almost 10 times more. This development was all the more worrying because it is assumed that the extremity dosimeters used actually record only a fraction of the extremity dose effectively accumulated, especially when dealing with beta-emitters. In facilities with high patient throughput and frequent therapeutic uses, it is therefore possible that the dose limit (500mSv/y) is occasionally exceeded. The SFOPH looked into this radiation protection problem and since 2006 has undertaken audits in the relevant nuclear medicine departments to determine the reasons for the increased extremity doses, to optimise doses as far as possible and to order corresponding actions. It was established that there is considerable optimisation potential not only in the preparation of radiopharmaceuticals but also in their application, such that a marked reduction of extremity doses is possible. However, this partly depends on investment in systems, which automate dose-intensive manipulations, such as the loading and activity determination of injection syringes or even the injection into patients. When staff are aware that even a brief manipulation with unscreened therapeutic doses could result in high extremity doses, they generally use the shielding aids more conscientiously and adopt work plans and procedures that optimise radiation protection.

S08-04

**Morphological dependence of lung counting efficiency for female workers****Farah, Jad; Broggio, David; Franck, Didier**

IRSN, Internal Dosimetry Department, FRANCE

*In vivo* lung monitoring of female workers is routinely performed using calibration coefficients calculated with a male thoracic mannequin since no female model exists. More appropriate calibration coefficients can be obtained using numerical models. In this work, flexible 3D Mesh and NURBS (Non Uniform Rational B-Splines) geometries were considered to design representative female thorax. Lung counting efficiencies were simulated for typical germanium detectors and the parameters of their morphological dependence were defined. A library of 24 different 3D female models was created representing the most common female morphologies with various cup sizes (A to F) and chest girths (85 to 120). Monte Carlo simulations were then achieved to investigate the chest girth and cup size effects on the counting efficiency. It was shown that for the 59.54 keV Am-241 gamma ray, the counting efficiency decreases of about 15% between the 85A and the 85B phantoms. Moreover, a 55 fold decrease in efficiency was observed at 22 keV between the 120C and the 85C phantoms. An equation was developed, involving simple physics assumptions, which defines any counting efficiency as a function of chest girth, cup size and a reference efficiency curve. Morphology-dependent parameters were obtained enabling the transformation from the reference efficiency to a given morphology efficiency. Furthermore, the developed equation was able to describe the relation between the calculated female efficiency and the Livermore calibration data. It was found that the simulated 85A efficiency curve is in close agreement with the calibration measurements performed with the Livermore and its first extra-thoracic plate. Since this agreement depends notably on the chosen counting position for females, it was also shown how to transform calibration measurements performed with other thoracic plates. This work enables a better assessment of the *in vivo* calibration coefficients improving the female workers monitoring.

S08-05

**ALARA-Education for Personnel Involved in the Plant Modification Process**Nilsson, Virva

Forsmark Kraftgrupp AB, Vattenfall, SWEDEN

In order to achieve optimal worker protection at a nuclear power plant the radiological protection aspects should be considered in an early stage of the plant modification process. It is of utter importance that staff involved in the planning of and in the plant modification process itself is well informed on how the ALARA-principle can be applied. Today no specific ALARA-education exists for the staff involved in these tasks. A development of suitable education and information material for the personnel in question has been initiated at Forsmark NPP.

The work to develop an education package "ALARA for Personnel Involved in the Plant Modification Process" has been started by assessing the present level of knowledge and understanding as well as the need and interest for education. An enquiry was sent out to the department managers involved in plant modification process to spread in their organizations.

The percentage of received answers was less than 15% of the number of personnel involved in these tasks. This clearly indicates that the ALARA-principle has not been among the highest priorities in this area. About 50% of the personnel that answered the enquiry were interested in obtaining more knowledge and practical examples on how to apply the ALARA-principle early in the planning stage of plant modifications.

There is an interest and demand for more knowledge in the area but only among a limited group of the personnel. Our goal is to make ALARA-principle more commonly known and to make it an every-day tool used in all the possible steps in the plant modification process.

S08-06

**Reduction of dose around a storage pool by changing the position of BWR irradiated control rods**Rodenas, Jose; Abarca, Agustin; Gallardo, Sergio

Polytechnic University of Valencia, Department of Chemical and Nuclear Engineering, SPAIN

BWR control rods are irradiated into the reactor by the neutron flux and consequently activation reactions are produced in the materials composing the rod mainly in stainless steel and its impurities. The dose produced by this activity is not important inside the reactor, but it has to be taken into account when the rod is withdrawn from the reactor and stored into the storage pool for irradiated fuel of the plant at a certain depth under water. The neutron activation has been modeled with the MCNP5 code [1], based on the Monte Carlo (MC) method. The pool containing hanger devices with irradiated control rods has been also modeled with the MCNP5 code. Doses potentially received by plant workers in the area surrounding the pool edges as well as in a platform moving over the water surface have been also calculated with the same MC code. In previous works [2, 3, 4], all these models have been validated. Results of the activation model proved that the rod handle is the most irradiated part of the control rod. Inverting the position of the rod into the storage pool with the handle at a deeper position under water should be a suitable method to reduce the dose out of the pool. In this work, the MC models are applied to verify the expected reduction of dose when the irradiated control rod is hanged in an inverted position into the pool.

1. X-5 Monte Carlo Team, *MCNP5 A General Monte Carlo N-Particle Transport Code*, Los Alamos National Laboratory, 2005.
2. J. Rodenas, et al., *Estimation of the activity generated by neutron activation in control rods of a BWR*. *Appl. Radiat. Isotopes* (2009).
3. J. Rodenas, et al., *Analysis of the dose rate produced by control rods discharged from a BWR into the irradiated fuel pool*, *Appl. Radiat. Isotopes* (2009).
4. J. Rodenas, J., et al., *Validation of the Monte Carlo model developed to assess the activity generated in control rods of a BWR*, *Nucl. Instr. And Meth. A* (2009).

S08-07

**Periodic review and update of the company ALARA program – Continuous improvement in the field of radiation protection**

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Forsmarks Kraftgrupp AB, Safety and Environment  
– Radiological Safety, SWEDEN

The presentation will show how continuous improvement in the field of radiation protection may be achieved by actively follow up the results from the existing company ALARA program at Forsmark NPP and depending on this updating the program for the next period. Our ALARA-program consists of the following parts:

- Collective and individual doses to the personnel
- Releases of radioactive substances to the environment
- Organizational acceptance of the ALARA principle.

By trending and monitor performance it is possible to focus on the most significant areas. In the presentation examples will be given from Forsmark NPP in all of the above mentioned areas.

S08-08

**ISEMIR: a new international system for improving occupational radiation protection in medicine, industry and research.**

**Lefaire, Christian<sup>1</sup>; Le Heron, John<sup>2</sup>; Czarwinski, Renate<sup>2</sup>; Van Sonsbeeck, Richard<sup>3</sup>; Padovani, Renato<sup>4</sup>**

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The Information System on Occupational Exposure in the Medicine, Industry and Research (ISEMIR) was set up by the IAEA in January 2009 to focus on very specific topical areas where radiological protection stakes for the workers are not trivial, and where there are still pending issues and deficiencies. The first two selected areas are:

- Interventional cardiology, and
- Industrial radiography.

2009–2011 is a test period for checking the ability of the system to cope with its main objectives, as stated in its terms of reference: “To help to improve radiation protection programmes in medicine, industry and research, and in particular:

- To facilitate the implementation of ALARA practices and effective exposure management;
- To internationally benchmark specific task-related occupational exposures in order to identify good practices as well as gaps; and
- To define follow up actions to address identified gaps and disseminate lessons learnt; To contribute to minimizing the likelihood of accidents, e.g. by identifying pre-cursors, user feedback and experience.”

This presentation will present the organisation of the system (advisory group, secretariat, working groups) and the first one and half years of experience. In particular it will describe what the Working Group on Interventional Cardiology, which will have already met three times, has performed and achieved, including the results of 3 simple questionnaires dealing with radiation protection practices and occupational exposures addressed to individual interventional cardiologists, chief interventional cardiologists, and radiation protection regulatory bodies. A total of 329 responses from 75 countries were received across the 3 surveys. Finally the complementarities and relationships with other international systems (e.g. UNSCEAR and ISOE) and networks (such as ALARA networks) will be addressed.

S08-09

**Problems of the radiation protection and health effects monitoring in Ukrainian radiation workers****Bebeshko, Vladimir<sup>1</sup>; Bazyka, Dimitry<sup>1</sup>; Likhtarev, Ilya<sup>1</sup>; Gaevaya, Liudmila<sup>2</sup>; Chumak, Vadim<sup>1</sup>**<sup>1</sup>Research Center for Radiation Medicine, UKRAINE;<sup>2</sup>ENERGOATOM National Energy Generating Company, UKRAINE

Nuclear energy sector in Ukraine includes 50,000 workers of the 15 power and research units, uranium mines, radioactive waste storages, staff of the Chernobyl zone and the "Shelter" object. Creation of a centralized registry with dosimetry and health data is essential and such understanding exists at the governmental and local levels. However, de facto this work is initiated slowly due to lack of budgetary funding. An analysis was performed of the existing sources of health and dosimetry data information. Two surveys defined the general status of dosimetry monitoring and number of occupationally exposed workers. The local data sources will be used including individual data from the local medical-sanitary departments, dosimetry shops and regional registries for radiologists. Cancer statistics of sufficient quality of case identification and pathological data could be obtained by linkage from the National cancer registry. The extended health data and dosimetry including external irradiation and transuranium elements are available for staff of the "Shelter" object at the RCRM. The existing experience of French and other international registries as well as of the State registry of exposed after Chernobyl, the Clinical-epidemiological registry, and dosimetry databases gained in the Research Center for Radiation Medicine from the prospective follow-up studies could help for practical implementation of the nuclear workers registry. Several tasks are foreseen that could be successfully implemented with international cooperation: a survey of professions, types of jobs and radiation qualities; development of qualification criteria and accreditation procedures for personal dosimetry services; pilot study of medical registry of occupationally exposed workers. Establishment of a new multi-thousand cohort for both prospective and retrospective biomedical and epidemiological studies will allow more precise estimated of the low dose effects of ionizing radiation.

P08-01

**EPR: Comparative approach of the French and Finnish instructions and optimization of radiation-protection at the design phase**

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Taking the opportunity of evaluating the preliminary safety report concerning EPR (the French advanced PWR) in France, the IRSN proposes to make a point focusing on the radiation-protection aspects. The overall picture drawn in this occasion is dedicated to remind the history of EPR, to compare French and Finnish safety evaluation systems (links between authorities and technical support organizations), to present the dose targets (calculated reference doses) planned by the nuclear operators in the design phase as well as the global radiation-protection optimization process. In France, for example, EDF performed a detailed optimization analysis on selected tasks known to have a major contribution to the annual average collective dose (thermal insulation, logistics, valve-maintenance, opening/closing of the vessel, preparation and checks of steam generators, on-site spent fuel management and waste management). The optimization process is set in France on an iterative method. In Finland the optimization of annual collective dose has to be described in a separate topical report. In every phase of system descriptions the RP aspects have to be taken in account to meet the requirement stated in specific regulatory guides. A comparison between the EPR collective dose target and doses received on other pressurized water reactors that are close to the EPR design (Konvoi of German design, “best French units”,...) is also presented. This synthesis is realized in association with the various French partners, i.e. the operator (EDF) and the expert body (IRSN), and the authority of nuclear safety in Finland (STUK). It allows to summarize 15 years of partnership and studies, focusing on radiation-protection, in the design phase of the EPR.

P08-02

**Individual monitoring for external exposure during the transportations of nuclear fuel bundles at nuclear fuel plant pitesti**

Ivana, Tiberiu; Epure, Gheorghe

Nuclear Fuel Plant, Nuclear Safety, ROMANIA

Nuclear Fuel Plant (FCN) is a facility that produces nuclear fuel bundles CANDU-6 type for CANDU nuclear power plant based on natural and depleted uranium. The transportation of nuclear fuel bundles from FCN to Cernavoda Nuclear Power Plant is performed by FCN authorised trucks (about 340 km between the two locations). FCN has the activity of transportation and the vehicles authorised by Romanian regulatory body National Commission for Nuclear Activities Control (CNCAN). In addition each transfer of nuclear material is authorised by CNCAN. About 15 nuclear fuel transportations were performed in year (20 wooden crates with 720 nuclear fuel bundles, containing 15 tons of natural uranium dioxide corresponding with 14 tons of natural uranium). From 1996 until now 120 transportations of nuclear fuel bundles were occurring. A crew is trained and authorised for these kinds of activities. The components of crew are monitored everytime for external exposure. Different type of instrumentations was used for conforming with radioprotection programme of transportation of radioactive material national and international norms. The doses registered are reported each year to CNCAN. Compared with the registration level (RL) of doses imposed by CNCAN norms, the doses received during transportation don't exceed this value. Starting with 2009 each occupationally worker is monitored with TLD and electronic devices. Due that the workers from the transportation crew are exposed to the ionising radiations category A, the annually estimated dose that can be received is around 6 mSv per year. Nobody of participants to the transportation of nuclear fuel bundles reach this value during 14 years of activity.

P08-03

### Six years of radiation protection of operators in the General Electric FDG-radiopharmaceutical facility at the Joint Research Centre in Ispra

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The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, in order to steer European research on nuclear industry. It currently hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in past years or are currently being decommissioned. Since 2003, a Radiopharmaceutical facility has been set up in JRC Cyclotron Laboratory, in collaboration with General Electric Healthcare, for the production and commercialization of (18F) FDG. This Radiopharmaceutical Laboratory has been the first FDG production facility to be officially authorized by the Italian Health Ministry and has been operating since 2003 without any interruption. The paper is a review of Radiation Protection activities performed in the Laboratory during its 6 years of operation: issues and outcomes in workers' Radiation Protection will be reviewed, annual doses to the Laboratory Operators and their optimization throughout the life of the facility, set-up and modification of internal standard operating procedures, as well as the evaluation of internal and extremity doses will be discussed. During these years, some upgrades in the capacity and maximum activity produced by the Lab have been studied and performed. Two irradiation lines (out of the 7 existing) and one complete irradiation vault (out of three) have been devoted to FDG production during the years, offering some testing and backup possibilities. A review of Radiation Protection in the production and transfer of F-18, which has remained a sole responsibility of JRC-Ispra, and the major issues in target-related Radiation Protection will also be included.

P08-04

### Radiation protection organization in the Joint Research Centre of Ispra

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The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, in order to steer European research on nuclear industry. It hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in past years, namely: two research nuclear reactors, hot cells facilities, radiochemical laboratories, one Cyclotron (still in operation), facilities for studies on fissile material (in operation), and some facilities for the treatment and storage of liquid and solid waste (in operation). The JRC accounts for 21 nuclear licences, 14 Controlled Zones and 12 main Surveilled Zones, on its Ispra Site. This paper will discuss the organization which has been developed, during the years, and put in place to guarantee maximum safety in all radiation work activities at the JRC-Ispra: the Radiation Protection Sector -which belongs to the "Nuclear Decommissioning Unit"-, the Radiation Protection Assistance Contract, and the role of Consultants and other External Contractors. The internal work authorisation processes, together with the work activities' preparation, assistance and reporting will be discussed: methods for the internal dissemination of experience and good practices will be reviewed. Some Laboratories give internal services to the Radiation Protection Sector: the Dosimetry Laboratory, the Whole Body Count Laboratory, the instruments' Calibration Laboratory, the Electronics Laboratory: their roles and functions will be presented. The Medical Service and the Radiotoxicological Laboratory give external support to the Sector: their role will be discussed. Emergency preparedness and response at the JRC will be reviewed, with emphasis on internal Emergency Squads training and integration. A brief outline of Radiation Protection permanent training organization at the JRC, and a summary of Radiation Protection archival methods will also be presented.

P08-05

### Support service of radiation protection in JRC ISPRA (Italy) using the methodology applied in Spanish nuclear power plants

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<sup>3</sup>IBERINCO, SPAIN

In the Joint Research Centre (JRC) of Ispra (Italy), there are different nuclear facilities, which are most shutdown and in a pre-decommissioning phase:

- Experimental dismantling reactors
- Research facilities to be dismantled o Hazardous Liquid Waste Treatment Area
- Waste Storage and Decontamination Area
- Cyclotron, for F-18 production (still in use).

Since 2006, a Service Provider Company (LAINSA) and an Engineering company (IBERINCO) have collaborated on support services of Radiation Protection in the JRC-Ispra. These companies have managed to introduce the operational radiation protection model applied in Spanish Nuclear Power Plants into the JRC. The support service consists of the development of radiation protection assistance and technical consultancy, related with the following topics:

- Operational Radiation Protection Assistance
- Management of routine controls
- Electronic Nuclear Instrumentation laboratory (E-Lab)
- Dosimetry and Instrumentation Calibration Certification (SIT)
- Whole Body Count (WBC) and Environmental Measurements Laboratory (LMR)
- Documental and technical consultancy

During the development of this project, a high quantity of radiological surveillances (surface contamination, air sampling and dose rate), spectrometry analyses, technical reports and RP procedures have been carried out, responding to the necessities of the JRC. Among fixed and portable instrumentation, most than 200 radiation and contamination detectors are managed in the E-Lab. Routine operational controls, repairs and training courses are the main activities in the Laboratory. Other RP services have been started during 2009, concerning the technical support to the Whole Body Count (WBC) and to the Dosimetry and Calibration Laboratories. From the work performed in the Centre, excellent results are being achieved by a highly qualified team of professionals with different technical profiles, having a high ability for adapting to the changing conditions of the JRC policies.

P08-06

### The pilot study of the radioactive aerosol particle size distribution in the air from the uranium mine Rožínka, Czech Republic

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The radiological importance of the radioactive aerosol particles depends not only on the kind of radionuclide and its chemical form but also on the aerodynamic properties of the particles mainly on their size. Our aim was to determine the aerosol particle size distribution connected to uranium and its daughter products in the environment of the Uranium Mine Rožínka (Czech Republic) – the last place where the uranium is mined in the Czech Republic – in dependence on conditions of the mine and the ore mill. We also tried to estimate the percentage of radon emanation from the aerosol. The 6-stages cascade impactors were repeatedly placed in three places where the maximum dustiness was expected – close to the workers at the crushing plant, at the face of the shaft and at the collecting site at the end of the ore chute. Gamma spectrometric analysis was performed using HPGe detectors to determine the activities of radionuclides on each collection substrate from individual stages and on the back-up filter. The results of gamma spectrometry were used to evaluate the particle size distribution for individual radionuclides in terms of the activity median aerodynamic diameter (AMAD) and the geometric standard deviation (GSD). The first results from all places show that the distributions are slightly bimodal with the boundary under 0.4 µm and that AMAD is about 6–7 µm and GSD about 3 in agreement with the literature. The total activity concentrations were in an order of magnitude 10<sup>-3</sup>–10<sup>-2</sup> Bq/m<sup>3</sup>. The ratio of the activity concentration of the radon daughter products (<sup>214</sup>Bi, <sup>214</sup>Pb) to the <sup>226</sup>Ra ranges around 0.5. Approximately 20–30% activity is attached to particles with aerodynamic diameter (AP) > 10 µm and more than 50% activity to particles with AP > 4 µm; about 10–20% of the activity is attached to aerosol particles with AP < 0,39 µm.

P08-07

**The characteristic of long-lived radionuclides in the uranium mine atmosphere in Dolní Rožínka in the Czech Republic**Otahal, Petr; Burian, Ivo; Vosahlik, Josef

SÚJCHBO, v.v.i., Nuclear department, CZECH REPUBLIC

The miners of the uranium mines are exposed by three ways: by the irradiation of external gamma rays, by dose which is caused by inhalation of not only short-lived radon decay products but also long-lived products of uranium family. The presence of  $^{232}\text{Th}$  and its decay products isn't considered. The derived limit for mixture of long-lived radionuclides which are emitting alpha particles is 1850 Bq per year according to Decree valid in the Czech Republic. The extensive measurement for studying the mixture of long-lived radionuclides in the atmosphere of the last uranium mine in the middle of Europe is realized as a part of the project VaV SUJ200407. The mine is situated in the Moravian ore region about 5 km of Dolni Rožínka. This village is situated in the varied series of Moldanubic, which is represented mainly by biotitic up to amphibolites gneiss which is affected of strong migmatization. The measurement was performed in two typical workplaces underground (in the forefield, at the filling of corf) and one on the surface (in the crushing plant). To the research of mixture of long-live radionuclides it was added the measurement of the concentration of radon and its decay products. The concentration and the properties of aerosol particles and the climatic parameters were also registered. The mean concentration of long-live radionuclides was  $0.34 \text{ Bq}\cdot\text{m}^{-3}$ , the mean concentration of radon was  $5700 \text{ Bq}\cdot\text{m}^{-3}$  and the mean concentration of RnDP was  $320 \text{ Bq}\cdot\text{m}^{-3}$  in the forefield. The high factor F is caused by the intensive ventilation. All parameters vary strongly influenced by the type of work operation.

P08-08

**ROBOSCAN – an advanced method and system that ensures a total radioprotection of the operators working with mobile vehicle scanners**Tudor, Mircea

MBTELECOM LTD, PRESIDENT, ROMANIA

The radiological scanning of vehicles containers is a non-intrusive inspection method capturing the interest of many current researches. It is realized by using a gamma ray source (Co-60, Cs-137, Ir-192) or a linear accelerator emitting a well collimated radiation beam. The radiation beam penetrates the inspected vehicle and reaches a system of detectors. An electronic system converts the radiation image into a corresponding visual image displayed on a high-definition monitor. The image can be saved and archived after visual inspection. The detection system and the radiation source are mounted on a special designed vehicle that was approved for traveling on public roads. The vehicle is robotized and is remotely operated from a command center placed outside of an exclusion area protected by infrared barriers. Any intrusion into the exclusion area is reported to the command center and triggers the automated turn-off of the radiation emission. Due to the fact that during the scanning operation the operator is situated outside the exclusion area, the radiation dose that he receives is situated within the limit of the natural background. The paper presents the technical achievements, the radiological safety measures and the operation of Roboscan 1M, a scanning system that implements the concept of total radiological protection of the operator. Such systems are currently used by custom officers on the Romanian borders for inspecting the vehicles and containers entering the European Union. Using personnel radiation monitoring equipment we proved that the equivalent dose is under the limit for the public. The obtained values are close to the radiation natural background and confirm the theoretical estimations and the efficiency of the radiological protection provided by the ROBOSCAN concept implementation. ROBOSCAN has won in 2009 the Grand Prix of the "Salon des Inventions" in Genève, and the "WIPO Best Inventor 2009 Award" at the International Warsaw Invention Show.

P08-09

### Special shielding solutions for the ITER neutral beam test facility

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The Neutral Beam Test Facility (NBTF) will be located in Italy, near Padua, and will be devoted to the testing phase of the Neutral Beam Injector system (NBI) for the International Thermonuclear Experimental Reactor (ITER). NBTF includes two facilities that will be used to test in the same time both the main components of the final system and the whole system. The facilities are named respectively Spider (the small one) and Mitica (the whole system) and are located inside two distinct shielded bunkers. In each bunker important penetrations for the ventilation, the power supply and the auxiliary systems were arranged, providing that the safety of workers and population is guaranteed. Tunnels in the underground region, with relatively large dimensions, were needed for both MITICA and SPIDER bunkers in order to allow personnel access for inspection and maintenance of cables and ducts. Each of these shielding weaknesses needed specific safety analyses that were carried out both making reference to the scientific literature and performing ad hoc calculations. In the paper the approaches applied to the different safety concerns due to the wall penetrations are considered and described. Reference analyses and computer calculations are reported together with the relevant results. The outcomes in terms of neutron flux and associated dose data are compared with the regulatory limits and the project constraints, showing that positions and local shielding solutions for the penetrations allow the same level of safety for workers and population as that allocated by the main shielding walls.

P08-10

### Effective dose to staff from interventional procedures: estimations from single and double dosimetry

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In the Academic Medical Centre (AMC) in Amsterdam numerous interventional procedures are performed by cardiologists and radiologists. During these interventional procedures the physicians are exposed to ionising radiation. From 2004 on the exposure of the physicians was measured by means of two personal dosimeters. One dosimeter was worn outside the lead apron and an additional one inside the lead apron. The study was set up to determine the added value of a second dosimeter worn inside the lead apron. The doses measured on both sides of the lead apron were used to estimate the effective doses of the physicians using one algorithm for single dosimetry and two algorithms for double dosimetry. With the algorithm for single dosimetry the effective doses ranged from 0.11 up to 0.85 mSv in four weeks while with the double dosimetry algorithms, the effective doses ranged from 0.02 mSv up to 0.47 mSv. The statistical analysis revealed no significant differences between the effective doses estimated with the algorithms for single and double dosimetry. It was concluded that the effective doses cannot be estimated more accurately when two dosimeters are used instead of one.

P08-11

**Exposure levels of workers during some surgical procedures****Rossi, Francesco<sup>1</sup>; Gori, Cesare<sup>1</sup>; Bertelli, Duccio<sup>2</sup>; Gugliandolo, Alessandra<sup>2</sup>**<sup>1</sup>Azienda Ospedaliero-Universitaria Careggi, Health Physics, ITALY; <sup>2</sup>Università degli Studi di Firenze, ITALY

The use of fluoroscopy during surgery is quickly growing up, involving more and more surgical specialties (neurology, urology, cardiology operating rooms, etc.). Such radiological interventional procedures often require long fluoroscopy times, sometimes longer than 30 minutes. It is thus critical the radiation protection of the whole staff (surgeon, nurse, radiographer, anaesthetist), but it is very difficult to evaluate a dose level due to:

1. the rapidly spatially varying radiation field
2. the worker changing his position during the procedure
3. many other quantities changing during the exposure (collimation, distance, tube position, x-ray pulse duration).

Moreover, present-day X-ray machines have automatic exposure controls, thus making more difficult to monitor exposure parameters.

Worker exposure dose level is thus evaluated almost entirely on an empirical basic. This study is performed with respect to two surgical specialties (cardiology and orthopaedy). Exposure levels for each procedure type (e.g. leg, humerus and hip for orthopaedy) were measured, collecting data from at least 10 patients for every procedure.

In order to measure average procedure exposure level, each member of the surgical staff was given a TLD dosimeter to be used only for that kind of procedure.

The collected results are also an useful tool to have a priori estimation of dose levels for new procedures and to perform classification of workers.

P08-12

**Staff doses in cardiological interventional radiography****Parviainen, Teuvo<sup>1</sup>; Kosunen, Antti<sup>2</sup>; Lehtinen, Maaret<sup>1</sup>**<sup>1</sup>STUK – Radiation and Nuclear Safety Authority, Radiation Practices Regulation, FINLAND; <sup>2</sup>STUK – Radiation and Nuclear Safety Authority, Radiation Metrology Laboratory, FINLAND

The aim of the study has been to assess the radiation dose to personnel involved in heart X-ray assessments (cardioangiography assessments, CA), as well as some cardiology procedures (such as PTCA, EF). In the study the dose exposure has been defined for each assessment and procedure. Three different types of dose meters have been used for dose assessments. Dose measurement protocols were also examined laboratory conditions at STUK. The study was done by STUK in cooperation with two university hospitals and one procedural unit in a central hospital.

Radiation doses were measured (in head, upper arm, hand and foot/ankle) for approximately 350 different procedures. The dose for the doctor performing the procedure varied significantly depending on the length and difficulty of the operation: the average measured dose for the procedures at the upper arm level was about 50 microSv. The highest measured dose was 576 microSv. The average hand dose was about 150 microSv. The highest dose to the hand was 1093 microSv, to the foot 1003 microSv, and to the head 196 microSv. The average dose for the nurses at the upper arm level during a PTCA-procedure was 19 microSv, and the maximum dose was 199 microSv. The largest measured hand dose for a nurse was 492 microSv. According to the measurements the effective dose for the doctor was about 1 microSv / procedure and maximum dose was 12 microSv. The annual dose limits will not exceeded under normal working conditions. However, the dose limits for hands and feet could be exceeded.

The doses received by the people involved in the procedures can be quite high when compared to the annual dose limits. The appropriate use of radiation shields is necessary. Radiation meters with displays, or meters suitable for direct reading are good for observing working conditions. The information obtained in the study can be used in the hospitals to improve procedural methodologies, planning off training, as well as interventional cardiology.

P08-13

### Radiation doses to occupationally exposed personnel working with radioiodine and technetium

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The I-131 and Tc-99m content in the thyroid of staff members working with radioiodine has been measured in some Departments of Nuclear Medicine performing therapy and diagnosis of thyroid disease in Poland.

The measurements were performed with mobile detection system for "in situ" measurements of radioiodine and technetium. The MDA for mobile unit ranges from 10 – 70 Bq at the time measurement of 300 seconds. The measurements were performed in selected as low as possible background places.

The measured personnel can be divided into some categories according to internal contamination risk to unsealed sources of I-131 or Tc-99m:

1. Technical staff mainly performing routine diagnostic investigation,
2. Nuclear medicine staff (physician, nurse) working with in vivo administration of I-131 to patients,
3. Hospital services staff (orderlies, cleaners) performing auxiliary activities to the patients (cleaning of the rooms, changing of bed-clothes).

All individuals actively working with iodine and technetium show measurable amounts of this isotopes in their thyroids. The average measured activity in the thyroid of the nuclear medicine staff was found to be equal at average 600 Bq within the range from 50 Bq to 50 kBq. The average and range of I-131 activity measured in thyroids for all medical units were: 1500 Bq, (100 Bq – 70 kBq Bq), 400 Bq, (30 Bq – 3000 Bq), 150 Bq, (50 Bq – 1000 Bq) for technical staff, nuclear medicine staff and hospital services staff respectively. There is no apparent correlation between the measured I-131 levels and risk categories. Nevertheless the technical and nuclear medicine staff show higher I-131 thyroid level comparing to hospital services staff. Base on results of measurements, the Effective Dose Equivalent for particular person due to inhalation of I-131 and Tc-99m was calculated. Calculated average Effective Dose Equivalent for particular exposed person is below 50 per cent of 20 mSv/year.

P08-14

### Occupational exposures from increased use of F-18 FDG in Denmark

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Since the national integrated cancer pathways were implemented in the Danish Health Care System in 2007 the number of PET investigations using F-18 FDG has increased considerably. 6000 investigations were performed in the year 2006 and in 2008 the number had increased to 16.000. In 2008 13% of all Danish nuclear medicine investigations were with F-18 FDG. Therefore, there is a concern that the increased use of F-18 FDG is going to affect the doses to the staff in the nuclear medicine departments at the hospitals. The National Institute of Radiation Protection has studied the trends and distribution of doses to the staff in the relevant departments in the period 2006 to 2008 by the use of the national dose registry. The dose measurements were performed by either TLD or film badges for personal dosimetry. The exposure of the entire staff was assessed by calculating the collective effective dose every 6 month for all departments and for those producing F-18. The study showed that the doses to the workers increased in the departments that produce F-18 in cyclotrons over the study period. The number of annual doses to individuals exceeding 5 mSv increased from 1 in 2006 and 4 in 2007 to 13 persons in 2008, all employed in departments producing F-18. Although there were some changes in the distributions of the individual doses the total collective dose decreased from 2007 to 2008. For the clinical departments the collective dose decreased over the whole period (possibly due to a decrease in investigations using Tc-99). This trend is also seen for the first half of year 2009, The expected raise in doses to the personnel handling F-18 FDG was not seen in this study. It is therefore concluded that the PET facilities has a well established radiation protection programme, and the personnel has been well educated and well prepared for this increase in investigations using F-18 FDG.

P08-15

**Control of radiation protection and occupational radiation exposure doses of medical staff in Ukraine****Stadnyk, Larysa; Yavon, Iryna;****Panchenko, Iryna; Smirnova, Inna**

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According to Ukrainian legislation in radiation protection it is necessary to provide the workplace and individual dose monitoring of occupational radiation exposure. In Ukraine the legislative dose limits for occupational exposure correspond to Basic Safety Standards (IAEA BSS-115). The best way to estimate radiation protection is to evaluate results of individual dose monitoring of occupational exposure. The main purpose is to get information about realistic doses for different groups of staff, compare it with dose limits (category A), estimate the radiation protection of workplaces, inform Regulatory Bodies (in Ukraine these are Ministry of Health and State Committee of Nuclear Safety) about results, and suggest further measures for reduction of radiation exposures. Individual monitoring of occupational exposure for medical staff in Ukraine is carried out since 1979 by Central Laboratory of Radiation Hygiene of Medical Staff at Grigorev Institute for Medical Radiology. Now more than 6500 medical workers from departments of radiation therapy, nuclear medicine and diagnostic radiology from all regions of Ukraine are covered by quarterly TLD-monitoring. In this work, the dynamics of radiation-hygienic parameters during 1980–2008, which characterized the state of radiation protection for different professional groups of medical staff, is analyzed. 92–98 % of medical staff annual doses are less than 2 mSv. The most exposed groups of medical staff are handlers of radioactive substances and radio-manipulation nurses in radiotherapy, as well as the personnel which is involved in interventional radiology. In some years the average annual doses in these groups were more than 5 mSv. Every year the annual reports with radiation-hygienic statistical analysis of occupational exposure are generated for each hospital, region of Ukraine, different professional groups. These are sent to each hospital and to National Regulatory Bodies for analysis of radiation protection.

P08-16

**The new method of distinguishing static exposure of individual TLD dosimeters****Kopec, Renata<sup>1</sup>; Budzanowski, Maciej<sup>1</sup>; Olko, Pawel<sup>2</sup>**<sup>1</sup>Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN), Laboratory of Individual and Environment Dosimetry, POLAND; <sup>2</sup>Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN), POLAND

It is not possible to distinguish between cases of static (against source) and dynamic exposure of thermoluminescence dosimeters (TLD) evaluated in readers with photomultiplier tubes. Budzanowski et al (2006, 2007) demonstrated that using TL reader with CCD camera it is possible to qualitatively identify the cases of static exposure of TL detector covered with an non-uniform filter. Kopec et al, (2010) developed and tested a method, which can be used for automatic detection the cases of static exposure in dosimetric RADOS badge with TL (MCP-N) detectors. Detectors were read-out in a novel type of thermoluminescent reader with CCD camera developed at IFJ PAN.

P08-17

### Occupational radiation exposure in Poland based on results from the accredited dosimetry service at the IFJ pan, Krakow

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Dosimetry service based on thermoluminescence (TLD) dosimetry has started activity at the Institute of Nuclear Physics (IFJ) in 1965. The dose measurements were done at that time for 250 IFJ's workers only. In 2002 the new Laboratory of Individual and Environment Dosimetry (LADIS) at the IFJ was formally established and got accreditation for EN-PN-ISO/IEC 17025 standard. The service is based on worldwide known standard thermoluminescent detectors MTS-N (LiF:Mg,Ti) and MCP-N (LiF:Mg,Cu,P). The TL detectors are readout in automatic DOSACUS or RE2000 (Rados Oy, Finland) readers. Laboratory provides dosimetric service for individual dosimetry in terms of personal dose equivalent Hp(10) and Hp(0.07) for photon and neutron fields, over the range from 0.1 mSv to 1 Sv, and environmental dosimetry in terms of ambient dose equivalent H\*(10) over the range from 30  $\mu$ Sv to 1 Sv, and also air kerma Ka over the range from 30  $\mu$ Gy to 1 Gy. Dosimetric service is currently performed for ca. 2800 institutions over the whole Poland. Exposure periods are on quarterly and monthly basis in Poland, measurements are performed mainly for oncology centres, hospitals, dentists, research institutes, food-, light-, fuel industry, state border officers, police, antiterrorist troops, prisons, museums and in many sites where X- or gamma-ray systems are used for inspection. The paper presents results of statistical evaluation of more than 400 000 quarterly effective dose measurements performed in years 2002–2009. The dose records are being divided in dependence of technical and medical institution and type of measurement performed (individual dosimetry or environmental dosimetry). Results show that more than 85% of measurements are below 0,1 mSv/quarter what means no occupational exposure. The rest 15% is above 0.1 mSv/quarter, with cases reaching even several hundreds of mSv/quarter. In this paper cases over annual limit will be also discussed

P08-18

### Finger doses in Poland in the view of the extremity ring dosimetry results of LADIS Dosimetry Service Krakow

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The dosimetry service (LADIS) of the Institute of Nuclear Physics (IFJ), Kraków, applies MTS-N (LiF:Mg,Ti) thermoluminescence (TL) detectors for individual monitoring of Hp(0.07) in photon radiation fields. The TLDs are inserted in a plastic ring holder (PI-01) that can be adjusted for any finger size. One standard TL pellet, 4.5 mm diameter and 0.7 mm thickness, is placed in the bar coded holder under the 0.4 mm thick plastic cover. The dosimeter's behaviour during various sterilisation protocols, used in the clients' hospitals, has been tested with positive results.

LADIS laboratory performs extremity ring dosimetry measurements since more than twenty years, whereas it is an accredited procedure since 2002, according to the quality system based on PN-EN ISO/IEC 17025 standard, for Hp(0.07) personal dose equivalent over the range of doses from 0.1 mSv to 1 Sv. The paper presents results of evaluation of extremity ring measurements performed by LADIS in years 2002–2009. More than 50 thousand measurements have been performed for more than 300 institutions in Poland on the quarterly basis. Radiation fields represent exposure situations of staff in hospitals, as the users of our ring dosimeters are from interventional radiology and nuclear medicine units mostly.

The results show that about 60% of Hp(0.07) doses are below 0.1 mSv/quarter, however there were some very high doses registered. We have found doses higher than dose limits and these cases will also be presented. The classification of the clients according to their medical activity has been performed and the levels of measured doses have been found for these categories.

Laboratory has participated in the international intercomparison of ring dosimeters organized in 2007 by the European Dosimetry Group EURADOS, in order to verify the performance of different extremity dosimeters in use in Europe, with positive results.

P08-19

**Study of deterministic and Monte Carlo simulation methods for neutron and photon dosimetry at the Royal Surrey Hospital Radiotherapy Facility****Morrissey, Craig**

AWE, Radiation Protection, UNITED KINGDOM

The application of linear accelerators in the treatment of cancerous cells has become increasingly common in the last few decades. During this period the operational beam energies have increased to a point where the dose from unwanted photoneutron production has to be considered. This can add an additional complexity to calculating the dose to the patient being treated and also the potential dose rate external to a radiotherapy bunker. To address these issues, the recently commissioned, 10 MeV radiotherapy linear accelerator at the Royal Surrey County Hospital has been used as a template to calculate the photon and neutron dose rates at the entrance of a bunker and to discuss the relative advantages and disadvantages of two different dose assessment methodologies. Calculation of the radiation beam path through the bunker and doses at the entrance have been performed using traditional deterministic methodologies and compared against Monte Carlo model simulations. The deterministic method examined photon beam energies of 6 MeV and 10 MeV, which yielded entrance dose rates of 0.34 and 0.27  $\mu\text{Sv/hr}$ , respectively. However, the use of correction factors, such as scattering coefficients, used in this method placed doubt on the accuracy of the results. The Monte Carlo method was used to simulate the radiotherapy bunker of the Royal Surrey County Hospital to examine the neutron dose at the bunker entrance, yielding a dose of  $8 \times 10^{-11}$  Gy per neutron. Further Monte Carlo simulations were conducted with the bunker configuration modified through the addition of shielding and neutron moderators to demonstrate further dose reduction options available in the bunker design. The advantages and disadvantages of the deterministic and Monte Carlo methods are discussed, concluding that Monte Carlo analysis offers an improved radiation protection tool for the calculation of doses and dose rates where complicated geometries and materials must be considered.

P08-20

**Practical implications of the RELID (Retrospective Evaluation of Lens Injuries and Dose) project in the radiation protection of medical professionals****Vañó, Eliseo<sup>1</sup>; Durán, Ariel<sup>2</sup>; Ramírez, Raúl<sup>3</sup>; Nader, Alejandro<sup>3</sup>**<sup>1</sup>Complutense University of Madrid, SPAIN; <sup>2</sup>University Hospital Montevideo, URUGUAY; <sup>3</sup>International Atomic Energy Agency – IAEA, AUSTRIA

An international study on Retrospective Evaluation of Lens Injuries and Dose (RELID) was carried out under the coordination of the International Atomic Energy Agency (IAEA) with the collaboration of the Latin American Society of Interventional Cardiology (SOLACI). Two surveys were performed during regional congresses of SOLACI and included an evaluation of potential radiation-induced lens opacities in a cohort of interventional cardiologists (IC), nurses and technicians working in cardiac catheterization laboratories, as well as a control group of non-medical professionals whose eyes were never exposed to ionizing radiation. Retrospective eye dose calculations were made by combining data from experimental scatter dose measurements in standard catheterization laboratories with answers to occupational and work-practice details from questionnaires and oral interviews of all participants. Personal dose records were requested to the participants. A total of 116 exposed individuals were screened. A control group of 93 non-exposed persons was included. Posterior sub capsular opacities were found in a 38% of cardiologists and in a 21% of paramedical personnel as compared to 12% of controls. Personal dose records values were practically not available in most of the cases. From the questionnaires fulfilled by the participants, cumulative professional life-time equivalent doses to the lens until several Sv were estimated. The use of personal protection devices reported by the some of the subjects with higher doses was scarce or never used. These findings demonstrate the necessity to improve the education in radiation protection for interventional medical and paramedical professionals especially in the aspects affecting occupational doses and on the importance of using ocular radiation protection tools. Personal dosimetry methodology for these professionals should be revisited and the need of the proper use of personal dosimeters should be highlighted.

P08-21

### Risk of occupational radiation-induced cataract in medical workers

**Milacic, Snezana; Djokovic, Jelena**

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The cataract is the most common degenerative opacity of the crystalline lens, developing with aging. Physical agents causing the cataract may be as follows: infrared, ultraviolet and microwave non-ionizing radiation, electric power and ionizing radiation. Other risk factors of cataract are the following: alcohol abuse, tobacco smoke, systemic diseases (endocrine and metabolic), impaired eye circulation, ocular pressure, refractory eye abnormalities (myopia), blood pressure, heart conditions, low food antioxidant level. The study involved 3240 medical health workers in Serbia, who used to work within and beyond the area of ionizing radiation. The annual periodical-preventive controls of health workers included the eye examination as well. After visual acuity measurement, the lens was examined by retroillumination method (red reflex) and using the biomicroscope. In case of impaired visual acuity or presence of cloudy lens, the examination was performed in mydriasis. X-ray radiation may be a significant cofactor of cataract in radiological technicians. It is an occupation-related disease and may, along with other impairments, contribute to diagnosis of chronic radiation syndrome as occupational disease. Absorbed doses in exposed subjects with cataract, measured by thermoluminescent personal dosimeter (TPD) ranged from 2.64 (min.) to 48.10 (max), mean value:  $7.58 \pm 4.78$  mSv/5 years ( $1.59 \pm 30$  mSv/year), and were not different from mean absorbed annual doses in the exposed subjects without cataract ( $1.63 \pm 1.45$  mSv/1 g), being below maximally tolerated dose of 100 mSv/5 years 920–50 mSv annually). It is evident that chronic exposure to low doses is not the cause of occupational radiation cataract as an independent occupational disease. The effects of radiation to biological DNA material failed to be proven on cataract development, it was rather related to type of radioactive emission, mode and type of radiation, working burden and working conditions as well as type of job.

P08-22

### Setting up a whole body counting system in Portugal

**Bento, Joana; Nogueira, Pedro; Neves, Maria;**

**Silva, Lídia; Vaz, Pedro; Teles, Pedro**

Instituto Tecnológico e Nuclear, Unidade de Protecção e Segurança Radiológica, PORTUGAL

We have recently set up a Whole Body Counter (WBC) at the ITN in Portugal (type Canberra Accuscan). This system is currently prepared to respond to any type of radiological emergencies adequately, if any should happen in Portugal. Also, in the near future, we intend to start a series of routine measurements of workers both inside and outside the ITN.

The WBC contains a moveable Canberra HPGe type GC 2520 detector, and is calibrated with the help of the GENIE 2K, and the ABACOS softwares. We use a calibration source consisting of a cocktail of several radionuclides, with photon energies within the range [55, 1900] keV. For the calibration, we use a Canberra RMC-II phantom in two different types of measuring geometries: the thyroid and the whole-body – both in BOMAB phantom type equivalent calibration arrangements. The calibration is checked on a daily basis, as well as the background.

This is being complemented by Monte-Carlo simulations. The simulations are being performed using the State-of-the-art MCNPX and PENELOPE codes and recent comparisons of calculations with measured results are extremely satisfactory.

Finally we have established collaborations on the European level to participate in future inter-comparisons, as well as in joint-projects, in the framework of EURADOS, with gradual harmonization with EURADOS and EC recommendations in mind.

In this talk we will discuss the actual and future projects associated with the applications of this equipment in the framework of Portugal's Radiological Protection policies, as well as present in some detail the results we have obtained so far.

P08-23

**Internal dosimetry at the Institute of Atomic Energy POLATOM in Poland**

Osiko, Jakub; Golnik, Natalia; Ciszewska, Katarzyna

Institute of Atomic Energy POLATOM, POLAND

Nuclear Centre Zwierk is the main and the biggest nuclear centre in Poland. Institute of Atomic Energy POLATOM, the Andrzej Soltan Institute for Nuclear Studies and Radioactive Waste Disposal Unit are located there. Institute of Atomic Energy operates a nuclear reactor and there is also the Radioisotope Centre which manufactures radiopharmaceuticals and other unsealed radiation sources. Waste Disposal Unit collects and treats radioactive waste of low and moderate activity from whole country. Monitoring of the internal exposure of employees is performed by Radiation Protection Measurement Laboratory of the IAE, which is the only laboratory of this type in Poland accredited by Polish Centre for Accreditation. RPML provides also monitoring of the internal exposure for employees from other institutions and sometimes serves as a public service in case of post accident contamination. RPML uses a whole body counter and thyroid counter for *in vivo* measurements and performs *in vitro* measurements using flow counters and liquid scintillators. All measurement results are gathered in data base which contains data since 1986. The paper shortly describes the procedures used in the laboratory and lessons from intercomparisons. Results of monitoring in 2008 are discussed for the group of 378 persons subjected to the measurements with whole body counter, 128 persons examined with thyroid counter and 122 persons using *in vivo* radiochemical. Occupational radiation contamination with iodine  $^{131}\text{I}$  was registered in 21 cases by whole body counter and in 57 cases by thyroid counter. Radiochemical measurements showed 9 cases of contamination (5 with  $^{32}\text{P}$ , 4 with tritium, 2 with  $^{90}\text{Sr}$  and 1 with  $^{35}\text{S}$ ). Contamination with  $^{137}\text{Cs}$  was registered in 53 cases. This isotope is still present in the environment in Poland after the Chernobyl accident.

P08-24

**Designing and using a veterinary megavoltage X-ray facility**Vos, Cornelis S.<sup>1</sup>; Teske, Erik<sup>2</sup>; Lenstra, Johannes A.<sup>2</sup><sup>1</sup>Utrecht University, NETHERLANDS; <sup>2</sup>Utrecht University, Faculty of Veterinary Medicine, NETHERLANDS

Until now cancer in companion animals is being treated in the Clinic for Companion Animals of the Faculty of Veterinary Medicine, Utrecht University, mainly by surgery and/or chemotherapy. The Faculty is currently building a megavoltage X-ray facility. In April 2010 treatment with radiotherapy using a linear accelerator will be started. The use of linacs in veterinary medicine is increasingly becoming more common and therefore the building of more structural shieldings in the near future is foreseen in Europe. The design of the structural shielding for the veterinary radiation therapy facility is based on the NCRP 151 (2007). Based on concrete, a shielding design goal (P) of 10  $\mu\text{Sv/y}$ , as prescribed by the national radiation control agency, a workload (W) at 1 m from the X-ray target of 17000 Gy/y (91% 6 MV and 9% 10 MV), a use factor (G) of 0.25 and an occupancy factor (T) of 0.25 for the residential environment, the primary barrier has been calculated at 150 cm concrete. The design of the maze without a special entrance door, is relative long and has multiple legs. Because of this only small companion animals (i.e. cats and dogs) can be treated. As the endpoint energy of the accelerator is below 10 MV the presence of photoneutrons and neutron capture gamma rays are disregarded. After presenting calculations of the primary and the second barrier locations, the design of the structural shielding was approved by the national state radiation control agency. Building the veterinary radiation therapy facility and purchasing the linear accelerator has been licensed in January 2009. As soon as the accelerator has been made operational, a preliminary survey shall be carried out to ensure that radiation exposures to the installation engineer and personnel near the facility do not exceed the applicable shielding design goal. Once the accelerator has been made completely operational and an initial calibration has been completed, a complete radiation survey shall be conducted.

P08-25

### Beta doses from handling $UO_2$ pellets at a nuclear fuel factory; Monte Carlo based simulations and TLD measurements

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**Aim:** The objective with this project was to establish beta radiation doses to workers (skin and eye doses) from  $UO_2$  pellet production work in a uranium fuel factory in Sweden.

**Material and methods:** The beta energy spectra emitted from  $UO_2$  pellet plates were obtained by Monte Carlo (MC) simulations using the MC-code MCNP5, yielding beta fluxes (from Pa-234m decay) at different positions and distance from the source. Also, the dose-rate distributions in soft tissue were calculated in order to obtain skin and eye lens doses. Validation of the MC-calculations were made by TL-based field measurements, where thin TL-discs of (i) LiF-PTFE; thickness 0.13 mm, and (ii) LiF-discs; TL-active thickness 0.04 mm, were used as follows: TL-discs were stacked in PMMA cylinders with a 8 mm deep hole holding the dosimeters and then exposed for 48 hours at various distances above source centre simulating workers hand and eye positions. In addition, the legal personnel badge dosimeters (LiF-discs, thickness 0.9 mm), with one closed position (3 mm plastic cover) to measure (gamma) deep dose and one open position for shallow dose, were exposed at several distances from the source. To assure good quality in the TL dose data, each dosimeter type was calibrated in beta fields from Sr-90/Y-90 at 0, 30 and 60 degrees angle of incidence at known doses (Hp(0.07) at the National Standard Laboratory at SSM in Stockholm.

**Results:** The MC-calculated beta dose distribution agreed well with field measurement data. Both at positions for workers hands and head/eyes, the beta radiation clearly dominate the contribution to Hp(0.07) over the gamma contribution. The badge dosimeters severely underestimate the shallow beta doses due to their location and orientation but also add dose to the closed position TL-disc which will then overestimate the deep dose. To obtain good beta dosimetry for the workers, i.e. for extremity and eye lens doses, thin TL-dosimeters (e.g. 0.13 mm thickness) in thin plastic bags are suggested.

P08-26

### Review of the constraints of the effective dose levels at OKG NPP

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OKG NPP, Oskarshamn, Radiation Physics, SWEDEN

The maximum level of the effective dose a worker that at a Swedish NPP accumulates during a year or over a five year period is regulated by the Swedish Authorities. In order to meet up to these standards, the NPP at Oskarshamn in Sweden (OKG AB), introduced constraints in the 1990s. These values were mainly based on the standards and limits set by the authorities and not so much the conditions at the NPP or up-to-date research in the field.

Recently a new electronic personal dosimeter system was introduced at OKG AB. It is now possible to determine both the effective dose and the dose rate in intervals as low as one minute and this can be followed online. It opens up for a whole set of possible evaluations, one being the trending of doses and dose rates. This is valuable information for setting our own standards regarding constraints of the effective dose/dose rate levels. The review of the constraints of the effective dose and dose rate levels at OKG AB has been carried out taking into account the trending parameters of the station, estimations given from the electronic personal dosimeter system, latest research results, PR policy at OKG AB,  $\alpha$ -value of ALARA and limitations set by the Swedish Authorities.

S09-01

**Low dose radiation-induced non targeted effects – How the changing paradigm impacts radiation protection of biota?****Mothersill, Carmel; Seymour, Colin**

McMaster University, Medical Physics and Applied Radiation Sciences, CANADA

Ever since the grudging acceptance that non-targeted effects (NTE) can be measured in unirradiated cells or distant progeny of irradiated cells, the discussion has raged about the relevance of these effects for radiation protection and risk assessment. Arguments will be made in this presentation, that NTE may call into question radiation effects pillars such as the LNT model. They may also have relevance to wider mechanisms in cancer biology, population ecology and evolutionary biology concerning process of selection, the transmission of heritable traits, the relevance of “social” interactions between cells, organisms and populations and the mechanism by which cells/organisms respond rapidly to environmental stress. This presentation will also argue that a key consequence of findings in NTE biology is that at any given level of organization, from gene to ecosystem – communication of stress signals and heritability of stress adaptations provide the bridges linking one hierarchical level to the next and enable the rapid propagation of change triggered by stress at one level, resulting in change at a higher (or lower?) level. This addresses a major problem in evolutionary biology because while the molecular mechanisms of natural selection are fairly well understood a major knowledge gap exists in translating mutational drift at the level of the individual cell to natural selection at the ecological level where sociobiological factors are so important. The existence of the mechanisms discovered in the NTE field provides a glimpse of a major way that evolution could be regulated through communicated signals between cells, individuals, and populations. These control and optimize responses at the level of the population and coordinate the emergence of exquisitely tuned systems which can adapt rapidly to micro or macro environmental change. Radiation protection strategies for biota mean that an understanding of the driving mechanisms is vital.

S09-02

**The activities of the IAEA in developing standards on radiological protection of the environment****Proehl, Gerhard; Louvat, Didier; Telleria, Diego**

International Atomic Energy Agency, Division of Radiation Transport and Waste Safety, AUSTRIA

Radiological protection of the environment is an issue that has been intensively discussed for more than one decade. A great deal of progress has been made during this time regarding the capabilities: (i) of estimating the uptake of radionuclides by flora and fauna in different habitats and ecosystems; (ii) in the development of dosimetric models that allow the calculation of internal and external exposures for a wide range of terrestrial and aquatic organisms; and (iii) in investigating and analysing the effects of radiation exposures to biota. The paper gives an overview of the IAEA's activities in this field and it describes the interactions with UNSCEAR, the ICRP and other national and international bodies and institutions in the work on analysis and evaluation of exposures to flora and fauna. The current status of the discussion on the integration of environmental protection into the radiation protection system is also summarized. Results of case studies are presented that assess the radiological impact to flora and fauna due to discharges of radionuclides to terrestrial and aquatic environments. Finally, the paper discusses the factors, assumptions and considerations that are regarded as important for risk characterisation and decision making in relation to radiation exposures to biota. It explores the remaining challenges related to the integration in regulating and controlling dischargeable waste.

S09-03

**Dose rates to freshwater biota in Finnish lakes**Vetikko, Virve

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In recent years there has been growing international interest in the assessment of doses and risks from ionising contaminants to biota. Incremental dose rates to biota in freshwater ecosystems in Finland mainly resulting from exposure to the Chernobyl-derived radionuclides Cs-137, Cs-134 and Sr-90 were estimated using the ERICA Assessment Tool developed within the EC 6th Framework Programme. Data sets consisting of measured activity concentrations in fish, aquatic plants, lake water and sediment for three selected lakes located in a region with high Cs-137 deposition were applied in the assessment. The selected lakes are among those having the highest activity concentrations found in Finland and therefore represent the highest exposure to biota in freshwater ecosystems affected by the Chernobyl fallout. The dose rates to most species studied were clearly below the screening level of 10  $\mu\text{Gy/h}$ , indicating no significant impact of the Chernobyl fallout on these species. However, the possibility of higher dose rates to certain species living on or in the bottom sediment cannot be excluded based on this assessment. In addition, dose rates from Pb-210 and Po-210 to selected organisms were calculated. Dose rates from these radionuclides were negligible in comparison with the screening level. In the ERICA Tool the parameter “occupancy factor”, defining the fraction of time the studied organism spends in a given habitat, can have a considerable impact on the dose rate estimates. The values set for this parameter should be as realistic as possible with respect to the use of the habitat of the studied organisms.

S09-04

**Effects of radioactive contamination on plant populations and radiation protection of biota**Geras'kin, Stanislav; Oudalova, Alla; Dikareva, Nina; Mozolin, Eugene; Prytkova, Julia; Dikarev, Vladimir; Chernonog, Elena; Novikova, Tatiana

Russian Institute of Agricultural Radiology and Agroecology, RUSSIAN FEDERATION

An assessment of the state of plant and animal populations inhabiting polluted territories and the analysis of mechanisms of their adaptation to adverse environmental conditions undoubtedly has general biological importance. Consequently, studies that examine biological effects on non-human biota in natural settings provide a unique opportunity for obtaining information about the potential biological hazard associated with radioactive contamination. Nevertheless, up to now there is a distinct lack of quantitative data on the real long-term biological consequences of chronic radiation exposure lasting a long period of time. Actually, few studies exist that are directly relevant to understanding the responses of plant and animal populations to radioactive substances in their natural environments. The results of long-term field experiments in the 30-km Chernobyl NPP zone, in the vicinity of the radioactive wastes storage facility (Leningrad Region), at radium production industry storage cell territory (the Komi Republic), in the Bryansk Region affected by the Chernobyl accident, and in Semipalatinsk Test Site, Kazakhstan that have been carried out on different species of wild and agricultural plants are discussed. Although radionuclides cause primary damage at the molecular level, there are emergent effects at the level of populations, non-predictable solely from the knowledge of elementary mechanisms of the pollutants' influence. Plant populations growing in areas with relatively low levels of pollution are characterized by the increased level of both cytogenetic disturbances and genetic diversity. Radioactive contamination of the plants environment activates genetic mechanisms, changing a population's resistance to exposure. However, in different radioecological situations, genetic adaptation to extreme edaphic conditions in plant populations could be achieved with different rates.

S09-05

**Peculiar disturbing effects  
of low radiation****Sarapultseva, Elena<sup>1</sup>; Bychkovskaya, Irena<sup>2</sup>**

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In model experiments on the crayfish *Daphnia magna* the importance of peculiar effects of low radiation was studied. We showed that even at a dose of 0.1 Gy, which is a thousand times lower than predicted as lethal (100 Gy), the probability of animals death increases. The process was registered for the greater part of daphnia's lifetime. The frequency of death of irradiated animals did not increase with dose increasing from 0.1 to 20 Gy. It was observed so the results of the negative impact of low radiation (0.1 Gy) on other aquatic organism – unicellular infusoria *Spirostomum ambiguum*. The modal experiments of the laboratory population of *Spirostomum* showed, that these protozoa are highly sensitive to gamma-irradiation by spontaneous motor activity (SMA) criterion. The reliable effect of SMA decrees was observed just after irradiation in doses 0.1 Gy. It was approximately on the similar level (about 35% below control) in a broad variety of doses (to 850 Gy inclusive). The effect evidently strengthened only after irradiation in doses 1000 – 1500 Gy. These changes were mass, and inherited in a number of generations. Changes had been inherited not only in the vegetative reproduction of organisms, but also through sexual reproduction (crayfish *Daphnia*). Due to the fact that the cellular dose-independent effects, induced by low doses, were found on the biological objects of different organizations (including rats [<http://irbb.ucoz.ru>]), we decided, that these effects are widespread in nature. The molecular-genetic mechanisms of these changes remain unknown. The mass character and non-linear nature of these changes can not be attributed to the mutations. In general, they can be classified as epigenetic changes, which attract more and more attention. This work was directed to the ecological problem. In doses that are lower than those considered dangerous, we had witnessed decline in the viability and functional activity of aquatic organisms.

P09-01

### Impact assessment of elevated levels of natural/technogenic radioactivity on wildlife of the north – INTRANOR

**Brown, Justin<sup>1</sup>**; Evseeva, Tatiana<sup>2</sup>; Sazykina, Tatiana<sup>3</sup>; Oughton, Deborah<sup>4</sup>; Hosseini, Ali<sup>1</sup>

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Arctic and boreal regions are often considered to be vulnerable to exposures from contaminants and therefore merit special attention in relation to the application of environmental impact assessment methodologies. The INTRANOR project has focussed specifically on environmental assessments for radiation exposure through application of existing methodologies and their adaptation to quantify transfer, exposure and effects in Boreal/Arctic ecosystems. Non-parametric statistical methods have been applied in order to estimate the threshold dose rates above which radiation effects can be expected in vertebrate organisms. The effects considered in the analyses include morbidity, reproduction, and life shortening and the approach has drawn upon data collations pertaining to databases on effects of chronic low-LET radiation exposure. In addition, industrial areas contaminated by uranium mill tailings and radium production wastes, in the Komi Republic, Russia, were selected as suitable study sites to study further the effects of exposure to radiation under boreal conditions. Dose-effect relationships have been established for natural *Vicia cracca* L. populations inhabiting this area. The various endpoints considered include chromosome aberration frequency in seedling root meristem, frequency of embryonic lethal mutation in legumes, germination of seeds and survival rate of sprouts of seeds. Analyses of data have allowed a benchmark to be established below which no decrease in reproductive capacity could be observed. Other work performed within the project includes the collation of data in relation to naturally occurring radionuclides and application of existing methodologies to characterise background radiation exposures. These dose-rates used in conjunction with dose rates known to have specific biological effects on individuals/populations may be a suitable means of contextualising the exposure attributable to enhanced dose-rates arising from human activities.

P09-02

### Testing of linearity assumption of soil-to-plant transfer factors in boreal forest

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There are still many open questions in the uptake of soil radionuclides into plant. The data gaps cause uncertainty in radioecological models which are important tools for assessing risks to humans and biota. It is generally assumed that transfer from soil to plants is linear, i.e., it can be described with a transfer factor that does not vary with concentration of the radionuclide in soil. This assumption, however has not been extensively tested in natural conditions. In this study the linearity of the transfer factors of uranium, lead, molybdenum, nickel, and zinc from soil to forest plant species was investigated. The study was conducted in uranium deposits in Eastern Finland during summer 2007. Narrow buckler-fern (*Dryopteris carthusiana*) collected from a herb rich forest was divided in leaves, petioles and roots. Pseudototal concentrations of these elements in plants and forest soil were measured by ICP-AES and ICP-MS. Bioavailable fraction of elements in mineral soil was estimated by ICP-AES and ICP-MS measurement after 1 M ammonium acetate (pH 4.5) leach. Transfer factors from soil to plant parts were calculated at varying soil concentration. Preliminary results suggest that the linearity assumption is not valid in the herb rich forest studied. The results of further analyses and their implications will be discussed.

P09-03

**Application of ellipsoid geometry in dose assessment of forest plants****Ikonen, Ari T. K.<sup>1</sup>; Aro, Lasse<sup>2</sup>**<sup>1</sup>Posiva Oy, FINLAND; <sup>2</sup>Finnish Forest Research Institute, FINLAND

Posiva is implementing a deep repository for spent nuclear fuel in Olkiluoto, Finland. A site-specific safety case is being produced, and data has been acquired for the assessment models. In the dose assessment of other biota, international approaches are applied. However, determining geometry parameters for the variability of forest plants is a challenging task, not to mention coupling of the geometry to plant physiology. First, it is well known that physical dimensions of plants differ widely between plant species. Secondly, dimensions of certain plant species are dependent on growth conditions (e.g. weather, soil fertility), biological age and developmental stage of plant (e.g. many annual herbs have their highest biomass in largest extent during late summer). Furthermore, plant parts have different physiological tasks, and they should be taken into account as well (e.g. photosynthetically active green leaves compared to lignified brown stems). In this paper we illustrate problems in plant geometry using some key plant species of boreal forests and propose alternative geometries for assessment use.

P09-04

**Assessment of critical doses for reproduction and survival of cultivated plants****Oudalova, Alla; Ulyanenko, Lilióa; Geras'kin, Stanislav; Filipas, Alexander**

Russian Institute of Agricultural Radiology &amp; Agroecology, RUSSIAN FEDERATION

The aim of the study is to estimate radiation doses that are critical for sustainability of agrocenosis. Available information on dose dependences in such umbrella endpoints as reproductive potential, survival, morbidity, alterations in morphological and biochemical processes, genetic effects in crops, vegetables, fruit trees, etc are gathered from papers issued mainly in Russian scientific press during last 50 years. Data are maintained as database in MS Access that contains about 7000 entries; the work is ongoing. Quantitative data obtained from different sources are transformed in relative units, which makes possible analysing unified arrays referred to specific endpoints. As critical, there are considered doses producing 50% changes of biological effect at acute impact, or dose rates resulting in 10% changes at chronic exposure of plants. There are three main exposure situations for plants: acute irradiation of seeds, acute and chronic exposure of vegetating plants. Critical doses and dose rates are assessed from dose-effect dependences constructed with data sets, referred to indexes of reproduction and survival. It is found that data on survival collected so far are rather insufficient to estimate critical dose (rates) for species of cultivated plants. From the available information, the predicted no-effect doses and dose rates for agrocenosis are estimated basing on reproduction endpoint. They range within 67–80 and 15–17 Gy at acute exposure of the most radiosensitive species in dormant and vegetation periods, correspondingly, and 3–10 mGy/h at chronic exposure of vegetating plants. The estimates obtained are going to be improved with further development of the database and treatment approaches.

P09-05

**Preliminary results on Cernavoda NPP operation impact on terrestrial and aquatic biota**

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Recently, the awareness of the vulnerability of the environment has increased and the need to protect it against industrial pollutants has been recognized. The concept of sustainable development, requires new and developing international policies for environmental protection. (Protection of the environment from the effects of ionizing radiation. IAEA-TECDOC-1091. International Atomic Energy Agency, Vienna.). As it is recommended in "Cernavoda Unit #2 NPP Environmental Impact Assessment it is Cernavoda NPP responsibility to conduct an Ecological Risk Assessment study, mainly to assess the impact of Nuclear power plant operation on terrestrial and aquatic biota. Long records from normal operation of Cernavoda Unit 1, wind pattern, meteorological conditions, and upgrad source terms data were used to evaluate areas of interest for environmental impact, conducting to a circle of 20 km radius around mentioned nuclear objective. The screening campaign established tritium level (because Cernavoda NPP is a CANDU type reactor, and tritium is the most important radioisotope evacuated in the environment) in air, water, soil and vegetation, focusing the interest area on particular ecosystem. Using these primary data it was evaluated which are the monitored ecological receptors and which are the measurement endpoints. This paper presents the Ecological Risk Assessment at Cernavoda NPP technical requirements, and the preliminary results of evaluating criteria for representative ecosystem components at Cernavoda NPP.

S10-01

**Update of impacts of the Chernobyl accident: Assessments of the Chernobyl Forum (2003–2005) and UNSCEAR (2005–2008)**
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Radiological consequences of the Chernobyl accident were recently revisited by the UN Chernobyl Forum (2003–2005) and UNSCEAR (2005–2008). The environmental impacts considered included radioactive contamination of terrestrial and aquatic environments, application and effectiveness of countermeasures and effects on biota. Updated dosimetric data were presented for more than half a million of emergency and recovery operation workers, about 100 million inhabitants of the three most affected countries, Belarus, the Russian Federation and Ukraine, and for 500 million inhabitants of other European countries. The average effective dose of the emergency and recovery operation workers was estimated to be about 0.12 Sv. An exception is a cohort of several hundred emergency workers who received high radiation doses; of whom 28 persons died in 1986 due to acute radiation sickness. The majority of the six million residents of the 'contaminated areas' in Belarus, Russia and Ukraine received relatively minor radiation doses which are comparable with the natural background levels. However, those who were children at the time and drank milk with high levels of radioactive iodine received during the first few months after the accident particularly high doses to the thyroid. Since early 1990s there was the dramatic increase in thyroid cancer incidence among those exposed to radioiodine at a young age. Also in 1990s there was some increase of leukaemia in most exposed workers. Apart from those two health effects revealed in the two different population cohorts as the result of 20-year epidemiological observations there was, until 2007, no clearly demonstrated increase in the somatic diseases due to radiation. There was, however, an increase in psychological problems among the affected population, compounded by the social disruption that followed the break-up of the Soviet Union.

S10-02

**Lessons learnt from an accidental release of 45 GBq <sup>131</sup>I in Fleurus, Belgium**

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 Olyslaegers, Geert<sup>2</sup>; Sweeck, Lieve<sup>2</sup>;

 Paridaens, Johan<sup>2</sup>; Rojas-Palma, Carlos<sup>2</sup>;

 Hardeman, Frank<sup>2</sup>
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On August 22, 2008, a cloud of <sup>131</sup>I was released from the Institut des Radioelements (IRE), a producer of medical isotopes located in Fleurus, Belgium. The peak of the release took place in the weekend of 23–24 August and was followed by a smaller, continuous release which lasted for several weeks. Several measures were taken after notification of the release to the Federal Agency of Nuclear Control, the Belgian nuclear safety authority. The nuclear emergency plan was activated on a N2 level. Under this emergency plan many environmental samples were taken and analysed with the purpose of verifying whether there was no risk for the population to obtain a significant dose via the food chain. Air samples were taken to confirm that no significant persistent release of <sup>131</sup>I was still occurring. This air monitoring was performed just after notification of the release and during major replacement work of the filter systems of the isotope production plant. The Belgian Nuclear Research Centre SCK•CEN collected and analysed many of the environmental samples, performed the air monitoring and participated in the evaluation cell of the National Crisis Centre. In the course of these activities and in the period after the immediate crisis, some points were discovered that could be improved. Most of these findings dealt with:

- acquisition and measurement capacity of environmental samples
- Public communication
- separation of different tasks in the field
- communication between experts
- availability of expert knowledge.

This paper elaborates on the main aspects of the SCK•CEN participation in the emergency response of this incident and draws important lessons to dealing with similar situations in the future.

S10-03

### How user involvement improves decision support: Experiences from the EURANOS project

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European countries have varying levels of preparedness to respond to radiation emergencies. Despite the fact that considerable achievements have been made in the past in developing new methods and information technology (IT) tools under the EC's 4th and 5th Framework Programme, many of these developments are still not fully operational or disseminated all over Europe. As a consequence, the EURANOS (European Approach to Nuclear and Radiological Emergency Management and Rehabilitation Strategies) project aimed to increase the coherence and effectiveness of nuclear and radiological emergency management in Europe including the rehabilitation of contaminated areas. Basis of this project was the establishment of an effective working platform of emergency management institutions, Research and Technological Development (RTD) institutes, end-users and other stakeholders. Demonstration activities were from the beginning a core element of the EURANOS project. The specific aim of the demonstration activities was to determine which of the tools, method and approaches for emergency preparedness developed in the previous Framework Programmes and/or within the EURANOS project are ready for actual operational applications and where additional research and development is needed to enable operational use. This activity was accompanied by the implementation of an international users group for the RODOS (Real-time On-line Decisions Support) decision support system (RUG), which acted as a discussion and interaction forum for all RODOS related topics. Reviewing the EURANOS project, the added value of implementing an extensive demonstration project and user group could clearly be demonstrated. Experience from the demonstrations has altered the RTD projects from the second year onwards. The contribution from the RUG has strongly influenced the prioritisation of the work program and thus laid the focus clearly on the operational aspect of the RTD work.

S10-04

### Enhancement of the Radiation Monitoring and Emergency Response System in the North-West Region of Russia

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One of the key elements of safe decommissioning is preparedness to respond to possible radiological accidents. Therefore, a modern emergency response system in the Murmansk and Arhangelsk Regions are an obligatory element ensuring protection of population and territories in case of radiological accidents at facilities connected to nuclear submarine decommissioning, spent nuclear fuel and radioactive waste management. The paper describes the basic results of the international project "Enhancement of the Radiation Monitoring and Emergency Response System in the Murmansk region" implemented in 2005–2008 by the Energy Safety Analysis Centre of IBRAE RAN. The Project was funded by the Northern Dimension Environmental Partnership Support Fund – Nuclear Window. The Government of the Murmansk Region was the customer and beneficiary of this activity. The same project was started in Arkhangelsk region in mart 2009. The main activities in the Project framework included the modernization of the existing and creating automated radiation monitoring systems for facilities and territories, including mobile radiation surveillance laboratories; establishment of the Regional Crisis Centre of the Murmansk Region and the Crisis Centre of FSUE "SevRAO"; setting up communication systems for transfer, acquisition, processing, storage and presentation of data for participants of emergency response at the facility, regional and federal levels; development of software and hardware systems for expert support of decision-making on personnel, population and environment protection; and establishment of a system for expert support of the created centres by the Technical Crisis Centre of IBRAE RAN. Exercise "Zapolyarie-2005" in October 2007 demonstrated operability of all created elements and interaction of all participants of emergency response in the Murmansk Region. The exercise was acknowledged as very successful by the management of the Murmansk Region and observers of IAEA mission.

S10-05

**Nordic Emergency Preparedness (NEP) – A regional concept for emergency planning****Husin, Stig**

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The Chernobyl accident 1986 led to number concrete steps that were taken worldwide aiming at enhancing the preparedness for Nuclear and Radiological Emergencies. One of these steps was the establishments of bilateral agreements and associated practical arrangements between Denmark, Norway, Finland and Sweden on Early Notification and Information Exchange. This in turn led to an understanding of the feasibility of setting up an organised form of cooperation between the Nordic nuclear and radiation safety authorities on emergency preparedness matters. This cooperation was formally established in the year 1993 and has over the years rendered a regime for regular communication tests, good cross border knowledge and understating of the set-up in our countries, detailed arrangements for the practical implementation of the bilateral agreements and a lot more. The presentation will describe the historical background of NEP, show its present agenda, work process and highlight some of results achieved. The overall objective of the presentation is to, by using the NEP cooperation as an example, show the value a good and structured regional cooperation on an institutional level could add to existing international agreements and arrangements.

S10-06

**Incident and emergency centre of the IAEA****Stern, Warren; Buglova, Elena; Baciu, Florian**

International Atomic Energy Agency, Incident and Emergency Centre, AUSTRIA

The Incident and Emergency Centre of the International Atomic Energy Agency is the global focal point for preparedness, event reporting and response to nuclear and radiological incidents and emergencies irrespective of their cause.

The Centre continuously works to develop standards and guidance for strengthening Member States' preparedness; practical tools and training programs to assist Member States in promptly applying the standards and guidance; and organizes a variety of training events and exercises. Lessons learned from response to past emergencies form the basis for developing such standards, guidance and tools. Together with the experts from the Member States and the ICRP the IEC made efforts to develop the generic and operational criteria for application in preparedness for and response to a nuclear and radiological emergency. A rigorous examination of the response to past emergencies has shown that there is a need for international guidance on taking protective and other response actions and for placing a guidance in a context that is both comprehensive for the decision makers and can be explained to the public. So the criteria developed are accompanied by the plain language explanation. In addition these generic criteria are developed in the way that their application will ensure consistency with the concept of reference levels presented in the ICRP 103.

The Centre evaluates national plans and assists in their development; facilitates effective communication between countries; develops response procedures; and supports national exercises. The Centre provides access to multiple information resources; assess trends that may influence crisis and consequence management plans and response; and develops and continuously enhances methodology for identifying conditions needed for early warning and response. The Centre provides around-the-clock assistance to Member States in dealing with nuclear and radiological events, including security related events through timely and efficient services and the provision of a coordinated international response to such emergencies.

S10-07

**Responding in the wake of a crisis resulting from the malevolent use of ionising radiation: TMT Handbook**

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Liland, Astrid<sup>2</sup>; Jerstad, Ane<sup>2</sup>; Jaworska, Alicja<sup>2</sup>;  
Smith, Karen<sup>3</sup>; Rahola, Tua<sup>4</sup>; Muikku, Maarit<sup>4</sup>; Etherington,  
George<sup>5</sup>; Pérez, Maria del Rosario<sup>6</sup>; Carr, Zhanat<sup>6</sup>

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The evolution of nuclear emergency planning has led to a broadening of the scope of response plans to include not only fixed nuclear sites, but also incidents such as accidents involving the transport of radioactive material. The magnitude of such events, whilst generally smaller due to the smaller quantities of radioactive material involved, pose their own problems due to the difficulties associated with prior planning for location-specific factors, high density populations, etc. Following recent terrorist acts (World Trade Center, New York; Atocha train station, Madrid; suicide bombings; London bombings) carried out by disaffected groups, nuclear emergency planning has increasingly focused on preparedness for incidents involving malevolent use of radiation. Therefore practicable tools are needed for an adequate response to such acts and more specifically to provide European guidelines covering triage through to treatment and long term follow up of exposed people. The European Commission through the Euratom 6th Framework Programme co-sponsored the specific targeted research project TMT Handbook. The main objective of this project was to produce a practicable handbook for the effective and timely triage, monitoring and treatment of people exposed to ionising radiation following a malevolent act. This paper elaborates on the work carried out and outlines the progress achieved during the execution of project; and also on the challenges that need to be dealt with in order to secure a sustainable development of what has been achieved through the lifetime of the TMT Handbook project.

P10-01

**Norwegian assessment of current national nuclear and radiological preparedness**

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Norwegian Radiation Protection Authority, NORWAY

In 2004, the Norwegian Crisis Committee for Nuclear and Radiological Preparedness initiated a project to assess the current national preparedness regarding nuclear and radiological emergencies. The purpose of the initiative was to make recommendations on how to further develop the preparedness within the Norwegian nuclear and radiological preparedness organisation and to improve current national emergency response planning. The project is expected to be completed during the summer of 2010.

The first phase of this project was finalised and published as a public report in the autumn of 2008 by the Norwegian Radiation Protection Authority. It constitutes of a comprehensive hazard assessment and points out changes in the Norwegian perception of nuclear and radiological hazards over the last few years. It provides an overview of possible nuclear or radiological events which may affect Norway or Norwegian interests abroad, as well as relevant consequences for public health, the environment and other public interests.

The second phase of the project will address two issues. Firstly, based on foreseen scenarios and relevant consequences from the study in phase one, it will study necessary management of nuclear and radiological emergencies and examine mitigation strategies. It will highlight some mitigation efforts in detail, including performing cost-benefit analysis and reviewing experiences in implementing them during past emergencies. The second phase will also review roles and responsibilities of different regional and national authorities and explore the practical implementation of different mitigation efforts.

Secondly, resource requirements within the nuclear and radiological preparedness organisation will be addressed. The project will give an overview of existing resources and examine current needs for funding, equipment, expertise etc. in order to provide an adequate base for managing future emergencies.

P10-02

**Collaborative software for the nuclear emergency management**

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A lot of expertise and teamwork is needed to understand an evolving nuclear accident, to assess its off-site consequences, and to make optimal recommendations. The working of the various groups involved relies on information exchange and on adequate computer support. In Finland we have been developing a Web platform that makes it easier to exchange information and for all users to be kept up-to-date with the development of the situation. The platform bridges the spatial remoteness of expertise (incl. hardware and software) and provides a consistent user interface to tools that could be used before only with special training. In addition, it provides the different users with their views of the situation and supports the process from source term input, over dispersion and dose assessment, up to the approval of various reports. Although still developed, the platform has been in use in the Radiation and Nuclear Safety Authority of Finland (STUK) and the Finnish Meteorological Institute (FMI) for roughly two years. So far we have received mainly positive feedback.

P10-03

**Assessing the hydrological impact in nuclear emergencies**

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The paper presents several aspects believed to be relevant for the integration into the decision support systems for the management of radiological emergencies, of assessment tools addressing surface water contamination. A few exemplary cases are discussed, relating to domestic and international alert exercises and including, in the major league, tools like RODOS and MOIRA, both developed by multinational consortia; and, in the domestic league, solutions trading off scientific appropriateness in grasping the complex phenomenology involved, with computational practicality, mainly revolving around a radiological assessment toolkit, developed as an open-ended software that assembles requisite source term evaluation, environmental transport, dosimetric diagnose and countermeasure projections. Tools complementarity and synergy; model streamlining; and interfaces comprehensible and palatable for the stakeholders appear to be the key factors paving the way of the aquatic path into the emergency response business.

P10-04

**SNIFFER: an aerial platform for real time measurements of contamination in the plume phase of a nuclear emergency**

**Castelluccio, Donato Maurizio; Cisbani, Evaristo; Colilli, Stefano; Fratoni, Rolando; Frullani, Salvatore; Giuliani, Fausto**

Istituto Superiore di Sanita', Technology and Health, ITALY

AGMS (Airbone Gamma Monitoring System), equipped with passive detectors, are used in many countries to face nuclear or radiological accident that results in a release of radioactive plume; however the AGMS is able to provide quantitative assessment on the radiological situation (land surface contamination level) only when the air contamination due to the passage of the travelling plume has become negligible. To overcome this limitation, the Italian Institute of Health has developed and implemented a multi purpose air sampling system based on a fixed wing aircraft, for time-effective, large areas radiological surveillance (to face radiological emergency and to support homeland security). A fixed wing aircraft (Sky Arrow 650) with the front part of the fuselage properly adapted to house the detection equipment has been equipped with a compact air sampling line where the isokinetic sampling is dynamically maintained. Aerosol is collected on a Teflon filter positioned along the line and hosted on a rotating 4-filters disk. A system of detectors allows radionuclide identification in the collected aerosol samples. A correlated analysis of these two detectors data allows a quantitative measurement of air as well as ground surface concentration of gamma emitting radioisotopes. Environmental sensors and a GPS receiver logs the sampling conditions and the temporal and geographical location of the acquired data. Acquisition and control system based on compact electronics and real time software that operate the sampling line actuators, guarantee the dynamical isokinetic condition, and acquire the detectors and sensor data. The system is also equipped with other sampling lines to provide information on concentrations of other chemical pollutants. Operative flights have been carried out in the last years, performances and results will be presented.

P10-05

### **SNIFFER: a unique aerial multifunctional platform for large area radiological surveillance and emergency management**

Castelluccio, Donato Maurizio<sup>1</sup>; Chiavarini, Salvatore<sup>2</sup>; Cisbani, Evaristo<sup>3</sup>; Fratoni, Rolando<sup>3</sup>; Frullani, Salvatore<sup>1</sup>; Gaddini, Massimiliano<sup>4</sup>; Giuliani, Fausto<sup>3</sup>; Marchiori, Carlo<sup>5</sup>; Paoloni, Gianfranco<sup>5</sup>; Pianese, Emanuele<sup>4</sup>; Pierangeli, Luigi<sup>3</sup>; Colilli, Stefano<sup>3</sup>; Fuselli, Sergio<sup>3</sup>; Marconi, Achille<sup>3</sup>; Paoletti, Luigi<sup>3</sup>; Ziemacki, Giovanni<sup>3</sup>; Colangeli, Giorgio<sup>6</sup>; De Otto, Gian Livio<sup>6</sup>

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The Italian Institute of Health in collaboration with the Ministry of Environment developed and implemented a multi purpose air sampling system based on a fixed wing aircraft, for time-effective, large areas radiological surveillance (to face radiological emergency and to support homeland security) and air pollution monitoring.

The system design has mainly originated from the experience gained during the emergency management of the Chernobyl nuclear power accident (1986).

In order to provide quantitative information on ground as well as atmospheric radioactive contamination (and permit, e.g., reliable plume behavior forecast), the SNIFFER consists of a fixed wings aircraft (Sky Arrow 650 by 3I) properly adapted to house a relatively compact payload equipped with a sampling line that works in isokinetic regime. The line serves the  $\beta$  and  $\gamma$  atmospheric radiation detection system made of: one small BGO scintillator and one Geiger counter providing a near real time information on the air sampled radiation excess and one high energy resolution hyper-pure germanium for radionuclides quantitative identification.

A large NaI scintillator detects the ground and atmospheric radiations; The combination of the information from the above 4 detectors permits the quantitative estimation of both atmospheric and ground contamination.

Two sampling devices devoted to polycyclic aromatic hydrocarbons and volatile organic compounds air quality monitoring are also integrated into the SNIFFER.

A fully automated acquisition and control system actively manage all the payload components.

The whole acquired data are integrated by environmental (temperature, pressure and air density) and geolocation information for a complete characterization of the sampling conditions and their temporal and geographical location.

The system and the results of the first aerial mission will be presented at the conference.

P10-06

**BALTRAD – An advanced weather radar network for the Baltic Sea Region meteorological institutes and authorities**

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<sup>5</sup>Danish Meteorological Institute (DMI), DENMARK; <sup>6</sup>Estonian Meteorological and Hydrological Institute (EMHI), ESTONIA;

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Weather radar systems are capable of monitoring rain, snow, hail and wind over large geographical areas with high resolution in both time and space. Accurate and timely weather forecasts provide essential information for the authorities by warning them of hazardous conditions (e.g. snow storms or floods). The objective of the BALTRAD project is to create a state-of-the-art real-time weather radar network for the Baltic Sea Region, the so-called BALTRAD system, which is foreseen to facilitate the harmonised production, exchange and use of real-time weather radar data. BALTRAD delivers value-added precipitation information to improve short-term weather forecasts. The technology developed by and for BALTRAD will be proposed as the standard for exchanging weather radar data in the World Meteorological Organization Information System. The project, headed by SMHI, was officially started in February 2009 and continues until the end of January 2012. The project is partially funded by the EU's Baltic Sea Region Programme 2007-2013. The Partnership comprises eight organizations from seven countries (Sweden, Finland, Poland, Latvia, Denmark, Belarus, Estonia). In addition, there are associated organizations in Denmark, Latvia and Poland which will be contributing in various ways. An integral part of the project includes so-called pilots that will demonstrate the value of BALTRAD for end users in the fields of e.g. hydrology, aviation and crisis management. Radiation protection authorities are amongst the potential end-user organizations because rain, for example, increases deposition and consequently dose rates at the ground level. Rain information can also be

used in planning measurement activities in emergencies and in interpreting higher-than-normal radiation levels during routine conditions, and numerical data (precipitation rates, accumulated precipitation) can be input to consequence assessment models.

P10-07

**The “NOODPLAN” early phase nuclear emergency models: an evaluation**

Camps, Johan; Turcanu, Catrinel; Braekers, Damien; Carlé, Benny; Olyslaegers, Geert; Paridaens, Johan; Rojas-Palma, Carlos; van der Meer, Klaas

SCK•CEN, BELGIUM

Over the past decades SCK•CEN has developed a set of models – called the NOODPLAN models – for consequence analysis of atmospheric releases during the early phase of a nuclear emergency. All these models use segmented bi-Gaussian plume dispersion algorithms based on the Bultynck-Malet scheme and are limited to a local scale (50 km from release point).

The different NOODPLAN models are largely customised to the needs of several external users. Customisation includes e.g. source term determination from stack monitoring, connection to on-site meteorological masts, graphic display of countermeasure areas corresponding to intervention guidelines, special modules with standard accident scenarios and specific calculations at the location of detector points (e.g. corresponding to monitoring network). These models have been primarily designed for the Belgian nuclear power plants, the results being used by the radiological evaluation cell of the Federal Crisis Centre, within the framework of the Belgian nuclear and radiological emergency plan. Additional users include research reactors and other nuclear facilities.

The NOODPLAN models perform real time calculations based on variable on-site measured meteorological data, as well as prognostic evaluations. Following a brief description of the different functionalities of the models, this paper will focus on the evaluation of the different NOODPLAN models. This evaluation will draw on our experiences with the NOODPLAN models from regular emergency exercises and will include an inter-model comparison study with state-of-the-art atmospheric dispersion models integrated into the European decision support system RODOS. The results of this evaluation highlight possible future development required to ensure a fast and reliable decision making during the early phase of a nuclear emergency.

P10-08

**The use of rain-radar data in the early phase nuclear emergency response**

De Clerck, Kristien<sup>1</sup>; Camps, Johan<sup>2</sup>; Turcanu, Catrinel<sup>2</sup>; Braekers, Damien<sup>2</sup>; Carlé, Benny<sup>2</sup>; Paridaens, Johan<sup>2</sup>; Rojas-Palma, Carlos<sup>2</sup>; van der Meer, Klaas<sup>2</sup>

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Following an atmospheric release of radioactive material during e.g. a nuclear or radiological incident, it is well known that local precipitation can have a large impact on the deposition pattern. Atmospheric dispersion and deposition models use different approaches to take precipitation into account. Moreover, often only limited precipitation information is available. Although rain-radar data are less accurate than rain intensities that are measured directly, they ensure a more detailed coverage of the potentially affected region, which can, in turn, affect the decisions on management options and measurement strategies.

Data from a C-band Doppler rain-radar located at Wideumont and operated by the Royal Meteorological Institute of Belgium were converted to be used with the Risø Mesoscale puff model (Rimpuff). This model was then used to execute several calculations concerning a possible nuclear event with different rain input data ranging from single station to rain-radar data. Results obtained for different parameters, such as deposition and cloud-shine, corresponding to precipitation measurements from weather stations on the one hand, and from rain-radar data on the other hand, are compared.

This paper assesses the importance of the rain-radar data in the early phase of a nuclear or radiological emergency. The resolution and the uncertainties associated with the different available rain data are discussed. Also, a quantitative analysis is presented of the results obtained when different rain input data are used. Finally, to strengthen our conclusion on the added value of rain-radar data in the early phase, a survey on the opinion of several radiological experts on the use of rain-radar data based on a case study with calculated examples will be discussed.

P10-09

**Is one set of intervention levels for radiation emergency planning enough?****Wirth, Erich<sup>1</sup>; Baciu, Adriana Celestina<sup>2</sup>; Gerich, Brigitte<sup>1</sup>**<sup>1</sup>Federal office for radiation protection, Emergency Preparedness, GERMANY; <sup>2</sup>National Commission for Nuclear Activities Control, Section for Radiation Emergencies, ROMANIA

A common set of intervention levels is still missing for introducing early (sheltering, evacuation and thyroid blocking) and late (relocation, resettlement, returning to evacuated areas) protective actions in radiation emergencies. In a previous publication, a two-step method has been suggested to derive a consistent set of intervention levels. In the first step, the run of the projected effective doses with time is calculated for an accidental release scenario. Subsequently, the relationships of the projected effective doses are estimated for four different time periods which represents integration times for sheltering and relocation or returning. In the second step, it is necessary to adopt an intervention level for one protective action or a more general reference level for a certain time period. The relationships between the projected effective doses and the agreed intervention, respectively reference level, are used to derive a consistent set of intervention levels for early and late protective actions. In this contribution the recommendation of ICRP to limit the annual dose to the public to 100 mSv in the first year is adopted. Based on this reference level, the intervention levels for the early and late protective actions are derived for a variety of scenarios. The influence of different parameters on the variation of results is systematically analysed and discussed with respect to establish appropriate intervention levels. Based on the results, it is further discussed whether it is of advantage to have only one set of intervention levels which covers even unfavourable conditions, or, whether it might be more appropriate to derive more than one set of intervention levels for different scenarios, which enable decision makers for a flexible response according to the accidental situation. First analysis show that the intervention levels vary significantly with the fraction of long-lived radionuclide in the source term and with dry or wet deposition.

P10-10

**Technical considerations for protective action strategy in nuclear emergency using probabilistic accident consequence assessment model****Kimura, Masanori; Takahara, Shogo; Homma, Toshimitsu**  
Japan Atomic Energy Agency, JAPAN

If an accident occurred at nuclear power plant and any plume of radioactive materials was released into the environment, country and local government immediately have to implement protective actions for people around the plant to reduce exposed dose. In order to efficiently implement protective actions, it is important to preliminarily develop the good planning for emergency preparedness and response to a nuclear accident. In particular, it is important to provide the technical guidance for the development of urgent protective actions (e.g. evacuation, sheltering and iodine prophylaxis), based upon a comprehensive threat assessment that takes into account the full range of postulated events for nuclear accidents. The most effective response strategy in nuclear emergency will involve a combination of these protective actions. The ICRP recommends focusing on optimization with respect to the overall strategy, rather than the individual protective action in the ICRP new recommendation, Publication 103. To develop a generic response strategy, probabilistic accident consequence assessment models can be very useful for providing a quantitative basis on discussing the effective emergency plan. Our study shows results of the technical considerations for the overall strategy of implementing protective actions in emergency exposure situation using a probabilistic accident consequence assessment model by Japan Atomic Energy Agency. For postulated accidents with source terms derived from a generic level 2 PSA of the reference plant in Japan, residual doses are calculated in case of implementing combination of these protective actions and then optimization process being guided by reference levels is applied. The preliminary results will provide the insights of technical guidance for the development of these protective actions.

P10-11

### System for the prognosis of the population doses due to emergency atmospheric release from nuclear power plants

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The system for the operative analysis of radiation situation after emergency atmospheric release of the nuclear power plant (SOARS) is developed by Ukrainian Radiation Protection Institute for dose calculation and support decisions about countermeasures.

The source data for calculations consist of release parameters and meteorological data (variable with time): release rate (activities of separate radionuclides), duration of release, release height, stability class, wind speed, wind direction, precipitation rate.

For the purposes of calculation of dynamics of dosimetric situation an emergency release is modeled as sequence of the discrete elements emitted through small time intervals. Such approach enables to represent continuous release as sequence of discrete "puffs" and to calculate concentrations and doses.

Result of calculations is the prognosis of spatial distribution and time dynamics of concentrations in the air and on the ground, dose rates, effective and equivalent doses (in consideration of radioactive decay and accumulation of radioactive daughters). All results are represented on a map with binding to settlements.

Predicted and avertable doses to the population of settlements in supervised area are estimated (accordingly to Ukrainian legislation). Predicted absorbed doses to organs (tissues) are calculated for 2 days after emergency release (for decision-making about emergency countermeasures). Avertable doses to whole body, thyroid and skin are calculated for 2 weeks after accident (for decision-making about urgent countermeasures). Avertable doses depend on efficiency and duration of one or several countermeasures (sheltering, evacuation, iodine prophylaxis, outdoor restriction).

SOARS is used at Rivne NPP (4 units). Works on adaptation of SOARS for use at Khmelnytsky NPP (2 units) are carrying out now. The state enterprise National Nuclear Energy Generating Company ENERGOATOM plans to extend SOARS to all 4 operating Ukrainian NPPs (15 units).

P10-12

### Dose assessment for population in case of beyond design basis accident at NPP

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Radiation protection of the population in case of a reactor accident utilizes generic or reference criteria which are mainly based on dose values.

Radiological consequences for the beyond design basis accident (BDBA) at NPP with a PWR reactor were studied. The following assumptions were made: power of reactor 3000 MW (th), level of core damage gap release; leak rate 0,02 %/hour, at which filters are assumed to blow out, containment spray system is unable to activate.

Radionuclide concentrations downwind from the NPP and projected doses due to the accident were estimated at a distance of 50 km from the NPP using the software InterRAS which was developed for application at the planning and response stages of the emergency. It was also assumed that it was raining over entire area.

The dose pathways in the result of the accident are: cloudshine from the plume, inhalation from the plume, and groundshine from deposited radionuclides.

The highest value of total effective dose for population living in the near zone was 94 mSv at a distance of 1 km from the NPP, the highest value for population living in the far zone was 1 mSv.

In the result of our calculations and its analysis versus international recommendations it was found that after the BDBA at NPP with a PWR reactor there is no need for evacuation or providing shelter for the public because the total effective dose will not achieve currently recommended generic criteria (100 mSv in the first 7 days). However, plans should be made to:

- recommend to the public to avoid eating potentially contaminated food or milk;
- perform an environmental monitoring and monitoring of food, water and fodder within 25 km from the NPP;
- provide food monitoring on the territory about 300 km round the NPP.

The need for these actions may be than revised based on environmental measurements and dose values.

The results of the study could be used for emergency planning purposes.

P10-13

### Prognosis of thyroid doses in case of an accident at a nuclear power plant

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Despite all the precautions that are taken in the design and operation of nuclear power plants (NPP), there remains a possibility that failures of any of the systems or of the equipment may lead to a nuclear emergency with a release of radioactive materials into the environment that may require emergency response actions.

The purpose of this study was to make prognosis of thyroid doses in case of an accident at a NPP. In order to achieve this the following was done:

- assessment of thyroid doses formed due to beyond design basis accident (BDBA) at NPP with water-water reactor (at different distances from the station);
- estimation of the length of the territories at which dose exposure may exceed the current international generic criteria for protective and other actions in case of the BDBA.

For modeling of the accident scenario geographic location and technical characteristics of the station, weather conditions were taken into account.

Simulation and evaluation of the potential nuclear accident were performed using the software (InterRAS, RASCAL) which takes into account all the above-listed parameters.

Various scenarios of possible weather conditions were considered in order to simulate the transfer of radionuclides in the atmosphere. The calculations also consider the contribution of internal thyroid dose due to consumption of contaminated foodstuff into formation of the thyroid dose.

This study allowed to estimate the thyroid doses, as well as the necessity of protective and other actions in case of the BDBA.

Results of prognosis using the international models have demonstrated that:

- there is a need in thyroid blocking for population at a distance up to 25 km from the station;
- the possibility of restrictions of consumption for potentially contaminated with iodine-131 foodstuff should be preplanned.

The results of modeling performed in this study form a basis for developing national arrangements for response to a BDBA accident at considered NPP.

P10-14

### Dose response of sugar and sweeteners for EPR retrospective dosimetry using sweets and chewing gum carried by victims at nuclear emergencies

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After a nuclear accident it is important to reconstruct the individual doses for planning the medical treatment. Another task is to establish moderate or small dose levels, in order to inform people about low radiation risk. Electron paramagnetic resonance (EPR) spectroscopy provides a mean to measure absorbed doses by quantification of free radicals induced in materials by ionizing radiation. Since people normally do not wear personal dosimeters, it is of interest to investigate radiation induced radicals in materials that are often carried by people with the intent to measure absorbed doses. The objective of this study is to investigate sugars and sweeteners for the possibilities of using sweets and chewing gum for retrospective dosimetry. Sucrose, sorbitol and xylitol are investigated by means of EPR spectroscopy regarding the dosimetric properties; radical stability, dose response and dependence on environmental factors. The knowledge obtained is applied to one common type of chewing gum by determination of the dose response, obtained accuracy and lowest detectable dose for that specific material. The sweeteners are sensitive to daylight and the EPR spectrum shows a complicated evolution with time. This is not a problem if the chewing gum is kept in dark and if the signal evolution with time is carefully mapped since the time between exposure and analysis is well known. The EPR spectrum of the irradiated chewing gum is mainly composed by the spectra from sorbitol and xylitol. By identifying the components of the dosimetric signal, the absorbed dose in the chewing gum can be determined and thus make an estimation of the effective dose to exposed individuals possible. With a new ultra sensitive EPR spectrometer, under installation, we expect the lowest detectable dose to be 50 mSv and the uncertainty in dose determinations less than 50 mSv.

P10-15

**Categorisation of sources: Is it only legal instrument for authorities, or also a practical tool for qualified experts and exposed workers?****Koželj, Matjaž**

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During the licensing or registration process and also during the use of radioactive source all applicants, and later licensees or registrants, meet with some kind of the source classification method when the source is categorised. The purpose of this procedure is to simplify legal decision process and to optimise requirements regarding required documentation and requests for safety measures and emergency preparedness. Authorities use characteristic categorisations for specific purposes: the first and basic one is the decision whether some material should be considered radioactive source. For that purpose they use Exemption Level. And when some source should be released from regulatory control, the Clearance Level is used. For other categorisations D-value (for emergency preparedness requirements),  $A_1$  and  $A_2$  (for transportation requirements) and High-Activity Level (for radiation safety and security requirements) are used. For practically all radionuclides all these levels are conveniently listed in relevant regulations and available to all users. But the real background of the values is not evident and clear to majority of people involved in authorisation process and use of sources. Therefore we have decided to review and describe scenarios that were used to develop and calculate the values which are used for categorisations and to discuss practical consequences for different practices. Since all these values were calculated by experts and for realistic scenarios, they have also practical meaning and could be used as a basis for quick and relevant estimates of potential exposure in different accidental situations. We will also discuss this possible application in more details and present the limitations of the approach.

P10-16

**Emergency response to accidents involving radioactive material: Italian fire fighter experience****Rosiello, Luca; Pianese, Emanuele; Mazzaro, Michele**

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Since 1987 Italy has not been producing electricity through nuclear fission; nevertheless, due to the presence of four Nuclear Power Plants undergoing decommissioning and to the increasing use of radioactive sources in medical, industrial and research applications, potential accidents involving radioactive materials can still occur (and actually took place). Italian Fire Brigades, which are a national Organization, represent one of the main government structures involved in this kind of events, as far as the initial phase is concerned. Actually, Italian Fire Brigades teams act as first responders for any kind of calamity. Accidents involving radioactive substances may be accompanied by hazards of different nature, and in these cases the wide range of tasks Italian fire fighters are used to face and their high level of training greatly simplify the approach to intervention. During the last five years some small accidents took place in Italy involving radioactive materials such as orphan sources; in all cases the action of the first responders has proved of fundamental importance. Italian Fire Brigades have special trained teams equipped with suitable devices and dresses for monitoring and protection, and they are able to manage emergencies involving radioactive materials. The aim of this article is to show the Italian response system provided by the Italian fire brigades from the very beginning of the accident until the post-emergency phase: some examples will be shown concerning recent events. Moreover the fire fighter's way of training, as far as radiation protection is concerned, will be presented. The authors will illustrate also the co-operation between different organizations and services involved when a relevant accident occurs.

P10-17

**Analyses of causes and consequences of internal contamination incidents at NRG****Draaisma, Folkert<sup>1</sup>; Minkema, Jeroen<sup>2</sup>**

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In the last years several unforeseen events happened leading to internally contaminated workers and members of the public. Beside committed effective dose estimations incident investigations were performed into the direct and underlying causes. Using the Tripod method Basic Risk Factors were identified and used for prioritizing actions to prevent occurrence of these incidents in the future. Besides poor design characteristics, human failures could be traced back to organisational shortcomings as procedures, education and training and communication. An important finding was the personal perception of an internal contamination leading to concern and anxiety by those exposed. Justifying investment in terms of means and human capital according to the ALARA principle in relation to the gain in terms of dose reduction this fear perception is not taking into account. This suggests that a kind of "psychological" weighting factor must be introduced correcting for the enhanced 'dose' perception of internal contamination and in this way justifying extra effort preventing internal contamination.

P10-18

**Investigating microphonic noise in mobile gamma-spectrometric HPGe measurements using accelerometers****Kock, Peder**

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Microphonic noise caused by vibrations can be a problem in mobile gamma-spectrometric measurements using HPGe detectors. When driving on uneven roads moderate speeds might give rise to a considerable amount of vibrational stress. The resulting distorted spectra can be difficult to interpret, and potentially important spectral information may be lost. However, accelerometers can be used to detect and quantify the vibrations. These measurements can then be used to reduce the vibrational stress on the detector system.

To demonstrate the impact of noise from detector microphonics, vibrational data was gathered along with spectral measurements from an experiment with a car-borne mobile platform. The acquired accelerometer data could then be connected to the spectrum where distortions were observed. Speed and position on the road was also recorded and stored in the same record. This technique makes it possible to evaluate and compare different detector mounting configurations.

As this article shows, a sane mounting configuration will reduce the microphonic noise. This could be crucial for example in an orphan source emergency situation, where measurements must be gathered with speed and accuracy. Using accelerometers can be one way of achieving a reliable car-borne HPGe system by reducing the interference from microphonic noise.

P10-19

**Assessment of potential consequences of hypothetical radiological incidents in the seas of North-West Region of Russian Federation****Pavlovski, Oleg; Krylov, Alexey**Nuclear Safety Institute of Russian Academy of Sciences,  
RUSSIAN FEDERATION

In Northwest region of Russia there are the sites of storage and decommissioning of retired nuclear submarines, their nuclear reactors, spent nuclear fuel and radioactive waste. Many of those sites are not isolated and protected. There are also the atomic shipbuilding plants, naval objects. In the seas there is the traffic of atomic-powered vessels (submarines, ice-breakers). There is a hazard of release of radioactivity from those sites. This was the reason of implementing of the International Project "Improvement of the Murmansk region system of radiation monitoring and emergency response" (Project), managed by the European Bank for Reconstruction and Development. The Nuclear Safety Institute (NSI) of Russian Academy of Sciences was the main executor of the Project. Hypothetical scenarios and consequences of accidental radioactive contamination of coastal waters of North-Western region of Russia are discussed in this work. The scenarios assume the location of the hypothetical accidents to be in the White Sea and in the one of the Bays of the Barents Sea. The modeling of possible consequences of radiological incidents was implemented for water bodies that strongly differ in size (from 5 to 300 kilometers), tides, currents, and characteristic times of water exchange with Arctic Ocean. The modeling of migration of the radioactive substances was carried out with the use of computer model developed by the specialists of the NSI. This model is based on the well-known three-dimensional Princeton Ocean Model. The results of modeling of considered scenarios of accidents have shown that these hypothetical incidents do not constitute danger to the areas of industrial fishing in the Arctic Ocean as so as to the sea-shore coasts outside the water bodies where the hypothetical accident have taken place.

P10-20

**Management of the radiological situation regarding the wreck of the cruiser Murmansk****Eikermann, Inger Margrethe H.; Selnaes, Øyvind Gjølme**

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In December 1993, the decommissioned cruiser Murmansk was torn from its towing towards India for dismantlement and ran aground just outside the fishing village Sørvær on the coast of Finnmark in Northern Norway. The Norwegian Radiation Protection Authority (NRPA) received information about the wrecked vessel from the Norwegian Defence Command Headquarters. The coast guard carried out measurements and collected sea water samples. The initial concern was the possibility that there might be nuclear materials onboard the vessel, either in form of nuclear weaponry or spent nuclear fuel. NRPA made initial assessments and concluded that it was very unlikely that the vessel would contain radioactive substances that could pollute the surrounding area. In June 2007 NRPA was notified by a private recycling firm that items taken from the wreck of the cruiser Murmansk showed sign of gamma radiation. The source was sent to a low level radioactive waste depository. Friday 1 August 2008 major Norwegian newspapers have lead stories on public concerns regarding radioactive substances at the ship. NRPA realized the need for a more thorough follow-up and decided to visit the wreck for new investigations. The investigations on the wreck was gamma dose rate measurements and collected samples of sea water and biota inside and outside the wreck. All samples was analysed and compared to expected values based on the Norwegian marine monitoring programme. The analysis did not show any radioactive contamination from the wreck. Also further measurements of concentrated sea water samples, alpha spectrometry of biota and sediments samples have not shown any trace of radioactivity. Handling of media was a main challenge through this event and it proved to be the most publicised news bulletin concerning NRPA in 2008. NRPA received very good public, political acceptance for handling the case and lead to a good cooperation between responsible authorities.

P10-21

### Overview of the observations on airborne and deposited radioactivity in Finland after the Chernobyl accident

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The Chernobyl nuclear accident happened in the former Soviet Union on 26 April 1986. The air parcel trajectories originating from Chernobyl at the time of the accident show that the radioactive plume moved first northwestwards over Lithuania the plume separated to two main paths. At lower altitudes (750–1000 m) the plume continued towards Sweden and Norway. At higher altitudes (1500–2500 m) the plume turned towards north. The plume arrived in South-Western Finland 27 April at 12 UTC for a release height of 2000 m. Then the plume went across the country north-eastwards and back to Soviet Union.

An aerosol beta activity monitor reacted to the Chernobyl-derived airborne radioactivity at Nurmijärvi, 40 km north-west of Helsinki, on the afternoon of 27 April. Unfortunately the alarm issued by the instruments did not cause any action due to a civil servants' strike. The first alarm leading to a nation-wide alert occurred at Kajaani, north-eastern Finland, on the evening of 27 April 1986. A monitoring station of the Ministry of the Interior measured an increased exposure rate value of 0.1 mR/h ( $\approx 1 \mu\text{Sv/h}$ ) in connection with a rain shower. 29 April a rain area moved from the west coast of Finland in an easterly direction. The rain scavenged the activity to the ground causing notable increases in the external dose rate at several monitoring stations.

The monthly mean total beta activity concentration in April 1986 was the highest ever recorded, 1 Bq/m<sup>3</sup>. The total beta activity concentration decreased five orders of magnitude at Nurmijärvi from 27–28 April to 31 May. In northern Finland the concentration level was clearly lower. In striking contrast to the 1960's nuclear weapons test fallout, the Chernobyl fallout was very unevenly distributed in Finland. The existence of "hot particles", highly radioactive agglomerates, in the Chernobyl plume was a specific feature during the early stages of emissions.

P10-22

### Hot particles from atmospheric nuclear explosions

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Hot particles were often observed with autoradiography in the 1960s and 1970s as a result of the atmospheric nuclear tests. These particles were formed by condensing material, both radioactive and inactive, from the exploding nuclear device, underlying soil etc. The Finnish Meteorological Institute (FMI) has monitored atmospheric radioactivity since the early 1960's at several monitoring stations in Finland by collecting aerosol particles onto paper or glass-fibre filters. After the measurement of total beta activity the collected filter samples have been archived. Since the mid 1960s some of the filters were also examined with autoradiography. Hot particles were frequently observed after atmospheric nuclear tests in Lop Nor, People's Republic of China. In this work the archived filters were analysed by digital autoradiography for screening the radioactive particles from them. Further analyses were done by scanning electron microscopy and energy dispersive X-ray spectrometer to study morphology, size and surface elemental composition of the localized radioactive particles. Based on electron microscopy results gamma and alpha measurements were performed. After this the samples were analysed by fission track technique to find out if fissile material is present in the particles. ICP-MS analyses were performed to determine plutonium and uranium content of the particles. Pu-239/Pu-240 ratios were determined with a sector mass spectrometer and U-235/U-238 ratios with a quadrupole mass spectrometer. The objective was to utilise modern instrumentation in the detection and analyses of hot particles in order to get new information on their physical and chemical characteristics. Contrary to particles found in e.g. lake or sea sediments or ice cores, the particles can be connected to individual nuclear tests. According to the preliminary results, uranium and plutonium were found in particles with a diameter of about 10 microns.

P10-23

**Biological dose reconstruction techniques operated by BfS****Romm, Horst; Oestreicher, Ursula; Kulka, Ulrike**

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Biological dosimetry is an internationally established, independent method, employed in the area of radiation protection. Mainly utilised in addition to physical dosimetry, biodosimetry provides a chance for individual dose reconstruction and is often performed after an unclear or suspected radiation exposure in man. The field of application involves detailed individual dose assessments as well as fast, rough estimations in case of a large-scale radiological event. In this context, special cytogenetic markers such as chromosome aberrations and micronuclei analysed in blood lymphocytes turned out to be highly reliable and solid biological endpoints and are therefore widely used for biodosimetry purpose. The Federal Office for Radiation Protection (BfS) operates a laboratory which represents the national reference laboratory for biodosimetry in Germany. The focus lays on the dicentric analysis with dose effect curves for various radiation qualities, on FISH-analysis of stable translocations and on the analysis of micronuclei. The method of choice depends on the particular circumstances. Over the years, individual dose estimations in one or only a few persons have been a routine task. However, a new challenge has emerged in recent years in the form of a possible large-scale radiological event with the potential to involve a large number of exposed persons. In order to be prepared to act in an efficient manner in such an event, the BfS biodosimetry laboratory has improved its own capacity, in particular by increasing the throughput of analysed cells, e.g. by automation or by optimisation of the calculation mode in dependence of the required information. Nonetheless, the power of a single laboratory is only limited. To meet the requirements in case of a mass casualty, the BfS has established close working arrangements with several biodosimetry laboratories in Europe as well as on international level and is actively involved in national and global networking.

P10-24

**<sup>85</sup>Kr in industrial krypton gas: origin, identification and dosimetry****Fischer, Helmut W.<sup>1</sup>; Bielefeld, Tom<sup>2</sup>; Hettwig, Bernd<sup>1</sup>**<sup>1</sup>University of Bremen, Institute of Environmental Physics, GERMANY; <sup>2</sup>Harvard University, Belfer Center for Science and Internat. Affairs, UNITED STATES

Industrial krypton gas is produced by fractionated distillation of liquefied air, in which it has a natural abundance of about 1 ppmv. The radioisotope <sup>85</sup>Kr is present in the atmosphere at a concentration of about 1.5 Bq/m<sup>3</sup>, due to continuous emissions from nuclear installations. Pure krypton gas thus will contain 0.35 MBq/kg of <sup>85</sup>Kr, and commercial gas cylinders will contain many MBq of the isotope, making it detectable by radiation monitors. A case of an explosion of such a cylinder inside a factory building with subsequent detection of increased radiation levels by the first responders, followed by evacuation of the building and (obviously useless) decontamination of persons, has been reported in the U.S. press in 2006.

We report on a case of transcontinental transport of krypton gas, triggering of a radiation alarm, and subsequent in situ measurement by different radiometric techniques. Dose rate and contamination measurements revealed values clearly above background. Quantitative gamma spectroscopy identified the isotope <sup>85</sup>Kr by its 514 keV line and revealed activity levels consistent with its atmospheric concentration and with measured and calculated dose rate values. Dose rate values at positions close to the cargo were below 0.2 µSv/h.

Possible other cases of such "TEARM" (technically enhanced artificial radioactive material) and possible techniques for detection and discrimination from attempts of nuclear smuggling are discussed.

P10-25

**Airborne and satellite data acquisition of the contaminated landscape for the countermeasures in agriculture****Hulka, Jiri; Cespirova, Irena**

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In case of the fallout from large accident of a nuclear power reactor or other large-scale release of radioactivity into the environment, a large area to the extent of 10 000 – 100 000 km<sup>2</sup> could be contaminated. To find out as quickly as possible the extent, magnitude and radionuclide vector of the contamination is important task for agricultural countermeasures and foodstuff restrictions in early/middle phase of accident. In this paper are analyzed the modern data gathering methods of landscape contamination. They are based on combination of satellite technology and airborne gamma dose rate and/or gamma spectroscopy. The issue of optimal height of flight, plane velocity, “hot spot” detection and strategy of mapping process are discussed. This work was supported by the grant of the State Office for Nuclear Safety Czech Republic No. 1/2008 “The new methods for evaluation of landscape contamination after large accident of NPP“

P10-26

**Long-term development of incorporation dose at Korma county (Belarus) after the Chernobyl accident****Dederichs, Herbert; Heuel-Fabianek, Burkhard;****Hill, Peter; Lennartz, Reinhard; Pillath, Jürgen**

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**Introduction:** Due to the Chernobyl accident in 1986 large parts of Belarus suffered from radioactive fall-out. In follow-up studies to the German Chernobyl project the long-term development of population dose has been investigated in highly contaminated regions. One project concentrated on the situation in Korma County. The measurements included mobile in-vivo monitoring of the population. We report on measurements performed between 1999 and 2007.

**Korma county:** The county is situated approx. 70 km north of the city of Gomel/Belarus and about 200 km from the Chernobyl NNP. There are areas of comparatively low contamination, but also confiscated zones. The municipality of Volincy is situated in the forest belt of Korma county and quite remote. Elevated body burdens had to be expected.

**Instruments and methods:** Van type mobile in-vivo monitoring laboratories were used to assess body burdens. The whole body counter especially designed to purpose used two large NaJ-detectors. Data acquisition and analysis was PC-based. A brick phantom had been used to determine weight dependent peak efficiencies. The calculation of dose is based on dose factors directly related to body burdens since a more or less chronic incorporation can be assumed. For youths and children dose factors were extrapolated for each year of birth.

**Evaluation of internal dose with time:** In 1999 body burdens of Cs-137 were still quite high. Over the time body burdens dropped significantly. The population group of 19 – 35 year old males proved to be of special concern. Generally the mean incorporation dose is now about to drop below 0.3 mSv/a, a value comparable to the dose obtained by the body content of K-40. Individual advice provided by the measuring team led to a changed attitude towards the consumption of contaminated food.

P10-27

**A real-time interaction environmental survey management system for nuclear and radiological emergencies****Fang, Hsin-Fa; Chang, Bor-Jing**Institute of Nuclear Energy Research, Health Physics Division,  
TAIWAN

In emergency events, environment could be polluted very severely and need a variety of environmental surveys. The environmental survey workers may be exposed to radiation and radioactive pollution. There is a need to confirm these survey workers are safe when they are working for emergency response. This study attempts to establish a management system with real-time interaction for environmental monitoring, which could analyze monitored environmental quality immediately, and manage the plans and areas of monitoring action online. The plans and areas of monitoring action could be adjusted interactively according to the manager's decision and monitoring results of environmental radioactivity. If the analyzed monitored results of the environmental quality exceeds a threshold standard, it can be an index of warning. Another purpose of this study is to provide a management system which could provide a safe area of monitoring actions with real-time interaction for environmental monitoring teams. The management has a data processing apparatus which could analyze the monitored data of the monitoring apparatus and send warning signal when it found that the monitored data exceeds threshold data. Then the monitoring teams and personnel could execute the work in safety.



S11-01

**Detection of and response to nuclear security events****Colgan, Peter**

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The paradigm of nuclear security continues to evolve. Whilst a body of work and a collective with relevant expertise is forming, the relationship and interconnectedness with the fields of nuclear safety and nuclear verification (safeguards) still needs day-to-day management to ensure States have in place an effective judicial, legislative, regulatory and policy framework which, when supported by coordinated implementation procedures, will assist in the prevention of malicious acts upon nuclear and/or associated facilities, as well as reducing the threats posed from the malicious use of lost, missing or stolen nuclear or other radioactive material to harm persons, property, society or the environment. This is particularly the case in the detection of and response to malicious acts involving nuclear and other radioactive material out of regulatory control. Here the States' traditional response arrangements need to be enhanced and coordinated to ensure that threats posed by criminal or unauthorised acts involving such material, and any dispersal event occurring as a consequence of a successful malicious act, are adequately dealt with in terms of both the need to detect the presence of the nuclear or other radioactive material in the lead-up to a nuclear security event, as well as the proper collection and control of evidence to ensure successful prosecution of the offenders, in accordance with the relevant international legal instruments to which States may subscribe. This paper outlines these additional considerations.

S11-02

**New threats and new challenges for radiological decision support****Andersson, Kasper G.<sup>1</sup>; Astrup, Poul<sup>1</sup>; Mikkelsen, Torben<sup>1</sup>; Roos, Per<sup>1</sup>; Jernström, Jussi<sup>1</sup>; Jacobsen, Lars H.<sup>2</sup>; Hoe, Steen C.<sup>3</sup>; Schou-Jensen, Leo<sup>2</sup>; Pehrsson, Jan<sup>2</sup>; Nielsen, Sven P.<sup>1</sup>**<sup>1</sup>Risø National Laboratory for Sustainable Energy, Technical University of Denmark, DENMARK; <sup>2</sup>Prolog Development Center, DENMARK; <sup>3</sup>Danish Emergency Management Agency, DENMARK

Over recent years the world has become increasingly aware that malevolent acts involving atmospheric dispersion of radioactive matter may occur and could severely affect large urban populations, both by leading to high radiation doses from dispersed radionuclides and by causing social disruption and fear. A comprehensive and reliable decision support system that can be operated in real-time is essential to ensure that the repercussions are addressed optimally and consistently from the very beginning and seen in the context of the actual health hazards. The dispersion could be carried out in different ways, involving, e.g., 'dirty bomb' devices, simple aerosol generators placed on a rooftop, or emission from an aeroplane. Depending on both the dispersion process and the initial contaminant matrix, aerosols with very different size spectra and physicochemical characteristics can be produced. The importance of aerosolisation processes, atmospheric dispersion in complex urban terrain, and post-deposition contaminant solubility, fragmentation and migration are all discussed in relation to the various dose calculations needed to form reliable consequence prognoses. The paper reports on how these issues are being dealt with in an extension of existing European standard decision support systems to cover the consequences of terror attacks. Also non-radiological perspectives of radiological terror attacks are discussed.

S11-03

### Nuclear inspections on container traffic in the port of Antwerp

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After the 9/11 events in the US an international programme was started against nuclear smuggling as part of the effort to tackle terrorism. The goal is to deter, detect and interdict the smuggling of special nuclear materials. One of the key aspects of this program is to equip border crossings with nuclear detection equipment. In 2004 the Belgian government signed a memorandum of understanding with the US Department of Energy on the installation of detection equipment in the port of Antwerp. In February 2007 the inspections started in the port of Antwerp. On a daily basis about 20 000 containers pass the portal monitors in the Belgian ports causing about 150–200 alarms per day. Almost all alarms are due to the presence of NORM. One of the most important features of the inspections is to release containers with NORM or licensed radioactive materials in the shortest period possible. Therefore inspections are performed in a standard three-phased approach in order to minimise the effect of the inspections on the container flow. The decision process is based on the Belgian regulations on radiation protection, and international standards for nuclear inspections at borders. This decision process is part of a standard of procedures agreed on by Belgian Customs and the Belgian Federal Agency on Nuclear Control (FANC). Experiences show that finding nuclear smuggling is not a common thing. In the three years since the inspections have started no cases are reported in Belgium. But on the other hand the installation of the equipment has proven to be a strong tool in protecting the public against the incidental occurrence of non-natural radioactive materials in consumer goods. The inspections have also proven to be very effective in finding NORM, even in very small concentrations, in a wide range of commercially available products and raw material. Belgian Customs have a database of at this point about 150 different classes of products, ores and consumer goods.

S11-04

### Optical remote detection of alpha radiation

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Nuclear radiation detectors are based on direct interaction of radiation with matter. This means that pure alpha-active nuclides can be detected only at distances less than the range of alpha particles in air. However, the remote detection of alpha emitters is possible by measuring the ionization induced fluorescence of air molecules. N<sub>2</sub> is the main emitter of fluorescence in air and its fluorescence properties are well known. The main challenge in optical detection is to discriminate the weak fluorescence signal from all other background lights.

In this work, an experimental setup was designed and built for measuring the alpha induced fluorescence at the distance of 40 cm. Fluorescence photons are collected with a lens system to photomultiplier tube and counted. In dark background, activities down to 1 kBq can be detected. It was found that one 5.5 MeV alpha particle emitted by an <sup>241</sup>Am source yields to approximately 70 fluorescence photons in air. The most of the fluorescence intensity is in the characteristic peaks of the N<sub>2</sub> fluorescence spectrum at the wavelengths between 300 nm and 400 nm.

Based on the experimental findings, a portable prototype device with background compensating was constructed. The collected light consists of fluorescence signal and background light, which are divided with an optical beam splitter into two photomultiplier tubes. The both channels are filtered with interference filters to detect the fluorescence signal and the background light separately. The signals are analyzed using Currie's critical level. The critical level is set so that the result is a false positive only once in a million measurements with no real activity present. In the presence of bright yellow fluorescent illumination or white LED illumination, we can detect 0.1–1 MBq point sources at a distance of 40 cm using one second integration time. The new method looks promising for safety and security applications, where fast remote scanning of alpha radiation is required.

S11-05

**Identpro/SIA, an identification algorithm for statistically “poor” spectra**Gunnink, Ray<sup>1</sup>; Schulcz, Francis<sup>2</sup><sup>1</sup>GAMMARAY, Consultant, UNITED STATES; <sup>2</sup>MIRION TECHNOLOGIES (MGPI), Detection and Identification, FRANCE

Source or contamination search with mobile systems is generally limited by sudden changes in natural background leading either to setting detection thresholds at the maximum value of the background or, if set at the average level, of accepting some false positive identifications. This can be overcome in a process that separates, by taking “instant” spectra in real time, the isotopes of interest from the background components or from other innocent alarms like medical isotopes. Identpro/SIA is an identification method that has been developed for processing statistically “poor” spectra. While laboratory measurements typically yield spectra with counts in the 100 000 range, Identpro/SIA is able to process spectra with a few 100 counts from the source of interest in the presence of 1000 counts of background. Identpro/SIA uses a combined ROI / deconvolution iterative method that will be presented in detail. This method does not use a peak search technique and therefore is well adapted for low counts spectra with a having large statistical fluctuations. It supports the full isotope library for homeland security needs as defined by the ANSI, IAEA, and IEC standards. Furthermore it has been optimized for SNM identification including NORM or Medical masking scenarios with large unbalanced ratios, much beyond current standard requirements. Typical application is the identification and real time rejection of innocent alarms when pedestrians pass by a spectrometric portal. Another applications are source or contamination searches and mapping with carborne or airborne spectrometric devices. Results of field feedback will be given.

S11-06

**Developments in Radiological-Nuclear Support to Security through the Canadian CBRNE Research and Technology Initiative (CRTI)**Quayle, Debora<sup>1</sup>; Ungar, Kurt<sup>2</sup>; Hoffman, Ian<sup>2</sup>; Korpach, Ed<sup>2</sup><sup>1</sup>Department of National Defense, Centre for Security Science, CANADA; <sup>2</sup>Health Canada, Radiation Protection Bureau, CANADA

The Chemical, Biological, Radiological-Nuclear, and Explosives (CBRNE) Research and Technology Initiative (CRTI) was created to fund projects in science and technology that will strengthen Canada's preparedness for, prevention of, and response to potential CBRNE threats to public safety and security. Canada's federal radiological community – collectively known within CRTI as the Radiological Nuclear Cluster – has benefitted enormously from the collaboration upon which CRTI insists in order to qualify for funding. During the past few years, the RN Cluster has taken steps towards becoming more operational, through field exercises, providing reachback support for responders and, on occasion, forward-deploying scientists and technicians for major events. This foundation, coupled with creative application of technologies developed by partners, enabled Canada's radiological community to rapidly and efficiently develop a smart, scalable solution for radiation security at the Vancouver 2010 Olympic Games.

S11-07

**Radiological security measures at the United Nation Climate Change Conference in Copenhagen, 2009**

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From December 7 to 19, 2009 Denmark hosted the United Nation Climate Change Conference, COP15. For an event of such magnitude, security was a major concern. Danish Police in cooperation with UN decided to establish a dedicated CBRN (Chemical, Biological, Radiological, and Nuclear) security and emergency management project. The National Institute of Radiation Protection (NIRP) was expert advisor on the radiological security measures. These included access control and radiological surveillance at the conference site (Bella Center) and a mobile team that could perform screening tasks and emergency assistance in the Copenhagen area. Daily screenings of key locations in Copenhagen were made with car born gamma spectrometry in cooperation with Danish Emergency Management Agency (DEMA). The radiological security check at Bella Center was constructed to be discreet and with a minimal distraction of the traffic of delegates. The conference access control area was airport style with all together 25 lines with metal detector and x-ray machines for luggage scan. It was expected that approximately 15,000 delegates, journalists and NGO members would pass the security control over the course of the meeting. For personal screening walk-by plastic scintillation detectors were installed. Detection of any gamma radiation above 60 keV would trigger an alarm. Police and UN-security personal were instructed to stop the traffic in the access control area in case of an alarm and to contact the radiation expert. NIRP radiation experts remotely monitored the detectors from a nearby office and could arrive at the access control area within a minute after an alarm. Their equipment included a mobile HR Ge-detector that could produce a high resolution gamma spectrum in minutes. Three incidents were recorded with persons who had received radiopharmaceuticals.

S11-08

**International action plan for strengthening the international preparedness and response system for nuclear and radiological emergencies**

McClelland, Vince

UNITED STATES

P11-01

**Testing of a portal monitor to detect illicit trafficking of anthropogenic radioactivity in operational field use**

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Measurements were performed at the cargo container checkpoint of the German Customs Office at the Hamburg Harbour. At this checkpoint a radiation portal monitor (RTM 910, produced by Mirion Technologies) has been installed. The RTM 910 is capable of neutron and gamma detection with a low energy-resolution. To detect the gamma radiation plastic scintillators are used.

The RTM 910 has detectors on both sides of an incoming street to the checkpoint. The distance between the two detector parts amounts six metres and the cargo containers are transported through this portal monitor with an average velocity of 30 km/h.

In the field experiment 30 to 40 cargo containers were controlled per hour. In this time approximately three alarms per hour were given. To examine what kind of radionuclides caused these alarms, it was necessary to analyse energy spectra of the radiation when such an alarm occurred.

For the identification of the radioactive substances two other gamma detectors were used in addition to the RTM 910. One detector (ReGeM, produced by Canberra) was a high-purity-germanium detector with an energy resolution of less than 2 keV. The other detector (Spir Ident, produced by Mirion) is based on sodium-iodide and has an energy resolution of about 10 keV.

The idea was to take spectra exactly at the time an alarm was given by the RTM 910 and to identify the alarm causing radionuclides by analysing the spectra.

It was possible to identify radionuclides in the spectra that were simultaneously recorded to RTM 910 alarms. All the detected radionuclides are Naturally Occurring Radioactive Material (NORM). The spectra were analysed with two different programmes; SMI (a product of Mirion) and Genie-2000 (a product of Canberra).

The measurements at the Hamburg Harbour were conducted in cooperation with Mirion (Hamburg), the Fraunhofer Institute for Technological Trend Analysis (Euskirchen/Germany) and the technical service of the German Customs Office (Hamburg).

P11-02

**Detection of radiation sources and assessment of measurement signals for nuclear security**

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STUK – Radiation and Nuclear Safety Authority, FINLAND

Nuclear security is important at major public events and political meetings. The organizers and the law enforcement have to guarantee that no radioactive material is hidden at the venues. Portal monitoring is effective in controlling flow of people and goods. However, mobile measurements have to be carried out during the pre-event search and the event itself. Radionuclide detection capability is needed at the venues and the major routes.

STUK – Radiation and Nuclear Safety Authority started a project, known as VASIKKA, for in-field measurements. With EU-support another project, SNITCH, was launched for data management. Together they are intended to detect criminal use of radionuclides at the critical venues. End-users of the system are law enforcement agencies.

VASIKKA and SNITCH secure critical venues through integrated radionuclide detection capability, based on mobile monitoring, efficient data communication (in-field sensors) and data management, including automated data exchange from database to database via Internet. SNITCH transfers the alarms and the key analysis results immediately to command and control center. This enables timely response, based on the assessment of the key findings, against unauthorized or criminal acts related to nuclear or other radioactive materials. VASIKKA and SNITCH provide detection and data management means to fight nuclear terrorism, provide a highly effective mobile nuclear search and survey concept and promote cooperation among law enforcement agencies (data exchange).

A highly effective and user-friendly mobile detection concept for nuclear security was developed. The key components of the system are:

1. detection instruments,
2. detection software,
3. in-field communication tools,
4. data management software.

Traditionally solutions are available for physicists on items 1 and 2. However, the law enforcement needs higher-level automation for in-field work. This is given by VASIKKA and SNITCH.

P11-03

**Indoor positioning for nuclear security**

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Mobile measurements are needed to search for nuclear material out of regulatory control at major public events and political meetings. The teams may have to screen hotels and other venues before the event and during the event. Measurement and positioning information are crucial for planning the mission and for reporting the findings.

Traditionally the global satellite navigation system is used for positioning outdoors. Positioning indoors is difficult. There are various indoor positioning techniques on the market. They often need a specific infrastructure installed in the building. For authority work, the navigation system has to be easy to set up and easy to use in buildings where there are no pre-installed techniques available.

Radiation and Nuclear Safety Authority (STUK) has performed indoor positioning tests with Ekahau's wireless network based system. The experiences with the field tests were encouraging. Also a novel indoor positioning system has been developed by VTI Technologies. In this system navigation is based on the measurement of the length and direction of every step of a person. It uses a chest-worn speed and distance measurement module, originally developed for the sports market, together with an instrument-grade gyroscope and a magnetometer.

The measurement system and the navigation system write continuously data to the database. The collected data are transmitted to the command and control centre. The team positions are shown on the screen. If any radioactive material is found, an alarm is generated and the mapping system shows the place on the online digital map.

The measurement system works the same way indoors and outdoors. Only the navigation system varies. It is envisaged that in future the user does not have to know when the system is using satellite or indoor navigation system for positioning.

P11-04

**Control of nuclear materials and related radiation safety**

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Nuclear materials are special fissionable materials and source materials, namely uranium, plutonium, thorium, etc. The definition of nuclear material is very often related to implementation of nuclear safeguards. Handling nuclear materials is strongly regulated by national legislations, e.g. laws regulating nuclear safety or physical protection, as well as by international agreements e.g. EURATOM Treaty from 1957, Non – Proliferation Treaty from 1970, Convention on the Physical Protection of Nuclear Material from 1979. The material can be found at different premises, namely laboratories, storages, workshops etc. When handling such material not only radiation risk should be taken into account but also other risks. A comprehensive analysis of all risks should be done and it is vital that harmonised safety measures are applied. The regulations of nuclear material are changing from the first regulations in the middle of the last century, when such material was called “a product” in the Manhattan project. Especially after the Second World War the nuclear material became a subject of very intensive investigations and as a consequence the development of regulations followed. A special attention to nuclear materials was intensified after 11 September 2001 regarding serious threats. The article gives an overview of the development of regulations related to nuclear materials taking in parallel the development of radiation safety standards. It focuses on specifics of different national and international definitions of nuclear materials as well as on a use of other terms related to nuclear materials, e.g. special nuclear materials, source material, byproduct material. An overview of relation between present standards regarding nuclear safeguards and radiation safety requirements (ICRP 103, EU BSS, IAEA BSS) is given, taking into account a control of the material from its cradle to grave, e.g. finally to its disposal as radioactive waste.

P11-05

**Direct Alpha Analysis for Forensic Samples (DAAFS): Techniques, applications, and results**

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The goals of the DAAFS project are to develop new methods of sample acquisition and analysis for in-situ measurement of alpha radiation. In-situ alpha tests of DAAFS have been performed using either a well-characterised swipe technique with a fluoropore membrane filter, or a vacuum sampling system and optional surface impactor. The unique components of the DAAFS system include:

1. a variety of specialized sampling techniques,
2. a Monte Carlo spectral acquisition simulation software called Advanced Alphaspectrometric SIMulation (AASI) that simulates the alpha spectra by using the specific geometry and sample collection parameters,
3. an Advanced Deconvolution of Alpha Multiplets (ADAM) software package for fitting actual sample spectra, and
4. an advanced MySQL database management/telemetry subsystem called LINUX System for Spectral Information (LINSSI) with alarming and notification via email and SMS.

In addition to the nuclear safeguards and security design goals, other potential uses for DAAFS are: thoron progeny identification and possibly quantification of alpha emitters in drinking water, urine analysis, decommissioning and contamination measurements in nuclear reactors and laboratories.

P11-06

**Explosion tests using radioactive substance**

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 Aleš<sup>1</sup>; Helebrant, Jan<sup>1</sup>; Hulka, Jiri<sup>1</sup>; Kuèa, Petr<sup>1</sup>;  
 Malátová, Irena<sup>1</sup>; Michálek, Václav<sup>1</sup>; Rulík, Petr<sup>1</sup>;  
 Škrkal, Jan<sup>1</sup>; Hovorka, Jan<sup>2</sup>; Prouza, Zdenek<sup>1</sup>

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During recent years, the assessment of possible radiological consequences of a terrorist attack associated with a release of radioactive substances has been in the focus of interest of specialists in the field of the emergency preparedness and radiation protection, experts dealing with the proliferation of harmful substances in the atmosphere and other professionals. Suitable tools for these analyses are applications of mathematical and physical models and simulation of this attack under “realistic” conditions. In the Czech republic tests were performed in which radioactive substance Tc-99m (eluate of NaTcO<sub>4</sub> in 0.9% sodium chloride solution) was dispersed by the explosion (Industrial explosive 350 g of the PERMON 10T) with the aim to accumulate reliable data sets and information on the distribution of surface and volume activities for testing physical and mathematical models, currently existing or being developed. Tests were performed in which a radioactive substance was dispersed over a free area and area with artificial obstacles. Detection methods and techniques employed in these tests are described and values characterizing the radioactive substance distribution are presented as follows: dose rates, surface activities in horizontal and vertical directions, volume activities and time distributions of these quantities. Meteorological conditions were measured on site too. For particular sites selected within the area involved, air volume activities, weight concentrations of aerosols and aerosol particle size distribution were measured. This work was supported by the grant of the State Office for Nuclear Safety Czech Republic No. 2/2008.

P11-07

**Genomic-based biodosimetry monitoring analysis method**

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Large-scale radiologic emergency due to terrorism or large-scale accidents could result in potential radiation exposure of hundreds to thousands of people. The present guidelines for biological evaluation after such an event are still scarce. Therefore, there is a need for biomarkers of retrospective biodosimetry after radiation exposure and assessment human health risk. The frequency of chromosome translocations in individuals exposed to low to medium doses of whole-body irradiation served up till now these goals. Measurement of chromosome translocations in peripheral blood lymphocytes is presently the golden standard to quantify the effects of ionizing radiation and has been used for workers exposed to low or chronic doses. The major problem associated with the assessment of chromosomal aberrations is that it requires a considerable amount of time and labor for aberration scoring and that the sensitivity is rather low.

In this study, we used whole genome microarray expression profiling to identify genes with the potential to predict radiation dose across an exposure range relevant for dose discrimination and medical decision making in a radiologic emergency. Human peripheral blood from 10 healthy donors was irradiated *ex vivo* using mainly 0.1 Gy X-rays as low dose and 1 Gy as a high dose to be compared to non irradiated control cells, and global gene expression was measured at 8h after exposure identified previously as optimal time for gene expression. Data analysis revealed a clear cut in terms of the pathways modulated with the two doses. At the high dose (1 Gy) we observed mainly the induction of p53 responsive genes (MDM2, DDB2, XPC, EDA2R, SESN1, CCNG1) and pathways associated with cell death processes. In contrast, at the lower dose (0.1 Gy), we observed modulation of another set of pathways mainly associated with mitochondrial oxidative stress and chromatin remodelling.

In conclusion, our analysis method allowed us to discriminate between low and high dose exposures based on the modulated pathways, in contrast to other studies attempting to identify sets of marker genes expressed in a dose-dependent way, which might be biased by inter-individual variation.

*This work is financially supported by Belspo ( Belgian Science Policy).*

S12-01

**State-of-the-art activity measurement methods in radiation protection****Maringer, Franz Josef**

BEV – Federal Office of Metrology and Surveying, Ionising Radiation and Radioactivity, AUSTRIA

Numerous issues in radiation protection require appropriate activity measurements. Although today many methods are established to assess radiation exposure to man by physical models and mathematical simulations, there is also a strong requirement in technologically adequate, fair accurate, traceable and reliable activity measurements techniques and radionuclide analytics. To ensure effectively traceable measurement methods for all medically and technologically used radionuclides up to end-user applications, a network of primary and secondary national metrological activity standards are provided by national metrology institutes under the coordinative umbrella of the *Bureau International des Poids et Mesures (BIPM)* in Paris. The international progress of activity metrology and measurement is scientifically supported by the International Committee for Radionuclide Metrology (ICRM). In this paper, an overview of state-of-the-art activity measurement methods for all categories of radiation protection is presented. Special focus is given on current developments in emerging medical applications, radioecology, NORM and radon measurements, and uncertainty assessment. Recent improvements and practical implementation on the metrological quantification of radionuclide activity – from fundamental metrology to end-user applications – are covered. The scientific support of ICRM in the field of radionuclide metrology is illustrated. Eventually, international, European and national standards and scientific and technological co-operations and networks in radionuclide metrology and analytics are discussed with regard to upcoming necessities determined by recent ICRP recommendations and IAEA & EU Basic Safety Standard development.

S12-02

**Location and identification of radioactive materials on sea using airborne gamma-ray spectrometry****Nikkinen, Mika<sup>1</sup>; Kettunen, Markku<sup>2</sup>**<sup>1</sup>STUK – Radiation and Nuclear Safety Authority, FINLAND;<sup>2</sup>PVTT, CBRN Protection Technology, FINLAND

Considering the homeland security, one of the threats is that a nuclear device or radiological explosive device is transported to the harbor over the sea. A ship can carry rather large radiological device and if it is detonated close to densely populated areas or economically or strategically important locations the consequences may be severe. Possible source term can also be a marine nuclear reactor release or underwater detonation of nuclear weapon. In these cases the detection of source term is based on identification of fission and activation products that are spread and diluted to a large volume of sea water. The mapping is based on same methodology that is applied to the detection of radioactive fall-out on the ground. As the water masses are constantly moving, the radioactive materials are also changing the location and this requires constant monitoring activity for long period of time. As part of national security, these scenarios are exercised by using airborne gamma-ray measurement devices on the sea. Measurement over sea is actually very sensitive method as the background from natural radiation is close to zero and the detection capability is significantly better over the sea than over the land. The experience gained through these exercises show that also high-speed jet plane can be used in the identification tasks as we need only few seconds measurement time over the source. The detection system and search logic are illustrated in the presentation.

S12-03

### Quantification of NaI(Tl) whole body counter spectra using the EGSNrc Monte Carlo System

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A generic EGSNrc-Monte Carlo model for a whole body counter (WBC) with four NaI(Tl) detectors in a stretcher geometry – which is the setup both at Karlsruhe Institut of Technology (KIT) and at University Hospital of Cologne (UKK) – and the bottle phantoms previously used for their calibration was developed. The main purpose of this work was to determine whether numerical calibrations can replace the ones based on measured spectra of known activity concentrations.

**Methods:** Three main methods were developed and applied for the evaluation of measured spectra:

- The MC code simulates the physical properties of a given nuclide and determines counts per decay in given regions of interest (ROI) in the spectrum. A matrix of efficiency factors  $\text{eff}(\text{ROI}(i) \leftarrow \text{nuclide}(j))$  is calculated for all nuclides of interest and used for the evaluation of measurements. As the method uses overall count rates in the ROIs, no subtraction of peak baselines is required. This is useful in low count situations typical for whole body measurements.
- Activities were derived from the weighting factors of a fit of a sum of simulated spectra of nuclide decays to the measurement.
- Simulations of artificial “single energy” decays (only one photon energy with a 100% probability per decay), yielding efficiency factors  $\text{eff}(\text{ROI} \leftarrow \text{energy of photon})$ . Nuclide-specific efficiency factors  $\text{eff}(\text{ROI}(i) \leftarrow \text{nuclide}(j))$  were derived from a set of such simulations and applied.

**Results:** All methods were able to successfully replace the measured calibration spectra as proven at both institutions in a number of intercomparison exercises. A full set of “single energy” simulations offers a quick and flexible way to calculate efficiency factors for any nuclide without the need for further simulations or measurements. Moreover, Monte Carlo simulations offer the possibility to study the response of the counting system without the need of handling radioactive materials or relying on the properties of a real nuclide.

S12-04

### New opportunities of radiation portal monitors with plastic detectors

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The prevention of unauthorized transportation of nuclear and radioactive materials through borders of the states demands the creation of a high quality system of the radiation control. As the international experience shows, the radiation portal monitors intended for the first stage of the control, i.e. the detection of a radioactive source in an object which crosses a control zone, create the basis of such a system. In highly sensitive gamma-neutron radiation monitors, the detection of gamma sources is provided by plastic detectors. Despite of a rather low cost of such detectors, the creation of systems of the border (customs) radiation control is rather expensive as the total number of radiation monitors is very high. A tendency has recently appeared to use the monitors based on essentially new detectors, providing not only detection of sources, but also their identification (the so-called spectroscopic radiation portal monitors). However, these are so expensive that can hardly replace traditional monitors with plastic detectors. So, it is very important to search for ways to increase their efficiency. In the present paper the authors consider a possibility to increase the efficiency of traditional monitors with the use of the additional lead collimators installed on both sides of each plastic detector. On the basis of simple analytical approximations, some relationships are obtained; results of calculations coincide well enough with the experimental data. The influence of the collimator length and an angle of its slope to a detector surface on the signal /background ratio and the probability of source detection are evaluated, an optimum is revealed. It is shown that additional collimators allow increasing the probability of the source detection at the same false alarm rate, or decreasing the minimum detectable activity at the same detection probability.

S12-05Y

### Measurements and simulations of fission neutron spectra at the MEDAPP beam at FRM II and subsequent developments

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At the MEDAPP facility at the research reactor FRM II at Munich, 540 g highly enriched uranium plates can be inserted at the periphery of the moderator tank in order to convert thermal to fast reactor neutrons. The fission neutrons are used for medical applications as well as for technical measurements. With a detailed knowledge of the spectral shape, e.g., calculations of the neutron dose in a patient can be performed more precisely.

The neutron spectrum of this beam has been simulated with MCNP and transmission calculations. The simulations were verified by multiple foil activation using threshold reactions. The measured spectra were unfolded and equalisation calculations performed. The full flux of the beam was determined by three methods: a specially developed gold-waterbath-method; calculation on the basis of dose measurements in a water phantom; and by the combination of the results obtained by the activation foils.

For standard filtering with 3.5 cm Pb and 1 cm B4C(50%) resin, the measurements expose a Watt-type neutron spectrum with small epithermal additions and a mean neutron energy of 1.9 MeV. The neutron flux at the patient position 5.9 m distant from the converter plates is  $3.2 \times 10^8$  s<sup>-1</sup>cm<sup>-2</sup>, yielding a dose rate of 0.54 Gy/min for neutrons (and 0.20 Gy/min for the accompanying gamma radiation) in 2 cm depth of a water phantom. For non-clinical applications, e.g., the investigation of the radiation hardness of electronic components, the n-g-ratio can be changed by use of filters. Based on these results, further projects like the construction of a new collimator and the before mentioned dose distribution calculations were initiated.

S12-06Y

### Feasibility study of a Low Cost Wireless Ionising Radiation Sensor Network

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For radiation protection of workers and the environment a source oriented approach is indispensable. For such an approach to be effective, operational area monitoring is very helpful. Traditionally, area monitoring is done with handheld survey monitors or by fixed area monitors. The latter monitors are sometimes equipped with local or remote alarm indications. If source conditions in a workplace are relatively stable, periodic manual surveys usually are quite adequate. However, in situations of strongly fluctuating source strengths or variable locations, real time monitoring is often desired.

Eindhoven University of Technology hosts a 30 MeV proton cyclotron, mainly used for large scale radionuclide production, and radionuclide processing facilities. In all stages of production and processing there has been a growing need to monitor radiation levels in workplaces. Until now this has been done by a wired network of area monitors and by many small scale active and passive dosimeters. We found the wired network to be inflexible and expensive; the small standalone dosimeters fit our needs much better, but require a lot of manual work and manual data processing.

Therefore, we strive for an area monitoring system that is networked, flexible and cost-effective. The aim of this feasibility study is to design a modular area monitoring system, consisting of wireless sensors and to produce a working prototype.

The system we designed has modules with ZigBee protocol based transceivers, capable of forming several types of network topologies and a MDA300CA data acquisition board with a custom made radiation detector. The detector was constructed using a widely used PIN-diode, capable of detecting photon energies ranging from 35 keV to 1173 keV.

The wireless radiation sensor network is a real-time monitoring instrument which can be implemented in existing organizations and expanded on in several ways using commercially available components.

S12-07Y

**Results of model calculations and algorithm development related to a 3D silicon detector dosimetric telescope****Hirn, Attila**

Hungarian Academy of Sciences KFKI Atomic Energy Research Institute, HUNGARY

One of the many risks of long-duration space flights is the excessive exposure to cosmic radiation. The dose equivalent in orbit may be two orders of magnitude higher than that under the shield of Earth's atmosphere. In order to determine the dose equivalent on board different spacecrafts, the development of a 3D silicon detector telescope got underway in the Hungarian Academy of Sciences KFKI Atomic Energy Research Institute several years ago. In the course of my doctoral research I was taking part in the R&D activities related to the instrument, such as designing the measurement system, developing the electronic system, reconciling the scientific, the electronic and the mechanical considerations of the development, working out the algorithms of the on-board software as well as coordinating, controlling and managing the development. The present paper addresses two important issues of my work: the method of determining in almost real time the time intervals of the South Atlantic Anomaly (SAA) crossings of the International Space Station (ISS) and the calculations performed in relation with the anisotropy of the cosmic radiation field in low Earth orbit in order to compare the performances of 1D and 3D telescopes on board ISS. To switch between the SAA and nSAA spectra I developed an algorithm, which has been tested with model time spectra generated from time spectra measured by the DOSTEL 1D telescope. I calculated the parameter of the algorithm such that the probability of false switching was less than  $10^{-3}$ . With model calculations I also analyzed the effects of the angular dependence of the geomagnetic cut-off, the shielding of the Earth and the east-west asymmetry of the trapped particles on the measured deposited energy spectra. The results have shown that in case of the untrapped radiation the differences in the spectra could be attributed only to the shielding effect of the Earth. As for the trapped radiation a more pronounced directionality was obtained.

S12-08Y

**Sequential separation of alpha and beta emitters from natural samples by mixed solvent anion exchange and their subsequent determination****Rozmaric Macefat, Martina**

Rudjer Boskovic Institute, CROATIA

Determination of alpha and beta radionuclides in environmental samples, food and drinking water is important from the aspect of human health and environmental protection. Low level activities determination of pure alpha and beta emitters in natural samples, prior to detection and quantitative determination, requires isolation of radionuclide from the sample and simultaneous separation from interfering elements. The extraction chromatography is mostly used method in last decade. However, due to chemical and mechanical stability and low price, ion exchangers are a good alternative to expensive extraction chromatographic resins because they don't lose their capacity with multiple usage, whereas resins do. It is very important, for the ion exchanger to be applicable in the separation, that its capacity is not a limiting factor (ion exchange must not be a dominant mechanism of bounding). This work will show that anion exchangers in nitric form, in combination with alcohol solution of nitric acid, can be used for separation of all kinds of cations. The effect of dielectric properties of solutions on the bounding strength of particular cations to anion exchangers in nitric form, its effect on exchanger selectivity conversion for Ca, Sr, Y, Pb, Th, U, Am and Pu from  $\text{HNO}_3$  solutions in methanol, ethanol and acetone, as well as the separation possibility of various cations, based on changes in solution properties, will be presented. The effect of change in dielectric constant on the bounding strength of certain cations to the exchanger will be shown in temperature range from  $-50$  to  $20^\circ\text{C}$ , and how it can be used in cation separation. For quantitative determination of certain isotopes, already existing methods have been modified (LSC, Cherenkov counting, alpha and gamma spectrometry, ICP MS). Finally, simple and rapid methods, which are used in daily Laboratory work, have been developed for isolation and quantitative determination of  $^{89,90}\text{Sr}$ ,  $^{210}\text{Pb}$ , and other isotopes.

P12-01

**Indoor- and outdoor radiation exposure in a Cs-137 contaminated village in Belarus measured using luminescence dosimetry (OSL in NaCl and TL in LiF)**

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Ordinary household salt (NaCl) have previously been investigated in the laboratory and showed several promising properties for dosimetry e.g. a linear dose response down to a few tens of mGy. Here we report on the first investigation of NaCl as a dosimeter when used under normal environmental conditions indoor and outdoor. For this purpose, special dosimeter kits consisting of two chips of LiF and 30–50 g NaCl, were positioned inside and outside 16 houses in a highly contaminated village in the Gomel region (Belarus) during the summers of 2008 and 2009. After 2.5–3 months the dosimeters were collected and read out in Sweden using optically stimulated luminescence (OSL) and thermoluminescence (TL), respectively. The estimated dose rates from the two materials were then compared for each kit. As a third comparison, direct measurements using a hand-held radiation protection instrument (GR-110, Exploranium) was also conducted.

The radiation level is highly inhomogeneous in the village and also within the gardens. Compared to an estimated normal background (0.10  $\mu\text{Sv h}^{-1}$ ), the average radiation level is 3–8 times higher. Hence, the signals are relatively low for the measuring systems used. Despite this, multi-regression analysis from the first 7 houses suggests a strong correlation between the results of NaCl and GR-110 (NaI(Tl)) ( $r^2=0.82$ ). The correlation between the results of NaCl and LiF is weaker ( $r^2=0.55$ ). The study indicates that household salt can be used as a monitoring dosimeter at absorbed doses from a few tenths of mGy and under field conditions.

P12-02

**Visualization and quantification of lung content of radionuclides associated with emergency preparedness by means of clinical gamma camera**

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In a situation when radionuclides accidentally or deliberately are dispersed in to the environment there is an urgent need for rapid investigation of internal contaminated individuals. Many hospitals are equipped with gamma camera imaging systems that are normally aimed for clinical investigations, but can potentially provide resources for rapid assessments of radionuclides associated with emergency preparedness, such as Cs-137, Co-60, Sr-90/Y-90. In this work the possibilities to visualize and quantify an uptake of different radionuclide in the lung region using clinical gamma camera systems have been examined, mainly on a two-headed gamma camera system (Siemens MultiSPECT 2). An anthropomorphic phantom, in three different body sizes, was used to imitate a lung uptake of radionuclides in a recently internal contaminated person with a known single radionuclide. The signal in terms of the net counts of the gamma camera was calibrated with the lung inserts filled with homogeneous solution of Tc-99m, Sc-46 and P-32, or with point sources of Am-241, Tc-99m, Co-57, Sr-85, Cs-137 and Sr-90/Y-90, located in the right lung insert. The minimum detectable activity, MDA, of lung uptakes for the MultiSPECT system ranges from 0.53 kBq for Sc-46 to 50 kBq for P-32. The MDA-levels were far beyond the ALImin-value (Annual Limit of Intake) for the investigated radionuclide except for Am-241 with a MDA-value equal to 3.6 kBq and a ALI-value equal to 0.2 kBq. Curves of counting efficiency vs primary photon energy were obtained for all three body sizes to obtain a general response curve for a wider set of gamma emitting radionuclides. Images of the MultiSPECT showed distinct intensity maxima of ~2–3 cm radius from point sources of Am-241, Cs-137 and Sr-90/Y-90 (0.14, 0.16 and 2.3 MBq respectively) located at the right lung insert of the phantom. High resolution images of point sources obtained by a SPECT-CT system is also discussed and compared with planar gamma camera images.

P12-03

**Whole-body counters for measurement of internal contamination in Finland**Huikari, Jussi; Muikku, Maarit; Pusa, Sauli

STUK – Radiation and Nuclear Safety Authority, FINLAND

STUK – Radiation and Nuclear Safety Authority has two whole body counters for measurement of internal contamination. Both counters use high purity germanium detectors. The stationary system is installed inside a 50 ton iron room and the mobile unit is built on a truck chassis. Both counters are used to assess the internal exposure of radiation workers and the exposure of the Finnish public. Up to now in the mobile unit, information of the location of the internal contamination has not been available due to measurement geometry. For this reason, a project was started to design and build a new counter in order to obtain location information and improve detection efficiency.

The location information is important for the radionuclides that are not homogeneously distributed in the body, like freshly inhaled radionuclides by radiation workers and in the emergency situations when the intake path may not be so obvious. In addition, this new spectrometer gives more precise information about possible  $^{131}\text{I}$  accumulation in the thyroid. Furthermore, lower detection limits for some specific nuclides (like  $^{241}\text{Am}$ ,  $^{123}\text{I}$ ) which emit only low energy (< 200 keV) gamma rays will be achieved. Monte Carlo simulations exploiting MCNPX were used with voxel phantoms to guide the design process.

The mobile unit can also be mobilised in emergency situations and provides fast and reliable method for both screening and dose assessment purposes. The need for assessing internal radiation doses in emergency situations is evident which has been demonstrated after the accidents in e.g. Brasil and Ukraina. This paper describes a design of the new mobile counter and presents calculated predictions of detection limits and efficiency.

P12-04

**Determination of chest wall thickness of anthropometric voxel models**Hegenbart, Lars<sup>1</sup>; Guen, Harun<sup>1</sup>; Zankl, Maria<sup>2</sup><sup>1</sup>Karlsruhe Institute of Technology (KIT), Institute of Radiation Research, GERMANY; <sup>2</sup>Helmholtz Zentrum München GmbH (HMGU), Institute of Radiation Protection, GERMANY

Chest wall thickness is a crucial parameter for *in vivo* measurements of inhaled radionuclides in the lungs, especially for low-energy photon emitters. It is important to know the CWT of anthropometric voxel models since they are commonly used in radiation transport simulations, where one aim is to reduce systematic errors in the determination of counting efficiency for *in vivo* measurement. The knowledge of the CWT of voxel models becomes even more important when considering creating customised voxel models for individual workers. At KIT a novel method was developed to determine the chest wall thickness of anthropometric voxel models. It is based on measuring and averaging the thickness of tissue of inhomogeneous voxel layers from a projection of a detector on the body surface to the organ of interest (i.e. the lung). The method could be validated using KIT's LLNL Torso Phantom and its voxel model. Calculations of the CWT of the voxel model showed good agreements with values measured mechanically on the real phantom. The method is integrated in the in-house developed software Voxel2MCNP that is able to generate and visualise *in vivo* measurement scenarios and furthermore to prepare and evaluate Monte Carlo simulations. The introduced method allows also the generation of three-dimensional, colour-coded illustrations of the distribution of the tissue thickness in the chest region, which are also valuable information for detector positioning. The method is flexible and can be extended measure tissue thicknesses from any body surfaces to other organs of interest (i.e. liver). Furthermore Monte Carlo simulations of lung counting scenarios involving two germanium detectors were carried out to show the performance of the method with a selection of voxel models.

P12-05

**Measurements and Monte Carlo computation of the  $^{241}\text{Am}$  counting efficiency pattern along the case #0102 USTUR leg phantom**

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Some Actinides like Americium are bone-seekers, and according to their biokinetics are retained in the skeleton after an intake. Because of the radio-sensitivity of red-marrow and endosteum cells, the assessment of the bone activity is an important matter to take into account. *In vivo* counting of bone seekers is usually performed at the skull or at the knee, since the attenuation of radiation is here limited.

The USTUR (U.S. Transuranium and Uranium Registries) disposes of a unique physical phantom containing the left half of the skeleton of a donor significantly contaminated by  $^{241}\text{Am}$ . The left leg phantom, containing bones from hip to foot, embedded in muscle equivalent plastic, has an activity of 1026 Bq. This phantom was measured in three European *in vivo* facilities and one Canadian laboratory; Monte Carlo (MC) simulations were also performed to assess the reliability of numerical calibration based on voxel phantoms.

Using different Germanium detectors the same efficiency pattern was found by participants, when counting positions were comparable. A sharp increase of counting efficiency is found at the patella level, about 10 times higher than at other locations, at this level a 5 cm displacement of detectors can result in 50% change in efficiency. Measurements on each side of the leg show a significantly different efficiency pattern.

A voxel phantom was build after acquisition of 234 CT scan images and used to simulate the measurements. Despite the gross feature of the efficiency pattern is reproduced by MC simulations, discrepancies larger than 50% have been found for some measurements. Several factors can explain these discrepancies: difficulties in building the voxel model and in reproducing the measurement

conditions, uncertainty about the total activity and the activity distribution in bones.

Based on this study recommendations will be given to ensure reliable measurements, the efficiency obtained in this study will also be compared with other relevant data.

P12-06

**Advanced Monitoring In mixed Radiation Area – AMIRA****Bürkin, Walter<sup>1</sup>; Kellerer, Albrecht<sup>2</sup>; Roos, Hartmut<sup>3</sup>; Dielmann, Rainer<sup>4</sup>**<sup>1</sup>Saphymo GmbH, GERMANY; <sup>2</sup>GSF-Forschungszentren, GERMANY; <sup>3</sup>Strahlenbiologisches Institut, GERMANY; <sup>4</sup>Saphymo GmbH, Deputy General Manager, GERMANY

AMIRA is the result of a research project in cooperation with the Radiobiological Institute of the University of Munich a workgroup of the Saarland University as well as Saphymo GmbH. An active universally applicable dosimeter for use in radiation protection was developed which allows precise measurement of neutrons and photons in unknown mixed radiation areas. AMIRA uses a miniaturized tissue-equivalent proportional counter (TEPC) which simulates a tissue volume of 1 µm diameter. Use of a microdosimetric detector has the advantage that to each event of the energy deposition not only the portion for the dosis but also the lineal energy the microdosimetric analogon of the LET can be determined. In this way each event can be allocated with the correct quality factor for the determination of the equivalent dose. The sensitivity of conventional measuring techniques often varies by a factor of 10. Measurement results of PTB, Braunschweig and IRSN, Cadarache, France verify an exceptionally high energy response over the entire measurement range. A separate detection for example of neutrons and photons is therefore not necessary. The now extended development of the measurement device is based on reduced size and weight disposes of an economized MCA with more than four decades dynamic measurement range suppresses microphonic effects. The software saves the LET spectrum calculates and saves the total dose according to ICRP60 as well as the neutron/photon dose by LET separation. Due to the small compact construction it could be achieved for the first time to make use of the TEPC technology for applications everywhere where there is occupational exposition. Examples are in aircrew dosimetry or in the complete spectrum of the nuclear fuel cycle for the determination of the personal dose and dose rate.

P12-07

**Rapid off-line detection method for alpha-particle emitting radionuclides in water samples****Vesterbacka, Pia; Pöllänen, Roy**

STUK – Research and Environmental Surveillance, FINLAND

In a nuclear or radiation emergency there is a strong need for rapid off-line and on-line analytical methods to detect radionuclide threat agents in water. Efficient analysis tools are needed especially for rapid screening of samples with low and medium activity concentrations. Although different types of rapid detection methods are available, there is room to develop sensitivity of the methods.

In the rapid off-line method presented here, water samples were evaporated and the residues were measured by alpha spectrometry. A novel analysis tool known as ADAM was used to unfold the alpha spectra. Because of the omission of radiochemical sample processing there may be a number of peaks of different radionuclides present in the spectra. In the fitting, the peaks of each radionuclide are treated as a group which enables efficient spectrum unfolding even in the case of complex alpha spectra.

Sixty water samples were selected for the study. From the samples, an aliquote of 15 ml was evaporated into stainless disc under IR lamp. After evaporation the alpha particles were counted from one day to one week. From the same water samples, gross alpha activity concentrations were determined by liquid scintillation method. In addition, radiochemical uranium analyses were performed for 18 water samples to verify ADAM software in calculating U activity concentrations and isotopic ratios.

The results demonstrated that the correlation between activity concentrations calculated by ADAM to that determined by liquid scintillation method was good. Radiochemical analyses indicated that U isotope ratios were equal. Based on the results obtained in this study ADAM software can be used to rapidly detect low and medium level concentrations in water. Moreover, ADAM gives more nuclide specific information compared to the conventional methods based on either liquid scintillation counting or proportional counting. With this method sample preparation is simple and availability of the results is fast.

P12-08

**The progress in Minimizing Activity and Dose with Enhanced Image Quality by Radiopharmaceutical Administration (MADEIRA) project**

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The introduction of new and more beneficial diagnostic procedures combining CT and PET or SPECT is related to a rapid growth of medical exposures. The European collaborative project MADEIRA (Minimizing Activity and Dose with Enhanced Image Quality by Radiopharmaceutical Administration) within the 7th EURATOM FP aims to improve 3D nuclear medical imaging in terms of increase of spatial and temporal resolution and also of reduction of the radiation exposure. The project is organized in 5 work packages, which are identified as: WP1 assessment of clinical data, WP2 PET magnifier probe development, WP3 physics-based image processing; WP4 biokinetic and dosimetric modelling; WP5 training and dissemination activities. In particular in WP1 quantitative biokinetic data were collected in patients after administration of <sup>18</sup>F-choline and those data were used to develop detailed compartmental models and to evaluate the internal dose to the patient. Moreover, the biokinetic models were used as a basis to define more efficient protocols for data collection (WP4). The collected tomographic images were used to test different reconstruction algorithms (WP3) including some newly developed ones for which a patent is pending. In addition a special phantom for checking image quality in nuclear medicine imaging was designed and also for this a patent is pending. WP2 deals with the construction of a PET insert probe. The different modules of the probe have been developed and their performances monitored, and the probe prototype is going to be tested in clinical conditions with the use of the developed reconstruction methods. Finally, training and dissemination

activities include the organization of two training courses (Milano, November 2008; Malmö November 2009), and the Malmö Conference on Medical Imaging (June 2009) as well as the tutoring of graduate and doctoral students and young post-doctoral researchers.

P12-09

 **$^{177}\text{Lu}$  produced with high specific activity by deuteron irradiation for metabolic radiotherapy**Bonardi, Mauro L.<sup>1</sup>; Manenti, Simone<sup>1</sup>;Groppi, Flavia<sup>1</sup>; Gini, Luigi<sup>2</sup><sup>1</sup>Università degli Studi di Milano & INFN of Milano, L.A.S.A.Laboratory, Physics Department, ITALY; <sup>2</sup>INFN of Milano, L.A.S.A.

Laboratory, ITALY

Nowadays metabolic radiotherapy is in constant progress and there is a range of new radionuclides (RNs) and radiopharmaceutical compounds on the market. Although the production of RNs is improved, often it is not possible to achieve high AS, even in NCA conditions, and sometimes long-lived radionuclidic impurities are co-produced.

$^{177}\text{gLu}$  ( $t_{1/2} = 6.734$  d,  $\beta$ -emission 100 %,  $E_{\beta\text{-max}} = 489.3$  keV and  $E_{\gamma} = 208.4$  keV) is one of the therapeutic  $\gamma$  emitting RNs, which is starting to find several applications in nuclear medicine, especially for metabolic radiotherapy of cancer and radioimmunotherapy, thanks to its favorable decay characteristics (half-life of the order of few days, relative low energy of negatrons and gamma emission suitable for detection). Presently, the production of  $^{177}\text{Lu}$  is carried out mainly in thermal nuclear reactor either in carried added (CA) form by direct neutron capture reaction  $^{176}\text{Lu}(n,\gamma)^{177}\text{Lu}$  on enriched  $^{176}\text{Lu}$  target, or by neutron capture reaction on enriched  $^{176}\text{Yb}$  target, followed by negatron decay. This second method produces a high specific activity (AS) no-carrier-added (NCA) radionuclide, since  $^{177}\text{Yb}$  decays to the ground state  $^{177}\text{gLu}$  only.

We started to study an alternative method for the production of  $^{177}\text{Lu}$  by the deuteron activation of natural or enriched Yb targets. In order to optimize the irradiation conditions, the thin target yields were experimentally determined in the energy range from the threshold up to 19 MeV. The thick target yields were measured in order to compare with the production yield by neutron activation route. The contamination from the long-lived metastable level was evaluated too. Moreover a suitable radiochemical separation of Lu radioisotopes from Yb target and from the contaminants was pointed out.

P12-10

**High-grade radiochemical analyses are basis for good assessment in radiation protection**

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Vartti, Vesa-Pekka; Heikkinen, Tarja

STUK – Research and Environmental Surveillance, FINLAND

High-level risk assessment is very much based on results of qualitative and accurate radioactivity measurements. In future, need of knowledge of low doses is increasing. These raise requirements for research infrastructure and quality management in laboratory. This means e.g. documented working practices, traceability of the results, participating intercomparison, professional skill of personnel, data management, uncertainty estimations, continuous improvement and need for accredited determination methods.

At STUK development of a uniform and modern quality system started in 1997. Accreditation of laboratory processes was awarded by FINAS in 1999 and was renewed twice in 2003 and 2007 according to the European Standard EN ISO/IEC 17025 standard. The accreditation field is “Test of radiation safety and related environmental sampling”. Fields of testing in radiochemical analyses are artificial radionuclides and natural radionuclides.

Radiochemical analyses are made from food-stuffs, environmental, swipe and urine samples. H-3 and Rn-222 are determined without radiochemical separation using direct measurement by liquid scintillation spectrometry. Ion chromatographic extraction is used in Sr-89,90 and Pb-210 separation and ion exchange in Pu-239,240, Pu-238, Am-241, U-234, U-235, and U-238 separation. Po-210 is determined via spontaneous deposition onto silver disk and measured using alpha spectrometry. Low background proportional counter is used for Sr-89,90 measurements, liquid scintillation spectrometry is used for Sr-90 and Pb-210 measurements and alpha spectrometry is used in measurement of actinides. All data from samples and measurement is stored either in LIMS or LINSI databases in order to maintain traceability of the result.

Maintaining quality system and accredited determination methods STUK assures high-grade quality in radiochemical analyses, which are used as basic data of doses in risk assessment in radiation protection work.

P12-11

### Condition of liver, and iron and plutonium content

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Plutonium and iron share a common metabolism in transportation and accumulation in human body. This was also supported by this study, where the accumulation of plutonium and iron in liver was investigated. The <sup>239,240</sup>Pu and iron contents in liver correlated positively ( $R_s=0.378$ ) in healthy livers, but not in livers having pathological changes. In contrast to iron content, the plutonium content of fatty degenerated or cirrhotic livers was significantly lower than that in normal livers. This difference suggests that plutonium and iron are not similarly accumulated or excreted in fatty degenerated and cirrhotic livers. The plutonium contents in lung and bone of these persons did not differ from the average values of the same age group, which may suggest that plutonium is excreted from the liver cells mainly by feces, instead of having been recirculated.

P12-12

### <sup>240</sup>Pu/<sup>239</sup>Pu ratio in peat, lichen and air filter samples contaminated by global nuclear test fallout, the Chernobyl accident and other nuclear events

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The <sup>238</sup>Pu/<sup>239+240</sup>Pu activity ratio by alpha spectrometry is a useful method for separating the influences from nuclear weapons testing and the Chernobyl fallout. However, <sup>238</sup>Pu/<sup>239+240</sup>Pu activity ratios in global nuclear test fallout and weapons-grade Pu are nowadays so similar, that it is difficult to reliably distinguish the two Pu sources by using this activity ratio. Besides, the activity concentration of <sup>238</sup>Pu is usually relatively low compared to <sup>239</sup>Pu and <sup>240</sup>Pu in environmental samples, leading to high uncertainties in <sup>238</sup>Pu/<sup>239+240</sup>Pu activity ratio. As a complementary method for alpha spectrometry, ICP-MS provides the tool for identifying the origin of the Pu from global fallout or weapons-grade Pu, since the <sup>240</sup>Pu/<sup>239</sup>Pu mass ratio is clearly different in Pu from nuclear weapons testing and weapons-grade Pu.

<sup>238</sup>Pu/<sup>239+240</sup>Pu and <sup>241</sup>Pu/<sup>239+240</sup>Pu activity ratios have been determined for peat and lichen samples collected in Finland immediately after the Chernobyl accident in 1986, air filter samples collected in Sodankylä in 1963 and air filter samples collected in Astana, Kazakhstan, in 2002. The Pu activity ratios indicated contamination from global nuclear test fallout in air filters from Sodankylä, and in peat and lichen samples Pu has been deposited from global fallout and the Chernobyl accident. <sup>238</sup>Pu/<sup>239+240</sup>Pu activity ratio in air filters from Astana corresponded with the ratio in nuclear fuel of high burnup. In this study, a more exact estimation about the origin of Pu in these different types of samples from Finland and Kazakhstan was sought by determining their <sup>240</sup>Pu/<sup>239</sup>Pu mass ratios.

The membrane filters used for alpha counting were decomposed and the resulting solutions containing Pu were purified with extraction chromatography. Mass concentration of <sup>239</sup>Pu and <sup>240</sup>Pu in the samples was determined by quadrupole ICP-MS. Results from <sup>240</sup>Pu/<sup>239</sup>Pu mass ratio determinations for the investigated samples will be presented in detail in the poster.

P12-13

**Sensitivity of standard and Fpg-modified comet assay for estimation of DNA damage in peripheral blood lymphocytes after exposure to gamma rays**Garaj-Vrhovac, Vera<sup>1</sup>; Gajski, Goran<sup>1</sup>; Miljanić, Saveta<sup>2</sup><sup>1</sup>Institute for Medical Research and Occupational Health, Mutagenesis Unit, CROATIA; <sup>2</sup>Institut Ruđer Bošković, Laboratory for Radiation Chemistry and Dosimetry, CROATIA

The comet assay is a rapid and sensitive technique for measuring DNA damage. This assay detects single and double stranded breaks, sites of incomplete repair, alkali labile sites, DNA-DNA and DNA-protein cross-links. In addition, particular enzymes such as formamidopyrimidine glycosylase (Fpg) can be used for detection of oxidative damage at the level of DNA molecule by cleavage of 8-oxodG, FaPyGua, FaPyAde and other ring-opened purines caused by reactive oxygen species (ROS). The aim of this study was to test the sensitivity of both standard alkaline and Fpg-modified comet assay and to detect the type of DNA damage caused by gamma rays. In that manner, human lymphocytes were exposed to gamma radiation doses of 0.1 Gy and 4 Gy in vitro. With the standard assay increase in DNA damage was noticed for both exposure doses but was significant only at higher dose of 4 Gy whereas at lower dose there was no statistically significant increase in neither of the standard comet assay parameters. The Fpg-modified protocol showed significant increase in all the parameters measured for both exposure doses indicating that the modified version is capable of detecting a wider scale of DNA damage induced by gamma radiation. In addition, with the modified protocol it is possible to detect ROS mediated DNA damage, thus significant increase in modified comet parameters in comparison to the standard ones suggests that gamma radiation induces oxidative damage in DNA molecule. Correlation between different protocols of the comet assay suggests that Fpg-modified version is more sensitive to gamma radiation by virtue of measuring oxidative DNA damage in addition to the basal DNA strand breaks. Results obtained lead to the conclusion that gamma rays affect DNA molecule by ROS that are the most frequent product of gamma radiation. Additionally, human lymphocytes proved to be sensitive to ionizing radiation depending on the radiation dose and are suitable biomarkers for this type of research.

P12-14

**Gamma spectrometric sample measurements at STUK laboratories**Klemola, Seppo; Leppänen, Ari-Pekka;

Mattila, Aleks; Renvall, Tommi

STUK – Radiation and Nuclear Safety Authority, FINLAND

Finnish Radiation and Nuclear Safety Authority's (STUK) gamma spectrometry laboratory has more than 40 years experience in analysis of environmental samples. In this paper the facilities and applications of the laboratory will be presented. These include 14 HPGe spectrometers operated in specially constructed counting rooms. The methods of spectrum analysis and detector calibration are introduced with the emphasis on newly implemented and validated software UniSampo/Shaman. Integrated LIMS (Laboratory Information Management System) databases offer tools to manage large amount of data involved in spectrum analyses.

Since 1999 the method of gamma spectrometric sample measurements at STUK has been accredited according to the Standard EN ISO/IEC 17025. The scope of accreditation is defined as analysis of radionuclides emitting gamma-rays in the energy range of 30 – 2700 keV in environmental samples, biological samples and foodstuffs.

Applications of gamma spectrometry include surveillance of environmental radioactivity in Finland, radioecological studies of both natural and artificial radionuclides and contracted services for industry and trade. Gamma spectrometry laboratories offer analytical services also to national and international organisations and institutes. STUK laboratory is one of the 10 Radionuclide Laboratories certified by Comprehensive Nuclear Test Ban Treaty Organisation (CTBTO). This status is demanding challenge for quality system, proficiency of personnel and preparedness.

One of the tasks of the laboratory is to maintain measurement standards which ensure the reliability of radiation measurement. Measurement standards for activity determination of gamma-emitting radionuclides are accurate spectrometers with traceable calibration, validated methods, and certified radiation sources.

P12-15

### When is *in situ* gamma spectrometry motivated?

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*In situ* gamma-ray spectrometry has since the introduction of portable germanium detectors been a widely used method for the assessment of radionuclide ground deposition activity levels. It is, however, a method that is most often associated with fairly large and poorly known uncertainties. A large part of the combined uncertainty originates from the source characterization, e.g. soil density and activity depth profile. In order to reduce this uncertainty soil sampling and subsequent laboratory analysis is often needed. The more samples collected for this characterization, the lower uncertainty in the *in situ* measurement result. However, if a large enough number of soil samples are collected, the uncertainty in the ground deposition activity measure directly obtainable from soil sample measurements will surpass the uncertainty of the *in situ* measurement. This will then render the *in situ* measurement superfluous. In this work we have considered *in situ* gamma ray spectrometry from a decision-maker-point-of-view; at which uncertainty level is *in situ* gamma ray spectrometry fit-for-purpose, and at which uncertainty level are laboratory measurements of soil samples preferable.

P12-16

### Review of a modern application of spectrometer- radiometer of gamma-beta-radiation MKGB-01 "RADEK"

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In the year 2001 STC "RADEK" Ltd. company produced spectrometer- radiometer of gamma-beta-radiation MKGB-01 "RADEK". Since then the device is widely used by various scientific and educational institutions, certification authority, research laboratories and organizations of nuclear fuel cycles. Apart its common use as a measuring instrument of activities of  $\alpha$ -radiating radionuclides in samples of ground, vegetation, water, foodstuff, materials of construction and other substances, it was also applied as a basis for the construction of unique spectrometric units.

Thus, the Railway Service Institute uses MKGB-01 as a measurement instrument of radionuclide contamination of railway acres and roads. On basis of MKGB-01 the underwater gamma-radiation spectrometer was developed for Geologic Institute, allowing the radioactivity measurement of bottom silt with the moving of detector along the bottom. The same spectrometer was also produced for the Federal Security Guard Service of Russian Federation for installation on boats patrolling water area.

The special place in radioactivity measurement of radionuclides belongs to spectrometry of body radiation. So the SEG-10P was developed as a modification of MKGB-01. It is completely implemented in the form of armchair and allows to measure the activity of incorporate  $\alpha$ -emitting radionuclides. The apparatus is used by nuclear power plants and medical centers.

In 2006 in the Russian Center of Emergency and Radiation Medicine the expert spectrometric unit for human radiation measurement was constructed and put into operation. It is completely composed of analyzers of MKGB-01 spectrometer (14 pieces) and different types of detectors (scintillation and semiconductor detector). The unit is presented by steel chamber with  $4 \times 2 \times 2$  meters dimensions edged by lead, cadmium and copper. The chamber is provided by scanning operation.

Due to STUK Finland has about 50 devices of such kind.

P12-17

**Radiation monitoring network with spectrometric capabilities: implementation of LaBr<sub>3</sub> spectrometers to the Finnish network**

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Dose rate monitoring networks equipped with Geiger-Müller or proportional counters can provide an alarm with sensitivity to about 0.1 µSv/h increase over the background. For airborne activity the 0.1 µSv/h increase translates to activity concentrations in the kBq/m<sup>3</sup> range. Better sensitivity and nuclide identification can be achieved by gamma spectrometers with sufficient energy resolution. LaBr<sub>3</sub> scintillators provide a good energy resolution of about 2.5% at 662 keV enabling the separation of <sup>131</sup>I (364.9 keV) and <sup>214</sup>Pb (351.9 keV) lines. The detectors have an adequate sensitivity and are reasonably priced, making them suitable for monitoring network applications. Drawbacks of LaBr<sub>3</sub> detectors are the radioactive impurities in the material and the gain variation as a function of temperature. A fitting algorithm based on the impurity <sup>138</sup>La/<sup>40</sup>K multiplet at 1430–1470 keV was developed to stabilize the detector. With the software controlling the LaBr<sub>3</sub> spectrometer during data acquisition the system gain is stable and provides environmental spectra of excellent quality. The same fitting algorithm is applied to the analysis of the whole spectrum. Several spectrometers have been recently installed around the Finnish nuclear power plants. Measurements are sent to a database at STUK headquarters over a secure wireless TETRA network at ten minute intervals. The spectra are automatically analyzed and checked for the presence of small signatures of man-made activity. Airborne or fallout nuclide activity concentrations and the dose rate are calculated from the spectra. The detection limit for <sup>131</sup>I is roughly 40 Bq/m<sup>3</sup>. An activity concentration of 1700 Bq/m<sup>3</sup>, yielding an increase of 0.1 µSv/h in the dose rate, would be needed to create an alarm in the Geiger-Müller monitors. The LaBr<sub>3</sub> spectrometer system now in operational use in Finland, is an excellent enhancement to the country-wide radiation monitoring network providing nuclide identification with high sensitivity.

P12-18

**Sample screening to locate active particles with position-sensitive alpha detector**

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In nuclear safeguards and in forensic studies, the number of collected samples is often large. In practice, all samples cannot be comprehensively analyzed with destructive assay methods, such as mass spectrometry. Therefore, it is important to screen the samples in order to find the most interesting spots. However, the screening methods currently in use are time-consuming or locate single particles inaccurately.

A position-sensitive alpha detector, supported with a novel locating algorithm, is a promising screening approach. The present analyses were made by analysing a sample containing multiple micrometer-sized particles consisting of weapons-grade plutonium. The measurements were done with the PANDA testbed, which contains a 64 × 64 mm<sup>2</sup> Double-Sided Silicon Strip Detector (DSSSD) with a pixel size of 2 × 2 mm<sup>2</sup> (see the work of Jani Turunen).

Our research revealed that screening with a pixel detector locates the alpha-active particles accurately enough for most particle analysis methods. If the sample contains one particle with significantly higher activity than the other particles present, the location of this particle can be determined quickly and reliably. Analysis of samples containing several particles with similar activities was found to be significantly more complicated. Typically, the distance between the particles of the same kind must be at least of the same order as the pixel size before the particles can be distinguished from each other.

For locating particles, the DSSSD is simply a pulse counter. However, if the number of detected counts is high, the alpha detector can also be utilized as a spectrometer to perform preliminary isotope analysis. Compiling isotope and location information allows further assay methods to be focused only on the spots containing the key isotopes.

P12-19

### Position-sensitive measurement system for non-destructive analysis

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The Finnish Radiation and Nuclear Safety Authority, STUK, is conducting research on non-destructive sample analysis. One of the main tools used for this research is called PANDA (Particles And Non-Destructive Analysis).

Rather than just being a device tailored for a specific use PANDA is more like a development platform. It has two vacuum chambers. The first chamber is for loading and changing the samples and the second for the measurements. The currently operational measurement set-up consists of an HPGe detector to detect gammas and a Double Sided Silicon Strip Detector (DSSSD) to detect alpha particles. These detectors are placed face to face in PANDA's measurement position 1 (MP1). Samples are transported from the loading chamber into the middle of these detectors using a linear feedthrough. The distance between the HPGe and DSSSD is about 8 mm. This setup allows simultaneous alpha-particle screening of large area samples (around 40 cm<sup>2</sup>), position sensitive alpha-gamma and gamma-alpha coincidence studies and various half-life investigations. For example, alpha-gamma coincidence technique provides nearly background-free gamma spectra of alpha decaying nuclides.

After the sample is screened in MP1 it can be transported to measurement position 2 (MP2) where interesting parts of it can be further investigated. At first MP2 will host a single small area (10 mm<sup>2</sup>) silicon drift detector that has a superior energy resolution as compared to the detectors of MP1. The main focus of MP2 will be in detecting conversion electrons, alpha particles and X-rays.

The data of MP1 are recorded in event mode, i.e. all events are timestamped. The resulting binary event files are converted to xml-format and transferred to a database. Various analysis algorithms are currently being developed to make the analysis process semi-automatic. The performance of PANDA is presented through the measurement and analysis of various environmental samples.

P12-20

### Application of the MKGB-01 spectrometer-radiometer in the KX gamma-coincidences setup at the D.I. Mendeleyev Institute for Metrology

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The prototype of setup that implements of KX-gamma coincidences technique developed at the ionizing radiation department of the D. I. Mendeleyev Institute for Metrology is described. The basic element of setup is MKGB-01 spectrometer-radiometer (STC "Radek"). MKGB-01 units – NaI(Tl) crystals of 100 mm × 40 mm and 80 × 80 mm are used for photon radiation detection. The standard set of "CAMAC" units is used as a secondary electronic part. Original design multi-channel counting system is used for counting rate measurements. The main metrological characteristics of the setup model were determined: a long-term stability, background, dead time, resolution time.

Using the described setup the electron-capture radionuclides Mn-54, Co-57, Zn-65, Y-88, Ce-139 activity was measured. The combined uncertainty ( $K=2$ ) of activity was estimated in the range 0,5–1,0%. Using KX-KX coincidences technique I-125 activity was measured with combined uncertainty of 1,0% ( $K=2$ ). The results obtained are in good coincidence with international comparisons results.

The main result of investigations is a conception of a new KX-gamma coincidence setup based of the MKGB-01 serial spectrometer-radiometer. A number of requirements for the secondary electronic units have been declared, a device for source positioning has been designed and an achievable uncertainty of the KX-gamma coincidence method has been evaluated. The supplementary investigation for determination of possibility to use the MKGB-01 spectrometer-radiometer for realization in beta-gamma coincidence technique.

P12-21

**Comparison of two techniques for low-level tritium measurement – gas proportional and liquid scintillation counting****Barešić, Jadranka; Horvatinčić, Nada;  
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Measurement of low-level tritium activities in natural/no polluted waters, e.g. in precipitation and groundwaters, requires special techniques for water pretreatment and detection of low-level radioactivity. Two methods for low-level tritium measurement have been developed in Zagreb Radiocarbon and Tritium Laboratory: gas proportional counting (GPC) and liquid scintillation counting (LSC). GPC technique has been used since 1978. CH<sub>4</sub> is obtained by reaction of water (50 ml) with aluminium carbide at 150°C, purified and used as a counting gas in a multi-wire GPC. The counting energy window is set to energies between 1 keV and 10 keV to obtain the best figure of merit. Gas quality control has been performed by simultaneous monitoring of the count rate above the tritium channel, i.e., above 20 keV. The limit of detection is 3 TU. New method of tritium measurement by LSC Quantulus 1220 using electrolytic enrichment of water samples has been developed in 2008. System of electrolytic enrichment consists of 20 cells of 500 ml volume and equipments for primary and secondary distillations. For each enrichment run 3 spike and 2 dead-water samples are used for system control. Final volume of water sample after electrolysis is 19 ± 1 ml and obtained enrichment factor is 20 ± 2. Mixture of 8 ml of water and 12 ml of scintillation cocktail Ultima Gold in plastic vial is used for counting in LSC. The limit of detection is 0.3 to 0.5 TU. Our Laboratory participated in the intercomparison study organized by the IAEA, TRIT2008. The data evaluation of six samples using S-plot analyses revealed that all results measured by LSC are accepted, and for GPC results four results are accepted and two results of samples with low tritium activity (<2 TU) are in the warning level. The tritium results of TRIT2008 intercomparison as well as of groundwater and precipitation samples will be presented for both GPC and LSC techniques.

P12-22

**Multi-screen diffusion battery for radon progeny dispersion analysis****Bastrikov, Vladislav; Rogozina, Marina;  
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The screen-type diffusion battery method was enhanced for size distribution measurements of radon progeny air particles. The measurement technique implies multisection arrangement of several dozens of screen stages and a backup filter during sampling with subsequent activity measurement of each component. Variations on quantity of screens, flow rate and screen meshness allows to obtain required cut-off diameters of the stages and essential operating size range in general. Serial mounting of screen blocks with continually narrowing penetration curve is also used. Optimal parameters were adjusted for radon progeny size distribution researches.

Size distribution measurements of radon progeny in the range of 1 – 400 nm were performed in the laboratory radon box with high radon equilibrium-equivalent concentration (5 – 20 kBq/m<sup>3</sup>). Generally accepted modes of unattached and aerosol fractions were confirmed. The smallest mode is represented by the primary free particles (geometric mean diameter 1.75 nm, geometrical standard deviation  $\sigma_g = 2.0$ ). It appeared that the nucleation mode consists of three modes (8.5, 20 and 40 nm with  $\sigma_g$  1.5, 1.2 and 1.7, respectively). Two modes of the accumulation mode were also observed (120 and 300 nm with  $\sigma_g$  1.5 and 1.2, respectively).

Knowledge of dispersion behavior of natural radioactive aerosols and gases is critical for understanding human exposure and for appropriate measurement technique development, especially in the case of unattached fraction. Results obtained in the work have particular value from this point.

P12-23

### Evaluating on-site monitoring cart conceptually developed for radiation workplace

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To develop an on-site radiation monitoring cart, necessary apparatuses including a NaI(Tl) scintillation survey meter,  $^3\text{He}$  proportional neutron survey meter, alpha/beta measuring system, HC collector, liquid scintillation counting system, dust sampler, and tritium gas monitor were selected from commercially available equipment. They were conceptually installed to construct a monitoring cart 1635 ~ 800 ~ 1500 mm and 750 kg. The cart was evaluated for its radiation detection limit. The NaI(Tl) scintillation survey meter and  $^3\text{He}$  proportional survey meter are used for monitoring radiation doses of gamma rays and neutrons, respectively. The detection limits of those survey meters are less than 1/10 of the regulated limit. The alpha/beta measuring system is used to measure radioactive surface contamination with the smear method. The detection limits are less than 1/100 of the regulated contamination limit. The HC collector and liquid scintillation counting system are used to measure the  $^3\text{H}$  and  $^{14}\text{C}$  concentrations in air. The detection limits of both nuclides are less than 1/1000 of the regulated limit. If only tritium is measured, a tritium gas monitor can be used. The detection limit of the monitor is less than 1/10 of the regulated limit. For monitoring other nuclide concentrations in air, the dust sampler is used to collect dust in its filter. The filtrated dust containing radioisotopes can be measured using the alpha/beta measuring system. The detection limits of these measurements are less than 1/100 of the regulated ones for the more commonly used nuclides  $^{32}\text{P}$ ,  $^{125}\text{I}$ , and  $^{35}\text{S}$ . It is concluded that all apparatuses necessary for radiation monitoring can be compactly installed in an appropriately sized monitoring cart and that the cart has detection capability sufficient for radiation monitoring in a radiation workplace.

P12-24

### A new AMS system for actinides isotopic ratio measurements at CIRCE (Caserta, Italy)

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Anthropogenic long-lived alpha-emitting radionuclides have been (and still are) released in the environment by nuclear testing, nuclear accidents, and operations of fuel reprocessing and plant decommissioning. Among these  $^{239,240}\text{Pu}$  and  $^{236}\text{U}$  are the most significant. The Accelerator Mass Spectrometry (AMS) technique surmounts the limitations of other techniques used. In Italy no Nuclear Power Plant (NPP) is in operation, but the four dismissed NPPs are now being decommissioned; moreover, new generation of NPPs are reconsidered for future installations. Both the operations demand accurate investigations about the possible contamination by radioactive releases of nuclear sites and neighboring territory and of structural materials of the reactors. The monitoring activity requests ultrasensitive methodologies for the detection and quantification of ultralow activity radionuclides. Among radionuclides the alpha-emitting isotopes of actinide elements are the most critical also because of their toxicity. The radiation counting methods, due to the long half lives, do not provide the necessary sensitivity and, in some cases, resolution (e.g.  $^{239}\text{Pu}$ - $^{240}\text{Pu}$ ). The present contribution reports on the state of the art of a project, carried out at the AMS facility in the Center for Isotopic Research on Cultural and Environmental Heritage (CIRCE, Caserta, Italy), aiming to establish an ultrasensitive system for the measurement of concentrations and isotopic abundances of U and Pu, and to exploit this technique for the characterization, from the point of view of the contamination by U and Pu, of both environmental samples from the Garigliano NPP site and samples representative of the structural materials of the building and of the reactor of the same plant. At the same time the system provides a tool able to fulfill the analytical needs of IAEA for the campaigns for nuclear safeguards against illegal nuclear activities and the military use of weaponry with depleted uranium.

P12-25

**Neural network method for activity measuring in environmental samples****Finkel, Felix<sup>1</sup>; Bystrov, Eugene<sup>2</sup>**<sup>1</sup>Russian Mendeleev Research Institute for Metrology, RUSSIAN FEDERATION; <sup>2</sup>Atomtex, BELARUS

The spectrometric method is one of the most popular methods for activity measuring in environmental samples. It provides application of semi-conductor and scintillation spectrometers. Despite high measurement accuracy, high price and some difficulties in operation make semi-conductor detectors difficult to apply. Scintillation spectrometers, which are cheaper, are applied to determine activity of natural radionuclides. But continuous spectrum image on the monitor permits the spectrometers to measure not so many radionuclides and, thus, it restricts application of the scintillation spectrometers.

One of the ways to solve the problem is to use sophisticated mathematical analysis of decomposition of scintillation spectra. Examination of different spectrum analyses and devices, produced by means of these methods, reveals that sometimes the above solution is quite improper and has weak solution stability. Besides, some problems appear while applying these methods in field devices, which are to carry out scale analysis without a computer. As a result, simplified methods are applied, which reduce accuracy of activity determination.

The current article describes the method of decomposition of scintillation spectra into spectrum components by means of artificial neural networks. The aim of the above method is to determine activity of radionuclides in the source under measurement according to its radiation spectrum. The spectrum is acquired by means of scintillation spectrometer. If applying a laboratory spectrometer, which, as a rule, is equipped with a computer, the spectrum is transferred from the ADC to the PC, which operates with the above method. If applying field spectrometers, spectrum is to be processed by either a smart sensor or operating control unit. Activity calculation algorithm is equal in both cases.

P12-26

**Whole body counting with large plastic scintillators as a tool in emergency preparedness – determination of total efficiency and energy resolution****Nilsson, Jenny; Isaksson, Mats**

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Increased demands on emergency preparedness have lead to a renewed interest in whole body counting. A comparison between measured and Monte Carlo (MCNPX 2.6.0) simulated total efficiency and energy resolution for a whole body counter (WBC) with plastic scintillators has been made. The WBC, originally set up in the early 70's, consists of four large plastic scintillators (NE 102A) each measuring  $91.5 \times 76.0 \times 24.5 \text{ cm}^3$ . Each detector is equipped with two PM tubes mounted on a perspex light guide and the stainless steel detector housing has a 0.397 mm copper window. The model of the WBC included the scintillation material, detector housing, light guides and patient bed. The total efficiency was measured and simulated for sources in the energy range 356–1332 keV, placed along the axis of symmetry in longitudinal and latitudinal direction with 10 cm intervals. The number of counts in the simulation was a summation of scored counts using the f8 tally which scores the number of counts and deposited energy in the scintillators. The energy resolution from the simulation is characterized by a well defined full energy peak while the measurements show a smeared distribution. A model based on Breitenberger's (Breitenberger, E. Scintillation spectrometer statistics. Prog. Nucl. Phys. Vol. 4, 1956) description of the statistics of the overall energy resolution that also includes light yield non-proportionality and source position dependence was used to describe spectrum broadening.

Preliminary results shows a difference of 1–10% between measured and simulated total efficiency, but further simulations with added WBC shielding which will increase backscattering will be made and might correct for some of the deviation. Considering the spectrum broadening function the ambition is to present a useful broadening function at the conference.

P12-27

### Examination of patients using the whole body gamma ray counter that is calibrated according to the individual anatomy properties

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Recently G.H. Kramer, K. Capello and E. Cardenas-Mendez (“Voxel Phantoms: NORMAN vs. VIP-Man, What Differences Are There?”, Supplement to Health Physics vol. 96, No.2) concluded that “whole body counters can now be calibrated more accurately using voxel phantoms, but the improvement is not as great as one might expect”. However, we have a slightly different view on the usefulness of voxel phantoms during the whole body counter-assisted examination of patients. Although the merits of voxel phantoms during calibration of whole body counters using the standard voxel phantoms are really not very significant, during the examination of patients the properties of individual anatomy can introduce considerable corrections into the whole body counting efficiencies (for low-energy gamma emitters, it may lead to the 2-fold increase/decrease of the assessed activity). As an example, we performed whole body counter calibration and examination of patients, using both standard plastic phantom (developed by the Livermore laboratory, USA) and voxel phantom method (using the OEDIPE software developed at IRSN, France, and the well-known Monte Carlo code MCNP). During our studies, we obtained the correction factors that are needed for the transition from the Livermore plastic phantom to the individual voxel phantom.

P12-28

### An extrapolation ionization chamber for A-Ray detection and measurement

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The extrapolation ionization chamber is a special type of the cavity ionization chamber, developed by Böhm for the absolute measurement of the absorbed dose rate in  $\beta$ -ray beams. The cavity theory was first created for the absorbed dose measurement in photon radiation, but it was also created for charged particles. In the radiation metrology laboratory from IFIN-HH we built such an extrapolation chamber for  $\beta$ -ray, but we tried to find how it would work when irradiated with  $\alpha$ -ray. Firstly, we obtained the experimental curves of the ionization current versus the polarizing voltage,  $U$ . The former have quite a net saturation region. Then, we measured the saturation current of the chamber for different values of the distance between the electrodes (i.e. different values of the sensitive volume of the chamber). When we represented the graph of the ionization (saturation) current against the distance between the chamber's electrodes, we noticed that this curve is quite analogous to the same curve obtained for  $\beta$ -ray irradiation. So, by analogy, we concluded that for this chamber, the main requirements of the cavity theory are also fulfilled when the chamber is irradiated with  $\alpha$ -ray. This paper presents the results of the measurements concerning the  $I = I(U)$  and  $I = I(d)$  characteristic curves of the extrapolation chamber when it is irradiated with  $\alpha$ -ray from a Pu-239 radioactive source. Some concluding remarks are also included, concerning the possibility of developing an absolute method for the measuring the absorbed dose for  $\alpha$ -ray, based on the cavity theory.



S13-01

**Mesenchymal stem cells as drug cells for radiation burn treatment**

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Local radiation syndrome is marked by necrosis that may extend to the deep subcutaneous structures. Today, treatment is surgery, excision, graft and flap with sometimes bad results. It has been suggested that Mesenchymal Stem Cells (MSC) therapy could be used in order to treat numerous tissue lesions. We have performed a novel therapeutic approach of local radiation syndrome by using local autologous MSC therapy combined to surgery. For this purpose, autologous bone marrow cells were collected from the unexposed iliac crest. For GMP production, MSC were expanded in a closed system (MacoPharma partnership) containing an innovative serum free medium supplemented with human platelet lysate as previously described (Doucet et al., *J. Cell Physiol.*, 2005). Quality control assays evidenced that expanded cell population retained typical MSC characteristics and did not exhibit chromosomal abnormalities. As previously demonstrated, MSC produced many cytokines and growth factors which could have a critical role in improving the healing process by counteracting the local inflammatory waves and by promoting the autologous skin engraftment.

We believe that MSC act as drug cells delivering in situ in the lesion growth factors which contribute to the healing of the lesion. We have also demonstrated that after in vitro cell activation, the conditioned medium of MSC exhibited a similar effect on wound healing than that obtained with freshly expanded MSC. In case of caryotypic abnormalities occurring after in vitro MSC expansion, the use of MSC conditioned medium could be considered as a relevant alternative of MSC therapy. Other sources of MSC such as adipose tissue, gingival mucosa are also taken in consideration in view of setting up an allogeneic stem cell bank.

S13-02

**A new therapeutic approach for radiation burns combining surgery and mesenchymal stem cell administrations: About four cases**

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The physiopathological mechanisms of severe radiation burns are well described and their treatments are well codified but very difficult to perform with an important functional and vital risk. We present four patients with accidental local radiation burns and propose a new therapeutic approach combining surgery and local stem cell therapy.

The first patient had local radiation burns of left fingers and left buttock (Chile, 2005). We performed early excision of the irradiated part of the buttock after dosimetric reconstruction. We covered the buttock and the fingers with full thickness skin graft. Autologous Mesenchymal Stem Cells were locally administrated in the lesion in combination with surgery. The second patient had a very important radiation-induced skin necrosis located to the left arm from the shoulder to the elbow (Senegal, 2007). The surgical procedure used a pedicle latissimus dorsi muscle flap and a proximal forearm ante brachial flap after a very large excision of skin and triceps muscle. Several Stem Cell administrations were combined to the surgery after many bone marrow collections. The third patient had a local radiation burn of the hands (Tunisia, 2008). Full thickness skin grafts were combined with local stem cells administrations. The fourth current case presented a local radiation-induced burn of the limb and was also treated by surgery and local stem cell therapy (Equator, 2009). We obtained a complete and stable healing in all cases. Stem cell therapy using autologous expanded MSC has to be considered as an adjuvant treatment of the surgery corresponding to excision of necrosis tissues and flap reconstructions.

Our results demonstrate that this new therapeutic procedure using surgery and local stem cell therapy is very promising. We believe that this innovative approach could improve the treatment of local radiation burns in term of functional and vital results.

S13-03

### Experience of stem mesenchyme cell therapy in case of severe local radiation (x-ray) injure

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On the 13th of January of 2008 patient, 61 years old, addressed to admission department of Burnazian Federal Medical Biophysical Center of Federal Medical Biological Agency. Patient asked for medical help to different hospitals and at 350th day after exposure diagnose of local radiation injure (LRI) was defined. Unsuccessful try of iterative autografting was made. At 592nd day after exposure patient was hospitalized to Burnazian Federal Medical Biophysical Center of Federal Medical Biological Agency. The result of conservative therapy was decreasing volume of fibrin and non-active growth of granulations. In connection with depth and area of wound conservative therapy was not successful, patient was need surgical treatment. But his cardiac pathology did not allow surgical treatment. This situation was the reason to looking for new strategies of treatment of LRI. Scientific dates and little clinical experience allowed to use mesenchyme cell therapy to cover wounds in cases of LRI in combination with conservative therapy. Result of using of new technology was active growth of granulation, active peripheral epithelization and total epithelization of ulcer. In conclusion, this clinical case shows opportunity to use modern hi-tech medical methods in combination with conservative therapy to treat consequences of severe local radiation injures. At present this strategy of medical management is preferable method for patients with severe LRI and with contraindication to surgery.

S13-04

### New hematological criteria of acute radiation sickness severity

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Diagnostic criteria of acute radiation sickness (ARS), which based on peripheral blood cells, were described in numerous publications. However, not all suggested indices meet the requirements of accurate and early determination of ARS severity and only some of them could be used for integral estimation of hematopoiesis damage caused by radiation.

Retrospective analysis of hemograms was carried out in 133 patients who suffered from Chernobyl accident. From this amount 7 patients survived ARS grade 3 (severe), 27 grade 2 (moderate), 32 grade 1 (mild), and 67 persons was irradiated in doses less than 1 Gy.

As the new criteria we suggest following indices: a day of granulocytes primary decrease to 2.0, 1.0 and 0.5 Giga/l, and a day of thrombocytes primary decrease to 100, 50 and 30 Giga/l. The ANOVA statistical analysis showed that the patients, who were discriminated by ARS grade, demonstrated highly significant difference of time period from irradiation (day 0) till granulocytes and thrombocytes came down to mentioned above levels.

For integral estimation of hematopoiesis damage it is suggested the index of summary deficit of peripheral blood granulocytes and thrombocytes count between 10th and 55th day after the irradiation. It was calculated as the square of a figure (or several figures) on a graph, which bottom is a straight line meaning the low normal level of granulocytes (2 Giga/l) or thrombocytes (150 Giga/l) count. Slanting lines granulocytes and thrombocytes decrease or increase on the graph serve as the figure sides. Any calculation follows the graphic presentation of these mature cells dynamics. The summary cells deficit significantly correlated with doses of irradiation.

The criteria that were suggested enabled to estimate the severity of radiation damage and start the adequate treatment already on the early stage of ARS (during primary reaction and latent period).

S13-05

**Calixarene nanoemulsion:  
a new treatment for uranium  
skin contamination**

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In case of uranium cutaneous contamination, no specific treatment exists although it may induce a high internal exposure of individuals. In this context, we have developed an oil in water (O/W) nanoemulsion containing calixarene molecules dedicated to emergency treatment of uranium skin contamination.

The physicochemical characterization of the calixarene nanoemulsion has been performed by oily droplets size, zeta potential and pH measurements, as a function of calixarene concentration. The results suggest that calixarene molecules are present at the surface of the oily droplets. Thus, calixarene molecules are potentially available to trap uranyl ions present in an aqueous contaminated solution. This was confirmed by the *in vitro* evaluation of the calixarene nanoemulsion efficiency by ultrafiltration techniques. Indeed, more than 80% of uranium can be extracted by the calixarene nanoemulsion from an aqueous contaminated solution. Then, uranium percutaneous diffusion kinetics over 24 hours experiments, on intact or excoriated pig ear skin samples using Franz cells system, have shown that the application of the calixarene nanoemulsion immediately after the contamination quantitatively (98%) inhibits the uranium cutaneous transfer. Concurrent analysis of uranium distribution in skin samples by SIMS technique showed no significant accumulation of uranium or calixarene-uranium complex through the different layers of the skin, except within the *stratum corneum* in case of intact and non treated skin. A delayed application of the calixarene nanoemulsion (5 min, 15 min or 30 min) after the contamination on excoriated skin samples is still efficient since uranium transfer is reduced by up to 75%. Thus, for optimal efficiency, the treatments should be applied the fastest after the contamination.

In conclusion, this study has successfully demonstrated the efficiency of the calixarene nanoemulsion constituting a promising system to treat uranium contaminated skin.

S13-06

**Premature chromosome condensation  
(PCC) assay for dose assessment  
in large radiological accidents**

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A dose calibration curve for a practical PCC-ring assay was established and applied in a simulated, mass casualty accident. The PCC assay was validated against the conventional dicentric assay. A linear relationship was established for PCC rings after Co-60 irradiation with doses up to 20 Gy. In the simulated accident experiment, 62 blood samples were analysed with both the PCC ring and the conventional dicentric assay, applying a triage approach allowing crude dose estimate through analysis of a relatively small number of cells. Samples received various uniform and non-uniform (10–40% partial body) irradiations up to doses of 13 Gy. The results indicated that both assays yielded good dose estimates for the whole body exposure scenario, although in the lower dose range (0–5 Gy) dicentric scoring resulted in more accurate whole-body estimates, whereas PCC rings were better in the high-dose range (above 8 Gy). Both assays succeeded poorly in identifying partial body exposures, most likely due to the low numbers of cells scored in the triage mode. In conclusion, the study confirmed that the PCC ring assay is suitable for use as a biodosimeter following whole-body exposure to high doses of radiation. However, there are limitations for its use in the triage of people exposed to high, partial body doses.

S13-07

**The French Defense radiation protection service (SPRA) and the national response in case of a radiological accident**

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The French Defense radiation protection service (SPRA) is located on the site of the Percy military hospital which is well known for the treatment of radio-contaminated and irradiated wounded.

The SPRA is involved in many military and civilian training courses, especially to teach the principles of medical response in radiation accidents (triage of absolute and relative emergencies, specific technics and drugs, psychological aspects). Intervention in case of a radiological or nuclear event is also one of the major missions.

First of all, the SPRA has to control all the Centers for the treatment of radio-contaminated wounded in France (CTBRC). During the exercises performed by the French Navy or the Air Force (transportation of a nuclear weapon, accident on a ballistic missile submarine), the SPRA provides hygiene and safety support to Ministry of Defense and advises the headquarters.

If necessary, the SPRA is permanently able to send, by road or by aircraft, an expert team and an analysis team with mobile laboratories (spectrometric and radiochemical analysis) in France or overseas if requested by military or civilian authorities.

The SPRA has initiated for the French armed forces health service conventions with institutions like the French Atomic Energy Commission (CEA), EDF Group (Electricité De France) or the French Radiation Protection and Nuclear Safety Institute (IRSN) in order to supply the best medical care for an ionizing radiation victim in the nearest CTBRC or in the Percy military hospital.

P13-01

**Radioprotective efficiency from consecutive application of indralin and interleukin-1 $\beta$  at the acute irradiation**

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One of the most effective among modern radio-protectors is indralin. Indralin was successfully applied to protection of participants of liquidation of the Chernobyl atomic power station accident. The mechanism of radioprotective action of indralin depends on its adrenomimetic activity owing to what in cells the contents of oxygen is reduced, local hypoxia is developed and high radioresistant is appeared. For early therapy of radiating injuries the mechanism of stimulation of hemopoiesis is more important. Similar action on hemopoiesis possesses interleukin-1 $\beta$  – cytokine stimulating of proliferative activity of early predecessors of hemopoiesis. The purpose of research was the experimental estimation of efficiency of consecutive application of indralin and interleukin-1 $\beta$  at acute irradiation. Experiments are executed on 316 male mice (CBA x C57Bl) F1. Animals subjected to X-ray irradiation in LD50-90/30. Indralin entered per os in a dose of 200 mg/kg for 15 minutes up to an irradiation. Interleukin-1 $\beta$  injected intraperitoneally in a dose of 50 mg/kg through 15 minutes after an irradiation. As a result of the researches it is established, that at consecutive application of indralin and interleukin-1 $\beta$  the survival rate of the mice irradiated in LD50-90/30 increases for 40–60 %, depth of postradiation infringements of hemopoiesis is reduced, proliferative activity of hemopoietic cells increases. It allows to reduce expressiveness of leuko-, lympho- and neutrophilopenia in early terms after an irradiation and to speed up restoration of the contents of cells in peripheral blood. The stimulating effect of consecutive application of indralin and interleukin-1 $\beta$  is shown also in prevention of decrease in activity of myeloperoxidase and alkaline phosphatase, maintenance of higher level of glycogen in neutrophils of peripheral blood of the irradiated animals.

P13-02

**Hospital response plan for radiation emergencies: the project of Careggi University Hospital in Firenze**

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The plan described in this paper outlines the procedures used by Careggi University Hospital in Firenze in response to incidents where individuals are exposed to radioactive material either in case of radiological accidents (for instance during transportation, industrial or medical activities) or in case of malevolent use of radioactive sources. The main challenge in planning a radiological emergency response is the proper definition of departments and people involved, their own duties and responsibilities, the effective coordination among them, also taking into account the pre-existing hospital structures and concurrent routine activities. Moreover in a mass casualty incident, many people may come to a healthcare facility injured, contaminated, or not. Most of them are likely to be minimally injured or simply concerned about potential contamination, therefore needing just an ambulatory care or measurement. In any case the correct answer to everyone has to be given without interfering with the other activities of the Emergency Department. In this plan the functions, duties and responsibilities of staff people of every involved departments are reported in detail. The plan covers all the operating procedures starting from the radiation emergency alert till the closure of emergency operation, including the waste disposal.

The main topics of the plan are the preliminary hospital activation, the contamination assessment procedure, the possible decontamination of patients, the radiation protection of the staff. Special sections are devoted to define a list of radiation measurement instruments, emergency supplies and pharmaceuticals to be stored in the Emergency Department in order to properly handle the response.

This plan is part of a more general CBR hospital response plan, and a first step towards a regional response plan to radiological emergencies through the Italian National Health Service structures.

P13-03

### **Occupational medicine professionals and radiation accidents**

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Protection of the public exposed to nuclear-radiological agents (NRA) in medical or industrial installations is required in many countries by Regulatory and Health Authorities. National Authorities require training in all aspects of occupational and public exposures to ionizing radiation. Specific aspect of public exposure is in the case of accidents or terrorist/malevolent acts. Many countries increase their efforts to prepare medical workers for the intentional release of NRA within the civilian population by terrorists or accidents on nuclear/radiological installations. Presumed targets for terrorist attack are urban or suburban heavily populated locations. They are usually industrial parts of the cities, and bring additional risk correlated with industrial installations. For many people, the first point of contact with harmful agents could be their workplace, and therefore occupational medicine professionals (OCP) are considered as potential first responders to a terrorist attack. They are educated in health surveillance of personnel occupationally exposed to low-doses of harmful agents, including radiation. Still, the lack of training for medical response in radiation emergency has been recognized. Therefore, OCP must be additionally trained on the specific challenges of terrorism and emerging situations, including how to recognize and isolate, treat and track individuals who will need prompt and appropriate care, especially in the case of mass casualties. OCP from MMA, as members of NRCB team, are involved in different radiation emergencies: from decommission, depleted uranium, to terrorism, and therefore additional educational courses for students, general practitioners, and OCP have been organized. In this paper, our experiences and the main topics of this program are presented.

S14-01

**Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study****Cardis, Elisabeth**

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The rapid increase in mobile telephone use has generated concern about possible health risks related to radiofrequency electromagnetic fields from this technology. An interview-based case-control study with 2708 glioma and 2409 meningioma cases and matched controls was conducted in 13 countries using a common protocol.

A significantly decreased risk was seen in relation to ever having been a regular mobile phone user both for glioma (odds ratio (OR) 0.81, 95% confidence interval (CI): 0.70, 0.94) and meningioma (OR 0.79; 95% CI: 0.68, 0.91), possibly reflecting participation bias or other methodological limitations. Odds ratios were below 1.0 for all deciles of lifetime number of phone calls and nine deciles of cumulative call time. While there was no evidence of dose-response, a significantly increased risk of glioma was seen among users in the highest decile of cumulative call time (OR 1.40; 95% CI: 1.03, 1.89). That risk was greatest among subjects with tumours in the temporal lobe, where RF absorption is generally highest, and among subjects who reported using their phones on the side of the head where their tumour occurred. Self-reports of phone use are, however, subject to considerable recall error. Sensitivity analyses conducted to evaluate the robustness of the findings generally showed similar results.

Overall, no increase in risk of either glioma or meningioma was observed in association with use of mobile phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and errors prevent a causal interpretation. The possible effects of long-term heavy use of mobile phones require further investigation.

S14-02

**UV-A radiation enhances melanoma metastasis in mice****Pastila, Riikka<sup>1</sup>; Pitsillides, Costas<sup>2</sup>; Ylianttila, Lasse<sup>1</sup>; Lin, Charles P.<sup>2</sup>; Leszczynski, Dariusz<sup>3</sup>**

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Ultraviolet (UV) radiation (280–400 nm) is considered the major factor in skin cancer development, but the possibility that UV radiation may affect the metastatic properties of cancer cells has not been addressed widely. We have investigated the effect of solarium-derived UV-A (320–400 nm) irradiation on the metastatic capacity of mouse melanoma. Previously we have shown that *in vitro* UV-A radiation enhances the metastatic properties of mouse melanoma B16 cell lines by increasing the adhesiveness of melanoma cells to endothelium and changing expression of adhesion molecules. We have also shown that mice, which were first *i.v.* injected with B16-F1 cells and then exposed *in vivo* to UV-A, developed 14 days after treatment 4-times more of lung metastases as compared with the non-exposed group. However, the *in vitro* exposure of melanoma cells, prior to injection into mice, lead to induction only of 1.5-times more metastases as compared with the animals injected with non-irradiated cells. Therefore, UV-A-induced changes in the adhesive properties of melanoma cells can not, alone, account for metastasis increase observed after *in vivo* exposure of mice. We also determined the clearance rate of circulating melanoma cells from the blood circulation by *in vivo* flow cytometry, but no significant changes in the clearance rate were found that could explain the increased metastatic capacity.

One reason behind the increased metastatic potential of the melanoma cells can be the UV-induced decline in the cellular immunity. The measurement of UV-A-induced immunosuppression by standard contact hypersensitivity (CHS) assay has shown that UV-A causes a moderate (14–17%), systemic immunosuppression in mice. Therefore, we suggest that the UV-A-induced increase of metastasis might be a combination of the UVA-induced systemic immunosuppression and, to the lesser extent, the UV-induced alteration of the adhesive properties of the melanoma cells.

S14-03

### Investigation of sun habits in Sweden 2005 – 2009

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Sweden has a set of “National Environmental Quality Objectives”. One of which is: “A Safe Radiation Environment”, that includes several goals. One is that the number of skin cancer cases in the year 2020 shall not be higher than in the year 2000. To help implement this goal an indicator for UV-related behaviour was developed 2005 at the former Swedish Radiation Protection Authority (SSI)\*. In situations with strong ultraviolet radiation (UV), a person’s exposure to UV depends largely on individual behaviour. The indicator is derived from an exposure model that takes into account individual answers to questions of an annual questionnaire. There are questions on time spent outdoors, work and workdays, holidays, vacation season and activity, latitudes, skin coverage of clothing, use of sun blocks and sunbeds. Additional questions inquire about sun burns, attitude to tanning and knowledge of UV-radiation and skin cancer. The questionnaire is distributed each autumn to 2000 randomly selected persons representative of the population age 18–74 by the “Statistics Sweden” agency (SCB) on behalf of SSM (previously SSI). Statistics Sweden also collects and summarizes results from all questions. Information will be presented, data, results and PR-highlights of the recurrent investigation on tanning and outdoor habits – as well as the population UV-exposure indicator – from the years 2005 – 2009.

\* Acknowledgements to former colleagues at SSI and experts who worked or assisted with the enquiry and the assessment model in previous years: K. Yuen-Lasson (SSI), Dr. L-E. Paulsson (SSI) and Dr R. Bränström (Karolinska Institute).

S14-04

### Role of modulation in the biological effects of radiofrequency radiation

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The biological effects of modulated radiofrequency (RF) radiation have been a subject of debate since early publications more than thirty years ago, suggesting that relatively weak amplitude-modulated (AM) RF electromagnetic fields have specific biological effects different from the well-known thermal effects of strong radiofrequency energy. This discussion has been recently activated by the increasing human exposure to RF radiation from wireless communication systems. Modulation is used in all wireless communication systems to enable the signal to carry information. A previous review in 1998 indicated that experimental evidence for modulation-specific effects of RF energy is weak. This paper reviews recent studies (published after 1998) on the biological effects of modulated RF radiation. The focus is on studies that have compared the effects of modulated and unmodulated (continuous-wave, CW) RF fields; studies that have used only modulated or only CW signals are not included. While the majority of recent studies have reported no modulation-specific effects, there are a few interesting exceptions that warrant follow-up studies.

S14-05

**Location of gliomas among mobile phone users**

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The objective of our study was to evaluate whether the gliomas within the brain differ between mobile phone users and non-users. The energy absorbed from the radiofrequency (RF) electromagnetic fields of mobile phones depends strongly on the distance from the source. We would expect gliomas among users to be located nearer to the source of exposure i.e. mobile phones if such exposure increases the risk of gliomas. We used case-case analysis to evaluate whether location of the gliomas in the brain is related to the source of RF exposure. The study methods applied were novel and provide an improved approach to studying focal effects in the etiology of gliomas. By utilizing information on the tumour location instead of only amount of mobile phone use as in earlier studies, the case-case method enables focusing on SAR distribution of RF field. This offers a possibility to study biologically and physically more meaningful and refined hypotheses. The data consisted of 762 gliomas from seven countries with tumour mid-points assigned by neuroradiologists on a three-dimensional (1 × 1 × 1 cm) grid based on radiological images. The typical position of the mobile phone while used was assumed to be in the line from the external acoustic meatus to the corner of the mouth and distance was computed between this line and the mid-point of the tumour. The data analyses were made using unconditional logistic regression with distance as a categorical outcome (5 cm as a cut-point) in the case-case approach. In the case-case analyses non-regular users, those using mobile phone at the opposite side as the tumour and long-term users (>5 years) had their gliomas nearest to the exposure line, but the differences were statistically non-significant.

Glioma cases were closer to the exposure line in long-term users, but the differences remained non-significant. Our results do not suggest gliomas being located in those parts of the brain with the highest exposure to the RF field of mobile phones.

S14-06

### Hyperthermia-induced proliferative response in human cancer cell lines is counteracted by a 2.2 GHz pulsed signal

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The present study describes the cell growth response of two human cancer cell lines, HepG2 and NB69, to 24-h simultaneous exposure to two physical agents: mild hyperthermia and radiofrequency (RF), 2.2-GHz pulsed signals. The samples were sham-exposed or RF-exposed simultaneously inside two identical waveguides placed in a CO<sub>2</sub> incubator set at 37°C (standard temperature) or 38°C (mild hyperthermia). A complete discretized model of the setup was created for numerical dosimetry using FDTD software SEMCAD X. The average dose of RF radiation absorbed by the cultures was estimated to be subthermal (Thermal increase <0.1°C). At the end of the 24 h treatment the cell growth was analyzed through Trypan blue exclusion and cytometry.

At 37°C the NB69 line responded to the RF exposure with a consistent reduction in cell number (13.5% below controls,  $p < 0.001$ ) together with slight but significant changes in the kinetics of the cell cycle. In contrast, the HepG2 cell growth and cell cycle were not changed after the RF treatment. The + 1°C thermal stimulus alone induced significant increases in the number of cells in both NB69 and HepG2 lines (about 14% and 19% above controls at 37°C). This cytoproliferative, thermally-induced response was blocked in both cell lines by the simultaneous exposure to RF. Consequently, the results indicate that under standard temperature the HepG2 line is not responsive to the cytostatic effect exerted by the RF exposure in NB69 cells. However, under thermal stimulation of cell proliferation, both lines showed a similar, cytostatic response to RF, likely to be mediated by changes in the cell cycle. Studies are in progress investigating the mechanistic and molecular basis of the herein reported effects.

Supported by Spanish MoD under the Project MOU EUROPA ERG 101.013.

S14-07

### French population exposure to 50 Hz magnetic fields: EXPERS study

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**Introduction:** In 2001, the International Agency for Research on Cancer classified ELF magnetic field (MF) as “possibly carcinogenic to human”. These conclusions were based on a statistical association found in some epidemiological studies, unconfirmed by experimental results, between childhood leukaemia risk and a 24h mean exposure to MF higher than 0.4µT. The crucial question of epidemiological studies is the exposure assessment. Another is to know the relative contribution of all field sources in the daily environment. In 2006 the French Ministry of Health initiated a large study of personal exposure of the French population to 50 Hz magnetic field. The database will contain data for 1000 children (0 – 14 years) and 1000 adults.

**Method:** The exposure data were collected during 3 measurement campaigns between 2007 and 2009. The volunteers were randomly selected from telephone lists. Each of them wore an EMDEX II (Enertech, USA) MF recorder during 24h, and simultaneously filled in their timetable. In addition, all volunteers answered to a questionnaire about socioprofessional data and home.

**Results:** The arithmetic and geometric means are respectively 0.09 µT and 0.02 µT for children, 0.14 µT and 0.03 µT for adults. The statistical analysis includes:

- Search for the most discriminating MF descriptors from a hierarchical clustering classification followed by CART method and characterization of probabilities of belonging to more exposed groups. This led to a distribution of the studied sample into three groups for each type of population.
- Identification, by linear and logistic regression methods or non-parametric regression models, of factors leading a person to be more exposed. These factors will be presented in function of the type of population and of the type of exposure (over 24h or only during the day).

**Acknowledgment:** This study was funded by the Ministry of Health and Solidarities and realized by Supélec, with the collaboration of EDF and RTE.

P14-01

**Impact of post-processing in human body dosimetry exposed to 50 Hz magnetic field**

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**Introduction:** Demonstrate compliance to directive 2004/40/CE of the current density inside human body is a challenging problem for computational electromagnetism because no measurements are available as reference to validate results. A lot of formulations to solve Maxwell's equations on different human phantoms have been proposed since early 80s. It is important to establish their reliability and accuracy. In this work, we compare 4 of these formulations using the same geometrical model and physical properties. We focus on the effect of post-processing method on maximum currents.

**Material and methods:** We used a medium 4 mm-resolution model from ANSOFT (130 000 tetrahedrons, 19 organs conductivity) exposed to a 50 Hz vertical B field of 1mT RMS. We used 3 software on that model: CST, code\_Carmel and an academic code based on Getfem++ dedicated to the human body.

In order to get reliable maximum values, we had to avoid non-physical values given by twisted elements of the mesh. To measure element quality, we used the geometrical « radius ratio » criterion, based on radius of the inner-sphere and circumscribed spheres and the statistical filtering correction (99th percentile in place of the maximum value).

**Results and conclusion:** A good agreement between formulations is reached on organs with a low conductivity, and for them, the filtering is quite efficient. Important discrepancies are obtained on other organs, mainly those with high conductivity. On these organs, the maximum computed current is highly sensitive to the formulation and the geometrical filtering has no effect.

Besides, correction by the 99th percentile limits the magnitude. However such a filtering, which is widely used on regular computational grids, is discutable when used with the Finite Element method because it eliminates elements whose quality looks good. We think that a more founded criterion based on error estimators or on the quality of elements has to be preferred when the Finite Element is used.

P14-02

**Electric properties of mammalian tissues: ex vivo results from 1 MHz to 1 GHz**

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Electromagnetic radiations may interact with biological tissues by the way of biomedical devices for therapeutic or diagnostic purposes (hyperthermia, ablation therapy, NMRI,...). Another situation is related to electromagnetic fields sources in the daily life such as mobile or public or domestic devices. Many studies are currently done to determine their potential effects leading sometime to controversy between the published results. The electric properties of biological tissues are frequency dependence and major parameters that governs these interactions inside the human body. Techniques for both invasive and non-invasive assessment of tissue characterization were proposed since many decades. Different methods are used to determine them among which the so called bio-impedance. This paper presents and discuss results of ex vivo measurements on mammalian tissues done less than two hours after excision in a surgery department at the Nancy Cancer Center (France). Dielectric permittivity and electrical conductivity of female breast human tissues in the frequency range from 1 MHz to 1 GHz were measured. They are compared to previously published results and the differences discussed according to the influencing parameters.

P14-03

### Occupational exposure to electromagnetic fields in electrotherapy services and possible related health effects

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**Aim:** The assessment of possible adverse health effects in occupational exposure to electromagnetic fields (EMF) generated by electrotherapy equipments (ETE).

**Methods:** Exposure evaluation included ergonomical analysis and EMF measurements (static and low-frequency magnetic flux density, low- and high-frequency electric and magnetic strengths). Health status analysis comprised anamnesis, clinical and neurological examinations, exposure and subjective symptoms questionnaires. Psychological tests aim to put in evidence subtle changes of nervous system activity.

**Results:** 38 electrotherapists vs. 82 matched controls were studied. Magnetic and electric field measured levels generally didn't exceed ICNIRP Guidelines. However, when personnel get closer to the applicators, higher local exposure occurs. Hands and head seem to be the higher exposed. The number of treated patients and the different electrotherapy procedures induce variations in exposure duration. We met three generations of ETE and stray fields seem to be important in older ones. The newer devices show significant lower levels of non-intentional exposure. Health investigations show mainly nervous system subjective symptoms and signs (asthenia, memory and attention disturbances, irritability, vegetative disorders, headaches, dizziness, etc.). These findings seem to be more frequent in exposed and seems to be correlated with the exposure length.

**Conclusions:** Significant levels of EMF occupational exposure levels were found. Higher exposures are attributable to practice procedures, to peculiar electrotherapy procedures, to bad positioning of ETE, and to older generations of ETE. The lack of risk knowledge is an important factor for some exposure situations, but it could be corrected. Health findings point out to possible effects at higher levels but further studies should be done. Risk awareness policies are to be performed for both employees and decision factors.

P14-04

### Analysis of electric network data in the EXPERS study

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**Introduction:** The French Ministry of Health initiated a study of the personal exposure to 50 Hz magnetic field of the French population. The global results of this study, named EXPERS, are presented in another communication. A point of interest is the contribution of each source of exposure to the total exposure. We focus here on electric networks.

**Materials and methods:** MV2 collected for each subject:

- 24h magnetic field measurement
- timetable
- general questionnaire about home
- GPS coordinates
- address.

For each type of electric network, we determined the maximum distance between the electric network and the residence at which the electric network influences the home exposure.

All subjects within this corridor are noted as "exposed" to electric networks. Given the position of residences, this subjects were found by RTE and ERDF from their information systems (all data not yet available for ERDF).

However, because of width corridor over-estimation, it is important to know whether the "exposed" subjects are really exposed to electric networks, by analysing the magnetic field measurements.

**Results:** The EXPERS database contains 2048 subject and 1596 addresses.

The distances of the corridor go from 200 m for 400 kV power lines to 20 m for low voltage lines, underground cables and substations. A distance of 200 m was chosen for electric train lines because of less position precision.

The number of "exposed" subjects goes from 8 for 400 kV power lines to at least 759 for low voltage underground cables.

The number of subjects really exposed to electric networks goes from around 85% of "exposed" subjects to high voltage power lines to around 10% for low voltage underground cables.

**Conclusion:** This analysis shows that:

- the population exposed to high voltage power lines is small
- the indicator of distance chosen in this study is not very precise.

**Acknowledgment:** *This study was funded by the Ministry of Health and Solidarities and realized by Supélec, with the collaboration of EDF and RTE.*

P14-05

### **On implementation of the new methodologies concerning measurement of occupational electromagnetic field levels**

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Measurement of electromagnetic field levels is a very important step in assessing human exposure to electromagnetic fields present in the working environment. After the year 2000, the methodologies on electromagnetic field measurement have been much developed and improved and, at present, there is a big number of technical standards dedicated to various exposure situations.

The implementation of the new methodology on electromagnetic field measurement in the national practice might be difficult, expensive, time consuming and it requires high qualified and special trained personnel. Considering the big change in the methodology to be applied, we analyze the limitations, difficulties and errors that might alter the quality of field measurement and exposure assessment.

To overcome the temporary lack regarding the good knowledge and clear understanding of the new methods, the authors propose a simple strategy consisting in a few steps. A general methodology was elaborated to be assimilated by the personnel involved in this domain, before learning complex methods. Standardized models of measurement report have been proposed. To ensure a solid background, training activities of measurement operators should be carried out by experts.

In agreement with European demands, some specific measures have been proposed to be taken concerning information dissemination, consultancy activities and, if the case, classification of measurement service providers into basic level and high level services. As an example, our activities in Romania in this domain are briefly described.

P14-06

### Microlens formation as protective mechanism against direct laser radiation

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Laser radiation poses a significant threat to human eyes. Depending on power, even scattered radiation can produce damage (mostly to retina), not to speak of direct laser beam. The usual method of protection is through different kinds of filters (absorption, reflection, polarization, holographic) inside goggles or protective windows. Without exception all types of filters protect human eye from scattered or otherwise diffuse reflected laser light. All manufacturers of laser goggles specify that the eye is not protected against direct laser beam. We describe a novel principle of eye protection which is based on expanding laser beam by the filter material itself. In other words, when the laser beam hits the filter material, negative (diverging) microlens is formed almost immediately. The beam is strongly expanded by the microlens, thus reducing the energy density to tolerable level. To test the idea we have developed a suitable material – tothema sensitized gelatin. Tothema is a trade-name of a mixture of gluconates used to treat anemia. Mixture is added to ordinary cooking gelatin, rendering the material sensitive to laser radiation. Sensitivity was further enhanced at 532 nm by additionally doping material with eosin or betanin. Experiments have shown that upon irradiation, strong microlens (focal lengths far below -1 mm) forms quickly and the laser beam diverges, reducing the overall energy density. Results of measurements of dynamics of the process are shown.

P14-07

### Changes in motional activity of unicellular aquatic organisms after low-intensity electromagnetic radiation

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The effects of low-intensity 1 GHz (a mobile connection frequency) and 10 GHz (radar and satellite communications) electromagnetic radiation with energy flux density (EFD) of 5, 10 and 50  $\mu\text{W}/\text{nm}^2$  on a laboratory population of unicellular aquatic organisms – ciliates *Spirostomum ambiguum* were studied. The effects were registered by the criterion of change in spontaneous motor activity (SMA). SMA of ciliater was observed under the microscope. Two lines were deposited in the eyepiece of the microscope, crossing each other at right angles. A quantitative measure of motor activity of each ciliate was a number of intersections of the lines on the eyepiece of the microscope for 1 min. To do this, each ciliate was placed individually in a drop of water in a special cell with holes 5 mm in diameter and 2 mm in depth. *Sp.ambiguum* used for a long time to estimate the negative effect of chemical and physical factors on the environment. These ciliates have proved to be a sensitive bioindicator of low-intensity influences. Our research has shown that electromagnetic radiation reduces motor activity of ciliates already at such low levels of exposure as 10, 45 minutes and 8–9 hours respectively with EFD 50, 10 and 5  $\mu\text{W}/\text{sm}^2$ . The negative effect did not depend on a frequency of electromagnetic radiation in the diapason from 1 to 10 GHz. The effect had a threshold character. After reaching the threshold, the negative effect did not change with exposure and had a mass character. The level of SMA in the population of ciliates decreased at 40%. The negative effect transmitted to descendants of irradiated ciliates. The results were confirmed by independent experiments involving more than 5000 *Spirostomum*. Our results are interesting for practical using of protozoa's behavioral reactions for testing of biological hazard of electromagnetic pollution of aquatic environments. It is of interest as the general problem of electromagnetic activity on the biota.

P14-08

**Sunbed-usage by 12 – 23 year old in Iceland 2004 – 2009**

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In Iceland, polls have been conducted every year since 2004 among 1800 randomly selected individuals aged 12 – 23 years inquiring whether they used sunbeds in the previous 12 months. The intention was to determine the level of sunbed use by the young and to monitor the effectiveness of a yearly information campaign on the possible consequences of such usage. On average; approximately 20% of those between ages 12 and 15 said they used sunbeds as compared to 52% of those aged 16 – 19 years. For the whole group of 12 – 23 years old, 41% reported using sunbeds. A statistically significant 20% reduction in the number of users took place for the whole group aged 12 – 23. However, the reduction was smaller and statistically insignificant for those aged 12 – 15.

P14-09

**Evaluation of low frequency magnetic field exposure system for ICDs for in vitro studies**

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This paper presents an experimental set up and methodology for the in-vitro characterization of Implantable cardioverter defibrillator (ICD) immunity. A The signal disturbance is applied to the implant placed within a phantom (Plexiglas tank filled with gelatine). The metallic electrodes and the device under test are placed in a Faraday cage. The entire set up is controlled by a PC with HP-VEE software.

Below 1000  $\mu$ T no relevant effect was noticed or recorded at any frequency. In this paper the effect of fields from 1000  $\mu$ T to 4000  $\mu$ T were characterized. For higher levels, at 50 Hz perturbations are observed at the higher EMFs. However, we no longer observe these perturbations at the higher EMFs when we have contact between the implant and the defibrillation solenoid. The position of the probe and the coil are thus of primary importance. At 60 Hz, we observe false detection in the absence of contact. Surprisingly, when we have contact between the implant and the defibrillation coil at 60Hz, we see even more false detections at higher fields. At a frequency of 50Hz, when the angle of inclination of the field is 19 degrees, false detections were observed at higher fields, especially above 3200  $\mu$ T. When we increased the angle of inclination above 19 degrees, we observed false detections at low fields, even as low as 2000  $\mu$ T. It appears that increasing the angle of inclination from 27 degrees to 90 degrees does not have any additional effect on the probability of false detections observed at fields higher than 3000  $\mu$ T. At a frequency of 60Hz, when we increased the angle of inclination above 19 degrees, we observed false detections at lower voltages. When the angle of inclination was 27 degrees, we could observe false detections above 2400  $\mu$ T.

These effects show the necessity of a well documented (geometry, position of the device and the source, field levels etc...) experimental set up when in vitro results are reported.



S15-01

**Main directions of Russia activity in the field of radiation protection and public health****Kiselev, Mikhail<sup>1</sup>; Shandala, Nataliya<sup>2</sup>**<sup>1</sup>Federal Medical-Biological Agency, RUSSIAN FEDERATION;<sup>2</sup>Burnasyan Federal Medical Biophysical Centre, RUSSIAN FEDERATION

The status of radiation protection and radiation safety at the Russian hazardous enterprises is assessed as satisfactory. According to data of many-year monitoring, annual dose to nuclear workers is not more than 2.5 mSv. Contribution of the atomic branch to the public doses is not more than some parts of the percent. Over many years, any excess radionuclide discharge/pollution has not been registered and chemical contamination of the common air and water environmental media do not exceed the permissible concentrations. Indexes of the public health are similar to those for the whole Russian Federation. Chronic occupational morbidity rates are lower than 2.0 cases per 10 000 workers. The acute occupational pathology occurs very seldom, mainly due to incidents. Over 60 years of the nuclear industry history, 754 persons have been radiation injured, including 350 persons had diagnosis acute radiation disease; amount of deaths due to radiation was 71 (taking into account consequences of the Chernobyl accident). Today, Russia must develop the national system for control and keeping RP at the required level. This issue is very important in cases:

1. available nuclear legacy,
  2. regulation of environmental remediation,
  3. intensive development of power engineering.
- In paper will give some examples of the current radiation protection problems important for public health and scientific results of research on the health effects of long-term, low-dose radiation exposure. To solve these and said before other problems, the special Federal Target Program to assure "Nuclear and Radiation Safety for 2008 and for the period till 2015" is in progress.

S15-02

**National campaign for the search and recovery of orphan radioactive sources in Spain****Carboneras, Pedro<sup>1</sup>; Ortiz, Teresa<sup>2</sup>; Rueda, Carmen<sup>3</sup>**<sup>1</sup>ENRESA (National Company), Safety, SPAIN; <sup>2</sup>ENRESA (National Company), Radiation Protection, SPAIN; <sup>3</sup>LAINSA (Company), SPAIN

This paper aims to describe the main approaches, the steps taken, the experience gained and the results obtained in the campaign for the "Search and Recovery of Orphan Radioactive Sources" undertaken in Spain between February 2007 and December 2009. The paper aims to share the experience gained with others who are considering or are already involved in similar campaigns and to enable opinions to be exchanged with those responsible for such campaigns in other countries. The campaign was initiated by the Spanish Ministry of Industry, Tourism and Trade with the expert assistance of the Nuclear Security Council as a result of national legislation currently in force regarding the control of highly active and orphan radioactive sources, and was commissioned to ENRESA (the Spanish National Body for Radioactive Waste Management). The campaign tried to seek and recover the largest possible number of orphan radioactive sources (an orphan radioactive source is understood to be one which is detected outside the standard regulatory control system and which, when detected, has an activity level higher than the exemption levels established in national and European regulations), and involved the collaboration of various different agents and organisations where such sources were or might be found. Searches for radioactive sources were both non-physical (administrative) and physical ones. The paper provides details regarding the number and radiological characteristics of the sources which have been recovered in Spain during the campaign. Experience shows that, even though a suitable regulatory framework exists and though it is implemented efficiently by the supervisory authorities, as is the case in our country, orphan radioactive sources may still exist for various reasons. The proceedings in Spain previous to this campaign were and continue to be very positive as regard the recovery of control of the majority of radioactive sources existing in the country.

S15-03

### Mitigation of exposure to radon by household water treatment

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Naturally occurring radioactive elements are found in all ground waters, especially in waters from drilled wells which are used by approximately 200 000 Finns. With respect to effective dose, the most significant of the waterborne radioactive elements is radon. The first choice for a household that has an elevated radon concentration in their well water is to connect to a water distribution network. These networks, however, are sometimes unavailable and the only viable alternative is to remove radon by household water treatment. As a dissolved gas, radon can be removed from water by aeration. Several aeration techniques for removing radon have been introduced including packed tower aeration, diffused bubble aeration, spray aeration, tray aeration etc. Domestic aerators designed for removing radon are available from several manufacturers and they conventionally combine jet aeration and spray aeration. Alternatively, radon can be removed by granular activated carbon (GAC) filters. As a non-polar monatomic gas, radon is effectively adsorbed on activated carbon. GAC filters sold in Finland are typically pressure vessels with carbon bed volumes of 39–105 litres. It is important that these units are installed to remove radon from all household water because waterborne radon is partly released into indoor air during water usage. Aerators and GAC units exhibit average radon removal efficiency of 95%. More than one thousand households with elevated radon concentration in their well water have these units now. Among those who have purchased them the average effective dose through both ingestion and inhalation of waterborne radon has been reduced from 3.4 mSv to 0.2 mSv per year. Expressed as collective effective dose, the reduction is about 9 man Sv per year. There are still, however, about 6000–8000 wells with elevated radon concentrations that have to be located and for which suitable mitigation measures need to be found.

S15-04

### Dose assessment for tritium releases during normal operation of NPP

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Radiation Doses (RD) codes for estimate of impact of air effluents during normal operation of Czech NPP assume that all atmospheric tritium releases are emitted from ventilation stacks only. Transfer of liquid tritium is modeled by diffusion process in river only. In reality, in the case of Dukovany NPP, cooling water in cooling towers contain significant activity of tritium, as water is coming from reservoir with liquid effluents. Until now no special attention was devoted to the transfer of water vapor with tritium from cooling towers, because it was supposed that the tritium released from NPP was already taken into account in the calculation of doses from hydrosphere; estimation of doses for Dukovany NPP was therefore conservative. The aim of present research is to find out how conservative is the present way of estimation of doses from tritium and a realistic approach will be sought. A computer code MHTO has been developed to assess tritium doses to the general public. The code enables to simulate the behavior of tritium in the environment released into the atmosphere and hydrosphere under normal operation of NPPs. The code can calculate the doses for the four forms: tritium gas (HT), tritiated water vapor (HTO), water drops and organically bounded tritium (OBT). Models in this code consist of the tritium transfer model including reemission of HTO from soil to the atmosphere. The comparison of results obtained from calculations using RD and MHTO codes prove that when taking into account the releases of tritium from cooling towers, codes RD provide a value of maximal individual effective dose from hydrosphere about 30% less and the dose from atmosphere is about 20% higher in comparison to the case without releases from cooling towers. At the same time, the collective dose is approximately 30% lower as in the case without releases from cooling towers.

*Work on this project was supported by State Office of Nuclear Safety of the Czech Republic (project SUJB-5200).*

S15-05

### The legacy of uranium mines – Pluralist Expertise Group experiment on uranium mines in Limousin (France)

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**Context:** In France, as mining and milling operations drew to a close, from the 80s until 2001, AREVA-NC has carried out with the administration important work on remediation and rehabilitation of more than 200 sites to assure the protection of the population and the environment, with continuous monitoring of the environment, which is ongoing. The closure and the remediation over this period have caused some concern in the public and NGOs. This issue is of particular concern in Limousin, the area that most contributed to uranium mining in France. Among actions taken by the French Government and Regional authorities, the Pluralist Expertise Group (GEP) concerning the legacy of uranium mines in Limousin was created after a joint mission letter from Ministries of environment, industry and health (2005).

**Method:** The group brings together experts from various technical fields including French institutes, the industrial operator, local and national NGOs, independent experts and foreign experts. Four multi-partite working groups (WG) have been set up to discuss the current status and management options for the sites:

- WG1: Inventory of substances and transfers in the environment
- WG2: Impact and surveillance
- WG3: Regulations and long-term control and management
- WG4: Analysis of measurements.

The purpose of this paper is to describe the work of WG2.

**Results:** At first the WG2 has drawn up a status report of the current situation, both at national and international level, for its topics (risk for the environment, impact on the population, health and ecological surveillance). Then the experts of the WG2 have put forward some recommendations concerning the actual management of the uranium mines in France. New methods in the

field of environmental impact, sanitary screening and dosimetric assessment have been proposed and tested in Limousin. The details of WG2 will be published at the end of this year ([www.gep-nucleaire.org](http://www.gep-nucleaire.org)).

P15-01

### Radiation situation in Moscow and public doses due to man-made radiation exposure

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Over 2002–2007, radiation situation resulted from global fallout in Moscow has been assessed in terms of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  contents in more than 500 samples of the environmental media. Such assessment showed that  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  contents in atmospheric precipitation complied with the average Russian levels, while annual activity concentration of these radionuclides in common air is six orders of a magnitude lower than permissible values regulated by the radiation safety standards.  $^{137}\text{Cs}$  content in foodstuffs intaken by Moscow residents varies over the range from 0.1 up to 1.4 Bq/kg(l), while that of  $^{90}\text{Sr}$  – from 0.08 up to 0.13 Bq/kg(l); this is much lower than permissible specific activities. Over the years under observation, excess  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  contents in comparison with the permissible ones have been registered in wild food samples (mushrooms, wild berries). This is due to the fact that such kinds of foodstuffs entered to Moscow from the regions affected by the accident at the Chernobyl nuclear power plant. The selective individual dose monitoring using thermoluminescent dosimeters showed that annual effective dose induced by external exposure of natural and cosmogenic radionuclides to Moscow residents is not higher than 1 mSv/a. Contribution of man-made radiation exposure is not higher than 5%. Effective dose induced by internal man-made radiation exposure to Moscow residents due to food intake over the inspected time period is 13 mSv/a on average.

P15-02

### Ionising radiation exposure of the Belgian population in 2006

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The radiation exposure of the Belgian population in 2006 was calculated with the methods of the UNSCEAR 2000 report. The annual average effective dose is estimated at 4.6 mSv, of which 2.5 mSv is from natural sources and 2.1 mSv from applications of ionizing radiation; more than 95% from medical imaging. Radiotherapeutic exposures are not accounted for in this overview.

Data, collected for the report on the state of the environment in Flanders, will be presented. The dose distribution of the population was calculated by multiplying the average effective dose per type of diagnostic x-ray examination with the National Health Service data on the number of examinations. The exposure is dominated by CT, which provides 60% of the effective dose; the number of CT-scans increased by 77% between 1997 and 2006 to 155 per 1000 people. Patient doses in interventional radiology and cardiology were measured in Belgium and a dose monitoring system was set up. The effective dose from diagnostic radiology is estimated at 1.88 mSv/y.

The number of diagnostic administrations of radiopharmaceuticals to patients in Belgium was 52 per 1000 people in 2006. Tc-99m is the most used radionuclide and a local survey has estimated the average dose per diagnostic procedure at 4.2 mSv. This value, multiplied by the number of procedures, results in an effective dose from nuclear medicine of 0.22 mSv/y.

The estimated contributions from natural sources in 2006 are the same as in 2001. From an average radon concentration indoors of 48 Bq/m<sup>3</sup> and outdoors of 10 Bq/m<sup>3</sup>, a radon dose of 1.35 mSv/y is derived. The thoron exposure is estimated at 0.1 mSv/y and the cosmic radiation exposure at 0.35 mSv/y; the external and internal exposures at 0.4 and 0.3 mSv/y respectively.

The risk perception from ionizing radiation is strongly correlated to the perceived possibility of potential exposure, with a high concern for nuclear waste management and a low concern for medical and natural exposure.

P15-03

**Sharing an environmental monitoring network: the Areva Tricastin experience**

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The AREVA Tricastin site (France) covers 650 ha, welcomes every day over 2,800 employees, 35% of whom lives in the neighbouring communities, and overlaps 3 municipalities, 2 administrative departments and 2 administrative regions. That is to say that the concern of numerous stakeholders about the protection of the environment from the industrial releases is very high. To warrant the absence of significant impact, a joint monitoring program was set up, in 2006, with all the AREVA group companies working on the Tricastin: AREVA NC, COMURHEX, EURODIF, SOCATRI and SET. Every year, more than 25,000 laboratory analyses are carried out on more than 9,000 samples taken from the natural environment at about 200 geographical points across the site and in its immediate vicinity. AREVA invests yearly about 2 millions euros to implement and improve the monitoring program. Half of the measurements are realized in answer to regulatory requests of the nuclear authorities, but the other half is largely realized on the initiative of AREVA to reinforce the knowledge of the environment of its site. The monitoring program involves atmospheric, aquatic as well as terrestrial monitoring. To realize and analyze these samplings, the site of Tricastin has more than 10 technicians dedicated to the environmental monitoring and laboratories certified and tested periodically. The results of these analyses are made public through AREVA website and will be soon available through the French national network of measure of the radioactivity of the environment set up by the French National Safety Authority (ASN) and led by the French National Institute for Radioprotection and Nuclear safety (IRSN). The communication will present the innovative organisation settled on the Tricastin site to share the means and the skills of the 5 groups companies, the main features of the results of the monitoring program and the challenging subjects currently in development to perform always more precise monitoring.

P15-04

**Activity concentrations of  $^{137}\text{Cs}$  in Polish beef, lamb, pork, poultry, and game meat – current levels and dose assessment for consumers**

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According to the Commission recommendation and the national law Polish Veterinary Inspection implemented a programme of radioactivity monitoring in a wide range of foodstuffs of animal origin. Samples of beef, lamb, pork, poultry, and game meat were taken at meat processing facilities and then transported to regional laboratories for analyses. Radiocaesium activity concentrations were determined by gamma-ray spectrometry using scintillation (NaI(Tl)) detectors. Generally, the radiocaesium activity concentrations in of beef, lamb, pork, and poultry were very low, and, in most of the measurements, reached MDA values. The slightly elevated radiocaesium activity concentrations, observed in several beef samples, may be partly explained by semi-free rearing of these animals. In some game meat samples fairly high levels of  $^{137}\text{Cs}$  were still noted. Ingestion of a large portion of game meat in a daily diet by hunters' families may increase  $^{137}\text{Cs}$  uptake in this group of consumers. Due to low radiocaesium activity concentrations in meat from domestic animals, the mean effective doses may be considered very low. The annual effective dose received by individuals in Poland and attributed to  $^{137}\text{Cs}$  intake with meat was estimated to be a few  $\mu\text{Sv}$ . Somewhat higher effective dose was calculated for hunters' families as a result of increased game consumption. Therefore, taking into account the permitted annual public dose, consumption of Polish meats are truly safe in terms of contamination with radiocaesium.

P15-05

### Public doses due to tritium emissions from Cernavoda NPP

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Heavy water reactors have a large tritium load. In a CANDU reactor most of the tritium is formed in the thermal-neutron-capture reaction,  $2\text{H}(n,f)\times 3\text{H}$  which occurs both in the moderator and heat transfer system. Very small amounts of tritiated heavy water may escape from moderator and heat-transport systems of CANDU reactors during maintenance and normal operation. Tritium emissions of Cernavoda NPP were continuously monitored. The tritium concentrations in environmental samples were monitored as part of routine program and public doses were calculated. This paper presents the supplementary tritium doses for a member of public, estimated using HTO concentrations in environmental samples and OBT doses estimated based on Candu Owners Group studies "OBT/HTO Ratio in plants" and "Contribution of Organically Bound Tritium to total Tritium Dose".

P15-06

### New Swedish regulations for clearance of materials, rooms, buildings and land

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The Swedish Radiation Safety Authority (SSM) is developing new regulations for clearance of materials, rooms, buildings and land. The work builds on work performed by the former Swedish Radiation Protection Authority (SSI). A draft version was sent for a broad national review in 2006 and a large number of comments were received. The SSM has therefore developed the regulations further and a new proposal is currently (September 2009) open for comments on a broad national review. The regulations are planned to be finalized in 2009 and to enter into force in July 2010. The paper will present the new requirements and the proposed system for clearance of materials, rooms, buildings and land in Sweden. The main features are:

- Rules applicable to all licensed radiation practices where contamination or activation may occur.
- Inclusion of EC recommended clearance levels in the Swedish legislation (European Commission recommendations RP 122 part 1 and RP 113).
- Clearance levels for materials for unrestricted use, used oils for regeneration or incineration, hazardous waste for disposal or incineration, rooms and buildings for unrestricted use and buildings for demolition. (Clearance levels for land will not be included in the regulations. Investigations on appropriate levels are currently being performed on behalf of the SSM. A status report will be included in the paper.)
- Requirements on a control program for clearance measurements, to be established by the implementer.
- Clearance of materials can be decided by the implementer without prior notice to the regulatory and supervisory authority (SSM).
- Clearance of rooms, buildings and land shall be decided by the SSM after control measurements by the implementer and application to the SSM.
- Rooms and buildings that have been controlled for clearance by the implementer may be used by the implementer for other purposes. Before the implementer leaves the localities for the use of others, clearance shall be decided by the SSM.

P15-07

**The approach to assessing doses to humans in the Posiva safety case****Hjerpe, Thomas<sup>1</sup>; Ikonen, Ari T. K.<sup>2</sup>;****Broed, Robert<sup>2</sup>; Avila, Rodolfo<sup>3</sup>**<sup>1</sup>Saanio & Riekkola Oy, FINLAND; <sup>2</sup>Posiva Oy, FINLAND;<sup>3</sup>Facilia AB, SWEDEN

Posiva Oy is responsible for implementing a final disposal programme in Finland for spent nuclear fuel. The next step of the nuclear licensing is by the end of 2012 submit a construction licence application for a KBS-3 type of repository at the Olkiluoto site. Currently, a safety case is produced to support this application, were a preliminary version was completed in 2009. Assessing doses to humans is a key part in order to assess compliance with regulatory requirements on the long-term safety. A prospective deterministic dose assessment, based on the ICRP concept of assessing doses to the *representative person* has been developed. Exposure characteristics are based on site-specific conditions and regional land use. For example, the number of exposed persons is limited by the site-specific capabilities to produce food and drinking water. Due to the temporal scale of the assessment, the surface environment will undergo significant development and many generations may be exposed. This is taken into account by deriving full dose distributions (the dose to each potentially exposed individual) for all generations during the assessment time window. Doses to representative persons, both for the more highly exposed individuals and for the other people in the exposed population, are then identified from the dose distributions. This paper present the methodology applied in the interim safety case to derive annual doses to humans from concentrations of radionuclides in environmental media, resulting dose distributions from the calculation cases analysed, and the doses used when assessing compliance with the regulatory dose constraints for humans.

P15-08

**Study of the site dose rate of the spent fuel storage facility with add-on shieldings****Chang, Bor-Jing; Kuo-Wei, Lee; Chung-Hsin, Lu; Uei-Tyng, Lin; Shu-Jun, Chang; Jeng-Ning, Wang; Ing-Jane, Chen**

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The site dose rate of a spent fuel storage facility is always the focus of public concern in Taiwan. For the strict limitation of the site dose rate committed by the nuclear power plant, an add-on shielding design is needed for the spent fuel storage facility. The purpose of this study is to estimate the site dose rate of the spent fuel storage facility with variant thickness of the add-on shielding design. The simulation model of the storage cask and the add-on shielding was constructed in detail. Neutron and photon sources of the spent fuel in the nuclear power plant was also considered in the simulation. The discrete ordinate code DORT was adopted to calculate the dose rate at the surface of the storage cask, and the SKYSHINE III code was used to estimate the site dose rate according to the fluence results calculated by DORT. Six designed thickness of the add-on shielding were simulated. Besides a single storage cask, a storage facility layout composed of 42 casks was also simulated for the site dose rate estimation. With the simulation results, the tendency of the dose rates at the surface of the cask and those at the distances for different add-on shielding designs were discussed. It is noticed that the dominant contribution of the dose rate at the cask surface comes from the photon source, but in the far distance the dominant dose contribution varies with the add-on shielding thickness. The add-on shielding design provide a simple and practical solution to the spent fuel storage facility for the condition of the nearby site boundary in Taiwan. The simulation results could offer information for the storage facility design in the future.

P15-09

### Dose analysis for the steel shielding cover of the turbine buildings using the equivalent point source

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The skyshine issue is one of the major concerns for the public dose coming from the turbine buildings in a nuclear power plant. The purpose of this study is to evaluate the dose with variant thickness of the steel shielding cover on the top of the turbines to conform the public dose criteria of the regulation for an under-construction nuclear power plant in Taiwan. The evaluations focus on the skyshine radiation transporting through the steel shielding cover. A point kernel radiation transport code QADCG/INER III and the SKYSHINE III procedure are adopted in the evaluation. The QADCG/INER III code is applied to calculate the doses, which is caused by a volume source, in different polar angles at a distance far above the turbines while the steel cover is present. At the same detecting points, doses are also calculated for a point source of unit activity without the steel cover. For each detecting point, the average doses are obtained by integrating the dose over the angle and then are divided by the total angle range. The source strength of the equivalent point source is the ratio of the average dose from the volume source and that from the unit activity point source. The calculated equivalent point source strength is applied to SKYSHINE III code with the energy spectrum of N-16 in the open roof condition, and the public dose through the skyshine is estimated. Most of codes to evaluate skyshine dose are restricted to deal with the point source. This procedure offers a fast way to obtain an equivalent point source for the skyshine codes. A comparison of the results calculated by this procedure and by other simulation codes is also carried out for a sample problem in this study. The comparison indicates that this procedure is conservative for the shielding design.

P15-10

### Shielding analysis for Proton Therapy Center in Prague, Czech Republic

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The study of radiation fields around the cyclotron room has been made for the proton therapy center in Prague. The proton cyclotron of energy 230 MeV will be installed there as well as additional components located along the beam path. The ambient doses have been computed by taking into account 3 major neutron and photon sources – cyclotron, energy degrader and its collimator.

The fluxes of neutrons/photons produced by protons have been computed using Monte Carlo code MCNPX™ 2.5.0. Energy and angular distributions have been computed for various targets and proton beam energies. Different physical models of high-energy proton interactions have been studied too. The annual charge at the cyclotron exit has been based on “patient model” (distribution of treatment type) established for similar therapy center in Essen (Germany). The cyclotron extraction efficiency of 50% has been assumed; the beam losses inside the cyclotron amount to 82200 nA.h/year. By convention, it has been considered no beam losses in the degrader, i.e. all the losses of degrader and collimator have been attributed to the absorption in the collimator.

As the cyclotron room is located underground, the outside concrete walls of the cyclotron room (West and South walls) have reduced thickness followed by soil. The annual doses have also been computed inside the fixed beam room (towards East), at the maze exit (towards North), inside the main control room (North, next to the maze), and above the cyclotron room roof. Calculated 3D dose distributions have been used to verify the radiation shielding design and the radiation protection optimization.

P15-11

**Ambient radiation monitoring in a corridor configuration****Lai, Yung-Chang<sup>1</sup>; Chen, Yu-Wen<sup>2</sup>; Huang, Ying-Fong<sup>2</sup>**<sup>1</sup>Kaohsiung Medical University, Graduate Inst. of Occup. Safety and Health, TAIWAN; <sup>2</sup>Kaohsiung Medical University, Department of Nuclear Medicine, TAIWAN

Real-time monitoring used of high sensitivity detectors to measure radiation levels in public access area at the Nuclear Medicine Department (NMD) is the prime interest of this investigation. The results of this study are used to verify and to improve the facility layout, patient routings and administrative control measures. The NMD outpatients, with an initial dose of up to 740 MBq (20 mCi) per case, may wait around and incidentally congest in one place that could cause an unexpected higher exposure level in public access areas. In this surveillance study, the ambient radiation time-profile and peak dose rates have been characterized for the transit hallway or corridor where non-NMD medical staff or patients, relatives may present with the source-bearing patients. In order not to interfere with daily NMD operations, a high sensitivity, collimated NaI(Tl) gamma spectroscopy system is deployed at the far end of the hallway to monitor the ambient radiation levels. The time-profile of the radiation levels were derived from a video-taped gamma spectroscopy using time-stripping, consecutive unfolding method. Another digital G-M dosimeter, which has peak rate locked-in capability, is also adopted for tracking the highest ambient radiation dose rate in this transit hallway to alert the medical staff whenever unexpected NMD patients are crowded at one place. Typical 10-min average count rates, based on a 12-hour observing time from 7am to 7pm, are evaluated from this remote collimated detector. From these 10-min average count rate data, we found the ambient radiation levels at some time intervals can reach up to more than 35 times of the natural background level. Also, the peak-rate dosimeter at this corridor has once registered to a peak value of 40.4 micro-sievert/hr. Based on these radiation monitoring data, suggestions to improve the NMD daily operation and the needed administrative changes have been reviewed and accepted by the management of the hospital.

P15-12

**Contribution to the national survey of population exposure from selected X-ray medical examinations in Slovakia****Nikodemova, Denisa<sup>1</sup>; Šalát, Dušan<sup>2</sup>; Horváthová, Martina<sup>3</sup>; Bohm, Karol<sup>4</sup>; Cabáneková, Helena<sup>5</sup>**<sup>1</sup>Slovak Medical University in Bratislava, SLOVAKIA; <sup>2</sup>Radiation Protection Institute, Trenčín, SLOVAKIA; <sup>3</sup>Trnava University, Theoret. Discl. and Lab. Exam. Meth., SLOVAKIA; <sup>4</sup>Public Healths Authority of SR, SLOVAKIA; <sup>5</sup>Slovak Medical University in Bratislava, Radiation Hygiene, SLOVAKIA

EC Medical Exposure Directive 97/43/EURATOM requires in the Article 12 that the Member States will determine the distribution of individual dose estimates for relevant groups of the population. Large differences in the published data from various countries are mainly the consequence of variations in the equipment used, in the adopted choice of the examination categories, in the measured dose quantities and in the limited sample size due to the financial problems with the collection of the data for such survey. Even the dose values collected for one certain examination type show large uncertainties following the imaging technologies and mistakes in protocol standards. The recently published "Guidance on Estimating Population Doses from Medical X-ray Procedures" (EC Report No.154/2008), helped also in Slovakia to specify examination types and to harmonize the methodology for gathering the representative effective doses and annual frequencies, in the framework of the professional bodies involved in public health and radiation protection, for the first stage of the population dose estimates. The poster presentation will show the preliminary results for mammography examinations.

P15-13

### Utility of a web based data survey form for a national MDCT radiology practice survey

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**Purpose:** To develop an Internet based survey form for national MDCT dosimetry surveys. To provide participating practices with a site specific practice reference level (PRL) report for submitted protocols and to use submitted and collated PRL data to construct national diagnostic reference levels (DRLs) for MDCT.

**Methods and materials:** As part of a national MDCT dose survey project, a web based MDCT protocol survey form is being developed to record appropriate parameters for dosimetry calculations. The initial draft Excel,µ version requested responders to provide practice contact and registration information. They were also asked to submit 20 sets of patient scan data for the 7 generic adult protocols chosen. These included integral protocol DLP (mGy.cm), patient weight, patient height and patient slice diameter at a specified anatomical landmark. Fifteen practices were invited to participate of which 11 responded. With version 2 of the survey form, more instructional detail was provided and the slice diameter data point was removed. Data sets are to be kept in an SQL database and transferred to a commercial spreadsheet program for additional analysis.

**Results:** Initially 15 radiology practices were invited to participate in the survey of which 11 responded. Practices were given 4 weeks to submit data and the survey response was poor. No practice managed to complete the survey with 20 patients per protocol (140 data points). Of the 77 protocols submitted (11 practices × 7 protocols) only 6 protocols were submitted with all 20 patient data fields satisfactorily populated. These were spread across 4 of the 11 practices. However, sufficient data was submitted, in most cases, for a generic dose report to be generated and a survey DRL to be calculated.

**Conclusion:** This pilot MDCT data survey has shown that the application of a web based MDCT protocol survey should provide sufficient data for accurate dosimetry calculations and comparative intersite surveys to be performed.

P15-14

### Application of the European DOSE DATAMED methodology and reference doses for the estimate of Australian MDCT effective dose (mSv)

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**Purpose:** To calculate the indicative effective dose per individual per annum to the Australian population from current MDCT procedures using DOSE DATAMED MDCT dosimetry as a reference.

**Methods and materials:** DOSE DATAMED was a multinational radiology dosimetry project with contributions from ten European countries with extensive experience in undertaking national dosimetry surveys ([http://ec.europa.eu/energy/nuclear/radioprotection/publication\\_en-htm](http://ec.europa.eu/energy/nuclear/radioprotection/publication_en-htm)). The lack of contemporary Australian MDCT dosimetry survey data post-2002, required the application of a recognised European dosimetry data set for current generic caput effective dose calculation. Utilising Medicare Benefits Scheme (MBS), CT procedure data, plus an additional 31% gross-up factor for data not captured by MBS, an indicative caput dose calculation was made based on the current European DOSE DATAMED dosimetry data.

**Results:** DOSE DATAMED grouped all MDCT procedures into 7 generic scans with the following doses; Head (2.4 mSv), Neck (2.8 mSv), Chest (8.2 mSv), Spine (6 mSv), Abdomen (13.5 mSv), Pelvis (8.8 mSv) and Trunk (24.4 mSv). MBS MDCT categories were rendered down to fit into these broad categories and a resultant effective dose of approximately 1.2 mSv per individual per annum was calculated.

**Conclusion:** Previous ARPANSA CT surveys have shown the per caput dose has grown from 0.37 mSv (1994) to 0.9 mSv (2002) The current per caput dose contribution is approximately 1.2 mSv (2008). As the number of MDCT procedures in Australia is growing at approximately 9% per annum, the MDCT dose contribution to the Australian population background radiation dose is also steadily increasing.

P15-15

**Comparison of spectroscopic investigation and computer modelling of lanthanide(III) and actinide(III) speciation in human biological fluids**

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Radionuclides represent a serious health risk to humans in case of incorporation. To get a first insight into the transport and metabolism in the human organism, we compared the speciation of Eu(III) and Cm(III) in human biofluids calculated by thermodynamic modelling with spectroscopic results obtained by time-resolved laser-induced fluorescence spectroscopy (TRLFS) with regard to the lanthanide/actinide analogy.

For the experiments, fresh saliva and urine samples were collected from healthy volunteers and analyzed within few days. For TRLFS measurements, all samples have been spiked in vitro with europium or curium. To identify the dominant species the measured spectroscopic data were compared to reference spectra with single organic and inorganic constituents of the biological fluids. The TRLFS spectra with urine showed that all samples with pH below and all samples with pH above 5.8 each exhibit strikingly similar spectra. The TRLFS spectra with saliva were all similar in the pH range between 5 and 8. Comparing the measured spectra with the reference data, we found that in urine at lower pH citrate complex species dominate the speciation of both metals while at higher pH and in saliva the spectra were identical to those in inorganic electrolyte solution.

The speciation calculation, carried out with the program MEDUSA and the accompanying database HYDRA, showed for urine in accordance to the experiments at pH around 5 a dominating citrate speciation for both metals. In contrast to the experiments resulted the calculation at higher pH values for urine and in the whole observed pH for saliva in a simple phosphate complexation. However, spectroscopic investigations signed of a more complex speciation behaviour which cannot be described with single inorganic complexes.

To conclude, the comparison of experimental speciation investigation and computer modelling shows that because of their simplifications models cannot always image the complex natural processes correctly.

P15-16

**Natural radioactivity of building materials: Radiation protection concepts, measurement methods and regulatory implementation**

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Most building materials, especially of mineralogical origin, contain natural radionuclides. Generally radioactivity in building material originates from radionuclides of the natural decay chains U-238, Th-232, U-235 plus progenies as well as the primordial radionuclide K-40. External radiation exposure by gamma-radiation and beta particles emission plus internal exposure due to inhalation of radon cause chronic exposure of the public. Due to increasing indoor habitation of persons – in average about 80% of time persons stay indoor – external and internal exposure caused by natural radionuclides in building materials are of increasing importance. Additional the rising production of building materials using industrial by-products and residual materials from NORM industry necessitate the consideration and regulation of this radiation protection issue in regard to chronically public exposure. In this paper historical and recent basic concepts of dose estimation, radioactivity measurement methods including metrology and calibration of instruments are given. Examples of building material evaluations are discusses with regard to approaches of regulatory standards and experiences with implemented legal guidelines and provisions. The result of this research could act as effective fundamental basis for harmonised guidelines in Europe to limit chronically public exposure due to natural radionuclides in building materials.

P15-17

### Mapping of aerosol releases from Forsmark nuclear power plant

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Forsmark NPP has set a goal to reduce discharges of radioactive aerosols, mainly airborne particles of corrosion products such as cobalt-60, <sup>60</sup>Co, by 50% by 2011. To reach this goal we have run a project to map when and where aerosol releases take place. We started by correlating aerosol discharges, measured in the stack, with events, such as reactor pool cleaning, in the plant. This has given us indications regarding which jobs release more aerosols. To further clarify the relationships of from which events and locations aerosol discharges emanate we have developed an instrument that measure aerosols in ventilation ducts, using the same millipore/coal filter cassettes that are used in the stack monitoring system. Our approach has been to confirm findings from the event-mapping project and further clarify which sections of the ventilation system that transport most radioactive aerosols. By analyzing data from the event – release correlation study and the duct measurement study we conclude that pool cleaning is the single major source of aerosol discharge and by introducing new work methods and air filtering systems during identified jobs aerosol discharge should be significantly reduced. We have also identified that the majority of aerosols comes from the reactor building, especially when small leaks occur -more optimized use of the filter banks might reduce the discharge of radioactive aerosols. In the end this will help lower the discharges of radioactive substances from Forsmark NPP making clean energy even cleaner.

P15-18

### A nation wide survey on drinking water radioactivity in Estonia: facts, risk assessment and remedial actions

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<sup>1</sup>ARPA Lombardia, Dipartimento di Milano, ITALY; <sup>2</sup>Health Protection Inspectorate, ESTONIA; <sup>3</sup>ARPA Veneto, Dipartimento di Verona, ITALY; <sup>4</sup>National Institute of Health, ITALY; <sup>5</sup>CGIAM, ITALY

Within the frame of a Twinning Light Project sponsored by European Union, a cooperative study between Estonia and Italy has been carried out to assess the actual radiological exposure of Estonian population due to the natural radioactivity of drinking water. Actually, about 22% of people is exposed to doses higher than 0.1 mSv/y (reference value for the Total Indicative Dose according to EU Directive 98/83) due to high concentrations of Ra-228 and Ra-226.

Estonian authorities were facing the problem of finding a feasible solution, but both a comprehensive overview of the situation and a deep cost benefit analysis were still missing.

Available radiometric data (nearly 1,000), as provided by Estonian institutions, were fully analysed in order to assess their representativeness and to identify the most critical situations. Though highest radioactivity values were found in the North of Estonia, where Cambrian Vendian waters are used, the few available data for the remaining part of the country cannot definitely assure compliance of drinking water, as previously supposed. On this basis, a new monitoring program has been proposed and the most suitable analytical tools have been suggested.

The effectiveness in radium removal of presently operating Fe/Mn treatment plants has been assessed. Since the resulting removal efficiency (about 15 %) was inadequate, a thorough cost benefit analysis of commercially available treatment plants for radium removal has been carried out, the main constraint being the small size of Estonian aqueducts (59 % serving less than 500 people).

Production and management of radioactive wastes and effluents in water treatment plants was examined on the basis of the technical documents issued by EU and IAEA (RP 122 and 135, IAEA RS-19).

A review of existing international guidelines was provided, and regulatory proposals were given in the light of proper risk assessments.

S16-01

**Regularities of long-term changes in artificial radionuclides content in the Barents Sea ecosystem****Matishov, Gennady<sup>1</sup>; Matishov, Dmitry<sup>1</sup>; Solatie, Dina<sup>2</sup>; Kasatkina, Nadezhda<sup>1</sup>; Leppänen, Ari-Pekka<sup>2</sup>**<sup>1</sup>Murmansk Marine Biological Institute, RUSSIAN FEDERATION;<sup>2</sup>STUK – Radiation and Nuclear Safety Authority, FINLAND

The comparative analysis is performed for the radiation contamination of the Barents Sea ecosystem in the 1980s and 1990s and in the first decade of the 21st century. Natural purification processes in the marine environment are the main factors of the decrease in the intensity level of artificial radioactive isotopes. These processes include repeated dilution, nuclear decay, sorption by sediments and suspended solid material, and accumulation by aquatic inhabitants. A stable decreasing trend is observed for the intensity level of artificial radioactive isotopes in the Barents Sea.

S16-02

**Human dose pathways from forests contaminated by atmospheric radionuclide deposition****Rantavaara, Aino; Ammann, Michael**

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Atmospheric release and distribution of radioactive material can present a threat to radiation safety of people using forests and forest products after radionuclide deposition. The deposition pattern can vary substantially due to the characteristics of the release, weather during atmospheric dispersion and deposition, and the distance from the source of release. Environmental processes change the initial distribution of radionuclides in forests. In addition, radioactive decay of short-lived radionuclides reduces the contamination during the first months after deposition. In the long term, climate and soil characteristics mostly determine the growth conditions and thereby the ranges of transfer rates of radionuclides. Both the early and late phase behaviour of radionuclides can be predicted by dynamic assessment models. Long-lived Cs and Sr can be sources of radiation exposure for several decades, or even longer. Radiation exposure of various population groups is related to the ways people are using forests and forest products. Analysis of dose pathways in a specified contamination context can reveal a need for intervention. Dose pathways that mostly need intervention are ingestion of wild foods, handling and transport of wood ash, living in a house made of contaminated timber and external radiation in forests. Examples are found in the contamination history of rural areas in Europe. Forest models of the European emergency response system RODOS are used for assessment of the time-dependent doses to people using forests, and the effects of selected management options and countermeasures. The aim of our intended presentation is, concerning forests, to *f*{ give an overview of the human dose pathways, *f*{ identify critical pathways and most exposed population groups, *f*{ present the averted doses from implementation of management options, and *f*{ recommend to experts on radiation protection a multidisciplinary approach in planning, implementation and follow-up of intervention.

S16-03

### **Occurrence of plutonium in the terrestrial environment at Thule, Greenland**

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Results from a detailed investigation on the occurrence of weapons plutonium from the Thule 1968 accident on the terrestrial environment in Thule will be presented. Samples of air, resuspended particles, water, soil and precipitation has been analysed in an area about 20 km<sup>2</sup> south of the impact point. The results from the soil sampling show a very inhomogenous distribution with hot spots ranging up to several hundred kBq per m<sup>2</sup> of Pu. Particles of Pu/U isolated from the different hot areas have been subject to investigation on stability and leaching behaviour.

S16-04

### **Environmental radioactivity assessment at nuclear legacy sites in the Republic of Tajikistan**

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The impressive number of extant nuclear and radiological sources in the Central Asia is a major environmental concern as they pose a potential threat of radioactive contamination to the whole region. Key sources of concern are technologically enhanced levels of naturally occurring radionuclides (TENORM) due to uranium mining and milling. Uranium ore mining and processing in the former Soviet Republic of Tajikistan resulted in origination of huge amounts of uranium tailing materials and waste rock deposits, often dumped near inhabited areas. Given the absence of a proper waste management in most of those areas, there is a considerable potential for the spread of contamination beyond existing contaminated sites. A joint field mission to Tajikistan was conducted in 2008 as part of the project: Environmental impact assessment of radionuclide contamination of selected sites in Kazakhstan, Kyrgyzstan and Tajikistan, coordinated by the Norwegian University of Life Sciences. The present work focuses on the assessment of radiation exposure and radioactivity levels in the former uranium mining and tailing sites at Taboshar, and Digmai, both located in northern part of Tajikistan. Gamma-dose rate surveys were carried out on each site. Generally, the dose rates measured at the uranium mining site in Taboshar varied between 0.70 and 4.4 µGy/h. However, this excludes some hot spots where dose-rates as high as 20 µGy/h were measured. On the tailing site which contains 1.2 mln tons of radioactive wastes the measured dose rates varied 0.7 – 1,9 µGy/h. It is noteworthy that the tailing site lies just 1 km far from the local school in Taboshar where we also did measurements. The highest level of radioactivity was exhibited by Digmai – 18.8 µGy/h. From each site soil samples were taken for subsequent lab analyses for radioactivity and track detectors placed on-site for determination of Rn concentration. The analyses are in progress and the results will be available by the end of 2009.

S16-05

**Improved model for estimation of fallout from atmospheric nuclear testing**

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Estimation of global fallout is still important when establishing background values for many radionuclides. Even where deposition measurements have been made, there is a limit for how comprehensive they can be or can have been. Using a model makes it possible to put the available data in a better framework. Two types of models for global fallout have often been used, one assuming that the variation in deposition is a function of latitude, the other assuming that the deposition can be described as the product of radionuclide concentration in precipitation and the amount of precipitation. The former has a meteorological basis for dividing global data into latitude bands and the quantitative estimate is based on the UNSCEAR compilation of deposition data, even though the original sources clearly state that the compilation is for the latitude band as such and should not be used as a model for individual sites. The latter has been used successfully for individual countries and regions, but the same parameters cannot be expected to hold for all conditions. The global model presented here uses the concentration function as a basis, but includes also latitude dependency and contribution of dry deposition through making the average annual deposition one of the parameters used in the model. The parameters of this new model have been determined using the data from the comprehensive global EML network and the model was validated with good results using data from other networks and data from the Nordic countries.

S16-06Y

**Reduction of radioxenon emissions from radiopharmaceutical facilities – A pilot study**

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The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) is building an International Monitoring System (IMS) in order to verify that the state signatories of the treaty fulfil their commitments of not performing any kind of nuclear explosion. The atmospheric noble gas monitoring is a part of this verification system and focuses on the measurement of short-lived radioxenon isotopes in the atmosphere. In order to improve the sensitivity of the IMS noble gas network, the radioxenon background should be decreased. Previous research <sup>(1)</sup> has shown that a very limited number of radiopharmaceutical facilities are responsible for the major part of the radioxenon background. In addition xenon routine releases from such facilities can hide the release of radiological more important nuclides like iodine during on- or off-site gas monitoring. Reduction of radioxenon release will consequently decrease the global background and enhance the basic safety of such nuclear facilities.

This study reports on several techniques that could be installed in a radioisotope production facility to reduce the discharge of radioxenon in the atmosphere. This pilot study was centred on the Institut des Radioéléments (IRE) facility in Fleurus, Belgium – the worldwide third largest <sup>99</sup>Mo producer. Each production step was analysed to determine the amount and the isotopic composition of a possible xenon release. Many techniques (e.g. adsorption on solid materials, cryogenic processes...) were discussed in terms of performance and practical aspects for the filtration and/or delay of xenon fission gas emissions.

It has been demonstrated in this work that significant reductions of radioxenon atmospheric discharges from <sup>99</sup>Mo production facilities are theoretically possible. Nevertheless it requires a complete inventory of each pathway of xenon release during separation and purifications steps of medical radionuclides.

1. Saey P.R.J.; *Journal of Environmental Radioactivity*; 2009; 100; 396 – 406.

S16-07Y

**Public exposure by natural radionuclides in drinking water – Models for effective dose assessment and implications to guidelines****Gruber, Valeria<sup>1</sup>; Maringer, Franz Josef<sup>2</sup>**

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In Austria the legal framework to “Exposure by natural radionuclides in drinking water” is the Austrian Drinking Water Ordinance (Trinkwasserverordnung BGBl. II 304/2001) which implements exactly the European Drinking Water Directive 98/83/EC. The minimum requirements on the quality of drinking water and water intended for human consumption are appointed in it. For radioactivity two indicative standard parameter limits are established – tritium activity concentration of 100 Bq/l and total indicative dose TID (effective dose from radionuclides in drinking water except H-3, K-40, radon and radon progenies) of 0,1 mSv/a. The appointment and the evaluation of the TID are specified in the Austrian Standard OENORM S 5251:2005. Generally only the radionuclides Ra-226 and Ra-228, dose conversion factors for adults and a yearly water consumption of 730 l are taken into account for dose calculation. In the paper the estimation of the TID according to the drinking water directive and the OENORM standard is compared to dose estimations for other age groups and other nuclides based on measurements carried out in Upper Austria. The dose contributions of Po-210 and Pb-210 clearly preponderate the dose contributions of the radium isotopes. An alternative model for dose estimations have been developed, which take into account a daily water intake and a continuous excretion of activity from the body. The presented dose assessment clearly yields lower annual effective doses for the population. Present regulations and guidelines for drinking water monitoring and surveillance are discussed and evaluated with regard to the results of this study. Disagreement persists on methods and applied parameters for estimating total doses caused by natural radionuclides in drinking water within Europe, its individual countries and experts. This paper contributes supporting facts and feasibilities to yield a good basis for future guidelines.

P16-01

**Influence of nuclear industry enterprises on the health of population (On the example of the "Almaz" plant)**

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The Burnasyan Federal Medical Biophysical Center (FMBC, former Institute of Biophysics), has gained considerable experience in the assessment of dose burden for population that is resulted from the radioactive nuclides releases. We have generalized and analyzed the data on the radiological monitoring of the environment and obtained the dose burden from the technogeneous sources of ionizing radiation for the population that resides near such nuclear industry plants as the Mining Chemical Combinat in Krasnoyarsk region, the "Almaz" plant, Novo-Voronezh NPP and compare the technogeneous dose burden with the natural dose burden. At the same time, we have conducted the epidemiological studies to unveil the possible relationships between the radiological situation near the nuclear plants and the health effects on the population. We have collected the data on malignant tumor morbidity for the residents of the sites of interest from 1991 to 2006. Special attention was drawn to the leukemia cases, which are considered as primary responses on the radiation exposure. We have studied the cases of malignant diseases of lymphoid, hematopoietic and related tissues, as well as the cancer cases for other critical human organs. We have accumulated the epidemiological database and have processed its content. The assessment of the technogeneous dose burden on the population that resided within the influence zone of the "Almaz" plant showed that the maximal effective dose for the milk and meat diet intake is about 2.5 mSv per year. The most significant radionuclide (its tribute to the dose burden is higher than 90%) for the diet intake is  $^{226}\text{Ra}$ . The maximal possible dose for the internal exposure after the diet intake with the fruits and vegetables grown at the cottage gardens ranges from 0.037 mSv to 0.47 mSv per year. Therefore, we have concluded that the most significant factor in the radiological situation in the city of Lermontov is the inhalation intake of radon and its products.

P16-02

**Modelling with a CFD code the near-range dispersion of particles unexpectedly released from a nuclear power plant**
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An event in November 2007 in Ascó-1 NPP (Spain) originated the release of a significant amount of hot metallic particles through the discharge stack. Particles were dispersed and deposited in roofs and neighbouring areas within the NPP controlled area. However, the event was not detected until March 2008. Some 1500 hot points with radioactive particles were found, 94% located inside the double fenced controlled area and 6% within the exclusion area; 5 particles were out of the exclusion area, across the river. To provide additional insights on the potential consequences of the release, a computational fluid dynamics (CFD) code, Ansys-CFX-11, has been used to simulate the near-range atmospheric dispersion and deposition of the particles. The purpose of the analysis was to assess the distance travelled by particles of different sizes. A very detailed model of the site was built, taking into account the buildings and the terrain features including the river valley and the surrounding hills. The modelled domain was  $3.2 \times 5.2$  km, with the atmospheric layer up to 4 km height. The atmospheric conditions recorded during different periods of time were classified into 37 representative categories. In general, the distribution of the particles found was adequately reproduced. Particles larger than 100 microns could not travel beyond the double fence. Particles between 50 and 100 microns could have been deposited mainly within the exclusion area, with a small probability of travelling farther. Smaller particles could have travelled beyond, but also should have been deposited in the nearby area, while the majority of particles found are larger, thus indicating that the size of the released particles should be above 50 microns. The detailed CFD simulation allowed answering relevant questions concerning the possibility of having an impacted region larger than the exclusion area. Acknowledgement: The support received from Asociación Nuclear Ascó-Vandellós II is deeply acknowledged.

P16-03

### Inspection plan for the detection of contamination at a nuclear fuel cycle site

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A number of incidents related to the finding of contamination spots outside main operation buildings were detected at different nuclear sites in Spain over 2008. In response to these incidents, the CSN (Spanish Nuclear Regulatory Body) issued a requirement demanding to all the operators the execution of site's comprehensive inspection plans in order to ensure there are no contamination spots at the site.

The ENUSA's Fuel Fabrication Plant at Juzbado is a nuclear fuel cycle facility whose specific features make it different to the rest of Spanish nuclear installations, provided that only Low Enriched Uranium (5% maximum) is handled as process material. Therefore, the inventory of isotopes consists only of U-isotopes and their daughters. These isotopes can be found everywhere in Nature in different amounts, depending on the geologic characteristics of the area, amongst other aspects. Then, the natural background can itself contain the contaminant, what must be taken into account for the preparation of the inspection plan adding complexity to its implementation. Criteria to distinguish background from non background values must be set (impacted and non impacted areas).

To implement the inspection plan at the Juzbado Plant, the decision was taken to use the MARSSIM methodology for the Scope & Characterization Surveys, following the Data Quality Objective (DQO) process. Derived Concentration Guideline Levels (DCGL) were not used: comparison between background values versus field values was used instead.

The MARSSIM (Multy-Agency Radiation Survey and Site Investigation Manual) is a tool to conduct radiation surveys and investigation of contaminated sites. This method is used by different agencies and it is a reference for NRC, amongst others, been described on NUREG 1575.

P16-04

### Establishment of a special radiological surveillance programme at the El Cabril solid radioactive waste disposal facility

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Due to a requirement by the Nuclear Safety Council, the Spanish regulatory authority, a special Radiological Surveillance Plan (RSP) has been developed at the low and intermediate level Radioactive Waste Disposal Facility (El Cabril centre). The objective of this plan, which covers outdoor areas on the site, is to identify and remediate possible contaminated areas, including exterior ground, walls, roofs or terraces, the walls of buildings, drains, channels, paths and roads. The RSP has been developed in accordance with the MARSSIM methodology and includes an historical analysis of the facility and an initial radiological characterisation of the protected area. The RSP included the following main tasks:

1. Definition of the Surveillance Units (SU) corresponding to the exterior areas of the site. The exterior areas at the Facility were classified as impacted areas and were divided into SU's.
2. Assessment of the radioactive background and identification of Reference Background Areas (RBA).
3. Reference levels. The following reference levels were established in order to determine whether any point presented a residual level of activity: Type of surface Action Levels Co-60 Cs-137 Permeable ground: earth, gravel, etc. 0.14 Bq/g 0.41 B/g Impermeable ground: concrete, asphalt. 1.18 Bq/cm<sup>2</sup> 4.67 Bq/cm<sup>2</sup> Surveillance Unit Class Level of sweep investigation Level of static measurement investigation Class 2 > 10 Action Level > Action Level Class 3 < Action Level > 0.5 Action Level.
4. Measuring method: Sweep measurements were performed to detect possible areas of high activity and static measurements to estimate the residual activity of the Surveillance Units.
5. Selection of equipment: The detection and measuring instruments used in performing the RSP were contamination detectors, scintillation detectors and germanium detectors.
6. Analysis of results: On completion of the Programme, a final analysis was performed on the results obtained and documented in a Final Results Report.

P16-05

**Monitoring of radionuclides in the vicinity of Czech nuclear power plants****Svetlik, Ivo<sup>1</sup>; Fejgl, Michal<sup>2</sup>; Pospichal, Jiri<sup>3</sup>;****Striegler, Rostislav<sup>4</sup>; Beckova, Vera<sup>2</sup>**<sup>1</sup>Nuclear Physics Institute AS CR, CZECH REPUBLIC; <sup>2</sup>National Radiation Protection Institute, CZECH REPUBLIC; <sup>3</sup>NPP Temelin, CZECH REPUBLIC; <sup>4</sup>NPP Dukovany, CZECH REPUBLIC

The monitoring in the surrounding environment of the Czech nuclear power plants (NPP) Dukovany and Temelin is performed routinely by the NPP. Independent monitoring, including also activity of tritium in atmosphere and <sup>14</sup>C activity in biota, is performed by research institutions. Systematic monitoring of tritium activity in the air (HTO chemical form) was launched by the National Institute of Radiation Protection in 2008. Two different time regimes have been used for air humidity sampling. A static sampler enables virtually constant rate air humidity sampling during a period from 3 weeks up to two month, dynamic method applies Dwarf JL-40 air sampler and is used for sampling with duration of about 10 minutes. Systematical sampling of biota and agricultural products for <sup>14</sup>C activity determination was started in 2002 by the Nuclear Physics Institute AS CR in the cooperation with the National Institute of Radiation Protection. Environmental monitoring, performed by the staff of the NPPs, includes these determinations: gamma spectrometry (both laboratory and in situ), <sup>90</sup>Sr, tritium (in drinking, surface and underground water), gross alpha and gross beta in water, and dose-rate. The observed activities of atmospheric <sup>3</sup>H and <sup>14</sup>C in biota are close to the range given by natural variations observed in reference localities. Our results will be statistically analyzed, discussed and summarized in the contribution. Likewise, utilized analytical routines will be briefly described.

P16-06

**Distribution of <sup>14</sup>C in the atmosphere and biological samples around the nuclear power plant Krško in Slovenia****Obelić, Bogomil<sup>1</sup>; Krajcar Bronić, Ines<sup>1</sup>; Horvatinčić, Nada<sup>1</sup>;**  
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Human activities disturbed the natural <sup>14</sup>C distribution in the atmosphere in the last half of the 20th century. Besides the big amounts of <sup>14</sup>C released by nuclear bomb tests it is produced also by nuclear power plants and in form of <sup>14</sup>CO<sub>2</sub> enters the carbon cycle contributing through food chain to the dose of the local population. The aim of this study was to determine distribution of <sup>14</sup>C in a close vicinity of the Nuclear Power Plant Krško (NEK) in Slovenia, and to estimate possible contribution of NEK to the effective dose. Atmospheric CO<sub>2</sub> was collected since 2006 on a monthly basis at two locations (A and B) inside the NEK area by absorption of CO<sub>2</sub> in saturated NaOH. The CO<sub>2</sub> recovered from the carbonate was used for benzene synthesis and measured in LSC Quantulus 1220. Sampling campaigns of biological samples (apples, corn, cereals, grass) were performed twice a year and sampling sites were chosen in the immediate vicinity and in the wider environment of the NEK smokestack, and at a control site 10 km away. <sup>14</sup>C activity was measured in LSC by direct absorption method. <sup>14</sup>C activity of the atmospheric CO<sub>2</sub> at site A inside NEK showed no observable deviation from <sup>14</sup>C activities at clean-air sites, but that at site B was slightly higher, because lies in the dominant wind direction. However, significantly higher <sup>14</sup>C activities were measured at both sites during the period of regular maintenance of the reactor in Oct 2007 and April 2009. <sup>14</sup>C activities in biological samples around NEK showed slightly higher <sup>14</sup>C activities than at the control site, and depend on the distance and on the most pronounced wind direction. Higher <sup>14</sup>C activities were recorded in periods following the maintenance of NEK and can be explained by an order of magnitude higher discharge of <sup>14</sup>C from the smokestack. An estimate of the effective dose received by ingestion of food (fruits and vegetables) grown in the vicinity of NEK results in the contribution of NEK to the natural dose of less than 1 μSv.

P16-07

### Uranium and long-lived decay products in water of the Mulde River

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The Mulde River is a left side tributary of the Elbe River and mainly situated in Saxony. The river system consists of the Freiburger Mulde River and Zwickauer Mulde River, which merge to form the Vereinigte Mulde River. The Zwickauer Mulde River drains the former uranium mining and milling areas in Saxony. This research project was established to quantify the long-term effect of the former uranium mining and milling activities by investigating the content of uranium and polonium of the water of the Mulde River. The specific uranium activity in samples from the Zwickauer Mulde River is still high compared with the natural background. The values measured in the water of the Vereinigte Mulde River are also elevated, but to a lesser extent due to the dilution effect caused by the merging with the Freiburger Mulde River. Furthermore, the level of contamination of the river water decreased by at least a factor of three as compared to the early 1990's. The specific activity of polonium shows no correlation with that of uranium and is generally much smaller.

P16-08

### <sup>129</sup>I in Finnish waters

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<sup>129</sup>I is a long-lived beta-emitting ( $E_{\max}$  154,4 keV) radioisotope of iodine. Its half-life is 15,7 million years. <sup>129</sup>I is produced mainly by human nuclear activities and especially it has been released to the environment from the spent nuclear fuel reprocessing plants. In the pre-nuclear era <sup>129</sup>I/<sup>127</sup>I ratios in the environment were approximately 10<sup>-12</sup>. Nowadays <sup>129</sup>I/<sup>127</sup>I ratios have reached values from 10<sup>-10</sup> to 10<sup>-4</sup>.

In this study, activity concentrations of <sup>129</sup>I and its distribution into various chemical species (iodide I<sup>-</sup>, iodate IO<sub>3</sub><sup>-</sup> and bound in organics) were analyzed from four lakes in Finland and from four different sea locations on the Gulf of Finland, the Bothnian Sea and the Bothnian Bay. <sup>129</sup>I was also analyzed from four rainwater samples.

After filtering the 0.3 l water samples, separation of various iodine species was done by anion exchange chromatography: <sup>129</sup>IO<sub>3</sub><sup>-</sup> passes through an anion exchange resin bed in NO<sub>3</sub><sup>-</sup> form while <sup>129</sup>I<sup>-</sup> absorbs into the bed. <sup>129</sup>I<sup>-</sup> is eluted from resin with NaClO. Finally samples were precipitated by AgNO<sub>3</sub> to form AgI and <sup>129</sup>I was measured by accelerator mass spectrometry (AMS). Stable iodine (<sup>127</sup>I) was analyzed by inductively coupled plasma mass spectrometry (ICP-MS).

First results from a lake in the southern Finland and from sea water taken from the Finnish Bay in front of Helsinki show that levels of <sup>129</sup>I in lake water are around 1 × 10<sup>9</sup> atoms per litre while in sea water the levels are 4–5 times higher. <sup>129</sup>I occurs both in lake and sea water mainly in iodide form and the fraction of iodate form is only about 5%. The <sup>129</sup>I/<sup>127</sup>I ratio is clearly elevated compared to natural levels, and are approximately the same in sea and in lake, 14 × 10<sup>-8</sup> and 8 × 10<sup>-8</sup>, respectively. These results are only preliminary and a better picture of the situation will be obtained after finalizing the project. The results obtained so far are, however, at the same level as obtained in Swedish studies at the same latitudes.

P16-09

### Monitoring and assessment of radioactivity in the Baltic Sea coordinated by HELCOM

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The Baltic Marine Environment Protection Commission (HELCOM) works to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation between Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. Investigations of radioactivity in the Baltic Sea has been part of the HELCOM work since 1986 and carried out by the MORS project (Monitoring of Radioactive Substances) with participation from laboratories and institutes in the countries and organizations mentioned above including the IAEA.

The objective of the MORS project is to implement the Helsinki Convention on matters related to monitoring and assessment of radioactivity in the Baltic Sea. The Contracting Parties to the Convention carry out basic monitoring programmes and transfer the data to the HELCOM database. The monitoring is carried out according to guidelines which are revised annually. The guidelines give details on sampling locations, sample types covering seawater, sediment, fish, aquatic plants and benthic animals, and radionuclides to be determined in the samples. The guidelines furthermore specify the format for reporting the data to the database. High quality of the data is ensured through participation of the MORS laboratories in frequent group intercomparisons of analytical data from laboratory analyses as well as from evaluation of the reported data at the annual meetings of the MORS group. Intercomparisons cover laboratory

analyses of radioactivity in seawater, sediment and biota.

The data collected is summarized in indicator fact sheets that present results of radioactivity in seawater and fish from the Baltic Sea. More comprehensive assessments of radioactivity in the Baltic Sea are made by the group at larger intervals. The assessments include summaries of sources and inputs of radioactivity into the Baltic Sea, environmental levels and model-assisted estimates of radiation doses to man.

P16-10

**Results obtained in monitoring programmes and environmental studies carried out during more than 40 years in the sea areas surrounding the Finnish NPP**

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Environmental effects of thermal and radioactive discharges from the Loviisa and Olkiluoto NPPs in the recipient sea areas were assessed. The effects of cooling water on the temperatures in the sea were most obvious in winter. The formation of a permanent ice cover has been delayed, and the break-up of the ice has been advanced. The prolonging of the growing season has been the most significant effect of thermal pollution. At Loviisa, the thermal discharges have increased the production of organic matter in the discharge areas, which has led to more organic bottom deposits. The depletion of oxygen has caused remobilization of phosphorus from the bottom sediments, and contributed to deterioration of benthic macrofauna. Phytoplankton primary production has doubled in the area, and the thermal discharge has contributed to a stronger increase in the discharge area than in the intake area. The eutrophication of littoral vegetation has been the most unambiguous biological effect of the heated water in both areas. Small amounts of local discharge nuclides were regularly detected in environmental samples taken from the discharge areas: tritium in seawater, and activation products in suspended particulate matter, bottom sediments and in indicator organisms. Discharge nuclides from the local nuclear power plants were almost exclusively detected at the lower trophic levels of the ecosystem. The concentrations of local discharge nuclides in environmental samples have noticeably decreased in both areas in recent years. The radiation doses caused by the radioactive discharges to the population and to the biota were very low, practically insignificant. The effects of the thermal discharges were more significant, at least to the wildlife in the discharge areas of the cooling water, although the area of impact has been relatively small. The results show that the nutrient level and the exchange of water in the discharge area of a nuclear power plant are of crucial importance.

P16-11

**Tritium level along Romanian Danube river sector**

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Danube River lies west from the Black Sea in Central and South-eastern Europe. Due to its geological and geographical conditions, the Danube River Basin can be divided into 3 main parts: Upper Danube Basin, Middle Danube Basin and Lower Danube Basin. 65% of Lower Danube Basin is the natural border between Romania and Bulgaria. Two important nuclear objectives for both countries are found in this region: Kozloduy NPP and Cernavoda NPP (CANDU type reactor with tritium as major radioisotope evacuated in the environment). Taking into account the future development of this important Romanian nuclear objective, the knowledge of the present status of tritium level becomes a necessity.

Therefore, an extensive monitoring program for this radioisotope, along the Romanian sector of the Danube River Basin, starting with Cazane Gorge and ending with the three branches of the Danube Delta has been carried on since 2006 and it was accomplished in 2008. The different tributaries from this sector: Cerna, Jiu, Olt, and Arges were included also in this monitoring program. The highest values were constantly recorded for the sites which are downstream the nuclear power plants. The anthropogenic nuclear activity could be identified by the maximum values acquired, but their effect to the Danube water is far from being critical from radiation protection point of view. Monthly sampling was established for Turnu Severin location (in the beginning of Romanian Danube section) during 2007 in Danube water and precipitation. Tritium level trends of Danube River for this location were compared with seasonal variations of tritium concentration in precipitation during the same period of monthly sampling in Danube water.

P16-12

**Gamma radioactivity monitoring of sediments in rivers in Serbia during the period 2005 – 2009**Eremic-Savkovic, Maja; Pantelic, Gordana; Vuletic, Vedrana; Tanaskovic, Irena; Javorina, Ljiljana

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In this paper we present radioactivity monitoring results of the sediments in Serbian rivers from 2005 through 2009. Sediment samples have been collected at eight sites on six Serbian rivers, usually during spring and autumn. We have applied gamma spectrometry, gross alpha and beta activity and radiochemical method of  $^{90}\text{Sr}$  separation as measurement methods. Our results show that activity concentration of natural radionuclides in sediments (mean annual values in Bq/kg) is within the average values limits for the territory of Serbia. Activities of long living radionuclide of artificial origin have tendency of mild decrease as a result of dissolution, leaching and changes in river flow.

P16-13

**Radiocarbon and tritium activity in the environment of the National Park Plitvice Lakes**Horvatinčić, Nada; Barešić, Jadranka; Krajcar Bronić, Ines; Obelić, Bogomil

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The disturbance of natural distribution of tritium ( $^3\text{H}$ ) and radiocarbon ( $^{14}\text{C}$ ) caused by thermonuclear weapon tests in the sixties of the last century made these isotopes very important tracers in environment. Their concentration can be also locally affected by fossil fuel combustion (decrease of  $^{14}\text{C}$ ) or by various nuclear facilities (increase of  $^{14}\text{C}$  and  $^3\text{H}$ ). In our comprehensive study of the environment in the Plitvice Lakes National Park we measured  $^{14}\text{C}$  in monthly samples of atmospheric  $\text{CO}_2$  and  $^3\text{H}$  in monthly precipitation in period 2003–2006.  $^{14}\text{C}$  activity was also measured in the beech leaves and needles of spruce and abies collected as 1-year composite samples in the woods of the Plitvice Lakes area in 2005 and 2006.  $^{14}\text{C}$  activity of monthly  $\text{CO}_2$  samples vary between 101.5 and 109.6 percent of modern carbon (pMC) with slightly lower  $^{14}\text{C}$  activities in winter months due to the influence of  $\text{CO}_2$  from fossil fuel combustion. The values are similar to those measured in the city of Zagreb, which is a densely populated industrial center. The  $^{14}\text{C}$  activities of tree leaves and needles are slightly higher than mean yearly atmospheric  $^{14}\text{C}$  activities: the highest values have needles of abies (111 pMC, 110 pMC) and spruce (110 pMC, 109 pMC), followed by beech leaves (106 pMC, 105 pMC) and atmospheric  $\text{CO}_2$  (104 pMC, 105 pMC). Higher  $^{14}\text{C}$  activities of coniferous wood indicate that the collected needles represent an average of several years period while the  $^{14}\text{C}$  of leaves of deciduous wood represent the mean  $^{14}\text{C}$  from the growing period (spring-summer).  $^3\text{H}$  activities of monthly precipitation showed seasonal fluctuations with maximum in summer (13–18 TU) and minimum in winter (0–5 TU), and are in good correlation with  $^3\text{H}$  in the Zagreb precipitation. In conclusion,  $^{14}\text{C}$  and  $^3\text{H}$  in the atmosphere of the Plitvice Lakes area reflect the global trend of these isotopes in the atmosphere, and are at the same level as in highly populated area of Zagreb.

P16-14

### **<sup>137</sup>Cs concentrations in Saimaa ringed seals during 2003–2009**

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STUK – Radiation and Nuclear Safety Authority, Research and Environmental Surveillance, FINLAND

The Saimaa ringed seal (*Phoca hispida saimensis*) became isolated in Lake Saimaa at the end of the last ice age ca. 8000 years ago when the connection between Lake Saimaa and the Baltic Sea was broken. The Saimaa ringed seal is one of the very few seal species that live in inland waters. Due to climate change, however, the lack of an ice cover on the lake threatens to drastically decrease the seal population. The Saimaa ringed seal is an endangered species, with an estimated population of 260 seals, and it is protected by law.

As top predators in the aquatic food chain, fish-eating seals are vulnerable to the accumulation of contaminants. Seals are also important indicator species, which give knowledge of current state of the environment. In this study the concentrations of <sup>137</sup>Cs were analysed in Saimaa ringed seals. A total of 54 seals were collected by the Metsähallitus Natural Heritage Services in Lake Saimaa between 2003 and 2009. The seals had died of natural causes or accidentally by drowning. The seals were sampled under the supervision of the Finnish Food Safety Authority EVIRA. Concentrations of <sup>137</sup>Cs were analysed in muscle, liver, kidney, bone, spleen and pancreas by the Radiation and Nuclear Safety Authority -STUK in Finland.

The mean radionuclide <sup>137</sup>Cs concentrations in muscle, liver and kidney, bone, spleen and pancreas were 76, 65, 64, 75, 90 and 83 Bq/kg f.w., respectively. The highest <sup>137</sup>Cs concentration, 180 Bq/kg f.w., was measured in 2004 and the lowest, 28. Bq/kg f.w., in 2009 in muscle tissue. The results indicate that the <sup>137</sup>Cs concentrations in Saimaa ringed seals decreased evenly not only in muscle, but also in liver and kidney, during the study period. A similar trend was found in the correlation between seal weight and the <sup>137</sup>Cs concentrations, which indicates high accumulation of <sup>137</sup>Cs in this species.

P16-15

### **Radioactivity of Po-210 in oysters collected in Taiwan**

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The Uranium-238 series decay product polonium-210 (Po-210) exists widely in the environment, and is well known to be enriched in the tobacco, animal's viscera and suspension particles in surface sea-water. Oyster is cultivated greatly along the coast of Taiwan, and it is one of the most favorite food for the Taiwanese. The oysters intake the suspension particles in surface sea-water, and the Po-210 is accumulated indirectly in them. The internal effective dose of Po-210 coming from the intake of oysters by Taiwanese is needed to be evaluated. In this study, oysters around the coast of Taiwan are collected, dried, spiked with a Po-209 tracer for yield, and digested with concentrated HNO<sub>3</sub> and H<sub>2</sub>O<sub>2</sub>, followed by dissolving in 0.5 N HCl. The polonium is then spontaneously deposited onto a silver disc, and the activity of Po-210 is measured using an alpha spectrum analyzer equipped with a silicon barrier detector. In the meanwhile, the internal effective dose of Po-210 coming from the intake of oysters by Taiwanese is evaluated.

P16-16

**Natural alpha emitting radionuclides in bottled drinking water, mineral water and beverages****Benedik, Ljudmila**

Jožef Stefan Institute, SLOVENIA

It is well known that water contains dissolved radionuclides from uranium and thorium decay chains. The geological setting strongly influences the occurrence of dissolved natural radionuclides in water. Their concentrations are variable and depend on the nature of the aquifer rock types and the prevailing lithology. Measurements of their levels in drinking water are therefore important to estimate the potential exposure of the public. Quantitative information about the activity concentrations of critical alpha emitting radionuclides in the food and drink is important in the study of cumulative radiation effects on human life. In most countries is an increasing tendency in consumption to replace tap water with commercial bottled natural and mineral water. On the other hand, various beverages as well as dietary supplements are also prepared from mineral water not ordinary tap water. In the present study, the activity concentrations of U-238, U-234, Ra-226 and Po-210 in drinking water, mineral water and beverages were determined. Water samples were collected from different geological or lithological background areas all over the country. For determination of investigated radionuclides alpha-particle spectrometry was used. After addition of tracers, uranium and polonium were preconcentrated from water samples by coprecipitation with  $MnO_2$  at pH 9 using an ammonia solution. The Po source was prepared by spontaneous deposition onto a copper disk before uranium separation. Then the radiochemical separation of uranium was performed from the remaining solution using a UTEVA column and the source for alpha counting was prepared by microcoprecipitation with  $CeF_3$ . For determination of Ra-226 a coprecipitation procedure with  $Pb(Ra)(Ba)SO_4$  was used. Results obtained showed that activity concentrations of U-238, U-234, Ra-226 and Po-210 in bottled drinking and mineral water from Slovenia are low and not exceed the limit values imposed by national legislation.

P16-17

**Radiation protection of the public and the environment: long-term, large-scale radioecological monitoring by spruce needles****Seidel, Claudia<sup>1</sup>; Gruber, Valeria<sup>1</sup>; Maringer, Franz Josef<sup>2</sup>**<sup>1</sup>University of Natural Resources and Applied Life Science, Low-Level Counting Laboratory Arsenal, AUSTRIA; <sup>2</sup>BEV – Federal Office of Metrology and Surveying, AUSTRIA

In a two years radioecological study spruce needle samples of the Austrian Bioindicator Grid collected between 1984 and 2008 were analysed retrospectively by low-level gamma-ray spectrometry to investigate the geographical and temporal distribution of radionuclides in spruce needles of the last 25 years. Main focus was the development of the radioactive contamination before and after the Chernobyl fallout 1986. Overall more than 750 spruce needle samples of selected locations – well distributed among the area of Upper Austria – were analysed for different natural and anthropogenic radionuclides: Cs-137, K-40, Pb-210, Ra-226, Ra-228, U-238. Additionally soil samples were taken at selected sites to estimate transfer factors to describe the transfer of radionuclides from soil to spruce needles. On the basis of the measured Cs-137 activity concentrations in the spruce needles and soil samples estimations are carried out, how to use the Bioindicator spruce needles for environmental radioactivity monitoring. Hence the detection limits for additional Cs-137 deposits ( $Bq/m^2$ ) in spruce needles samples are estimated at various locations. Furthermore the results have been integrated into an existing environmental surveillance programme in Upper Austria.

P16-18

### Slovenian experience with inconsistencies in radioactive contamination monitoring results

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Monitoring of the global radioactive contamination has been carried out in Slovenia since the early sixties with the purpose to provide a basis for calculating the exposure of the population due to radioactive contaminants and to observe and understand radionuclide concentration trends in different media over long periods. Above all, two long-lived fission radionuclides,  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$ , have been followed in environmental samples, as well as in foodstuffs and feeding stuffs. In addition to that, river water contamination with  $^{131}\text{I}$  due to medical use was also monitored, as well as  $^3\text{H}$  in drinking water and precipitation. The measurement program was roughly equally divided between two technical support organisations, each always measuring same sample. With the changes in legislation and public procurements procedures in 2005, this mode of operation had to be changed. The monitoring program is still divided into 2 roughly equivalent parts, with organisations switching between those parts practically every year. As a consequence, the continuity of measurements was broken. Both organisations are accredited for performing monitoring by the Slovenian nuclear Safety Administration. The Slovenian legislation has set the accreditation according to ISO/IEC 17025 standard as one of the conditions for this. If we take this into account, the change of monitoring operator should not present a problem and all results should be consistent. Nevertheless, we have noticed some irregularities in long term trends. Evaluation has shown that the inconsistencies can be often attributed to change of micro location, which can lead to change of results due to different characteristics of the same media. Some are also due to differences in calibration between laboratories and some are yet unexplained. These inconsistencies can lead to different exposure estimates on yearly bases, artificially boosting or diminishing the calculated influence of the radioactive contamination on the population.

P16-19

### Problems connected to measuring a valid Peak-to-valley ratio in field gamma spectrometry

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During in-situ gamma spectrometry, the ratio between count rates of the full-energy peak and the count rates of an energy region just below the peak, can be used as an indicator of depth of the source below ground level. The peak-to-valley ratio decreases with increasing depth of the source due to forward scattered Compton photons producing counts in the valley. The concept Peak-to-valley ratio used for environmental radioactivity measurements, is connected to a lot of difficulties regarding equipment and measurement geometry. There is great need to keep the ratio as free from disturbance as possible, this because the ratio is always suffering from bad statistics. Tests how changes in measurement geometry changes the ratio in laboratory environment was performed to better understand what to be accounted for in a normal measurement situation. Tests of how dead time might influence the ptv-ratio was conducted with good results for two specific preamplifier types, the resistor feedback and the transistor reset type. The transistor reset preamplifier was showing stability of the ratio for the different settings of the electronics and preserving the ratio to a constant value.

P16-20

**Interception of wet deposition of radiocaesium and radiostrontium by *Brássica napus***

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In the present study, wet deposition of  $^{134}\text{Cs}$  and  $^{85}\text{Sr}$  were applied to spring oilseed rape at different growth stages in order to study interception of  $^{134}\text{Cs}$  and  $^{85}\text{Sr}$  of different development stages of the crop and of plant growth. The crop used was spring oilseed rape (*Brássica napus* L.) and the contaminating isotopes that were used,  $^{134}\text{Cs}$  and  $^{85}\text{Sr}$ , were deposited using simulated rainfall. The study was conducted in the field, on agricultural land under normal cultivation treatments. Biomass samples were dried and activity measured by HPGe detector. The interception fraction was found to be positively correlated to the leaf area index, with an  $r$ -value of 0.75 for  $^{134}\text{Cs}$  and 0.77 for  $^{85}\text{Sr}$  and to crop biomass, with an  $r$ -value of 0.80 for  $^{134}\text{Cs}$  and 0.77 for  $^{85}\text{Sr}$ . It is important to investigate the direct uptake of  $^{134}\text{Cs}$  and  $^{85}\text{Sr}$  during the first year after wet deposition, when the rate of translocation of these radioisotopes to edible plant parts is high compared with the rate of transfer from soil to plant (Madoz-Escande et al., 2004). The level of radionuclide capture, or interception, by plant parts is dependent on climate conditions, physico-chemical form of the radionuclides, plant morphology and biomass density (Vandecasteele et al., 2001; Rosén & Eriksson, 2008). The proportion of precipitation that can be held by the plant declines over time, but after the maximum water retention capacity is reached, the concentration of radioactive particles may continue to increase due to accumulation depending on their physico-chemical properties (Kinnersley et al., 1997). The time from deposition to harvest also has an effect on the total uptake of radio isotopes in plants. This effect, referred to as 'field losses' has been described by Chadwick and Chamberlain (1970).

P16-21

**Variation of dietary intake of radioactive cesium after the Chernobyl fallout in Finland**

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The deposition of radiocesium after the Chernobyl accident in 1986 was unevenly distributed in Finland. The variation of ingestion doses was studied in three areas, in central Finland with the  $^{137}\text{Cs}$  deposition 50–80 kBq m<sup>-2</sup> and in southern and northern parts of the country where the deposition was 1–5 kBq m<sup>-2</sup>. Estimates of dietary intake of radiocesium were made for years 1987, 1997 and 2007 by using the foodstuffs monitoring data and statistics of food consumption. The annual internal radiation doses in the three areas ranged in 1987 from 0.04 mSv a<sup>-1</sup> to 0.38 mSv a<sup>-1</sup> and decreased then ranging in 2007 from 0.006 to 0.09 mSv a<sup>-1</sup>. The peak values of radiocesium in agricultural products were found in 1986–87 and the contents of  $^{137}\text{Cs}$  decreased rapidly thereafter. The contribution of wild products to  $^{137}\text{Cs}$  intake in 1987 varied from 32 to 56 percent. Due to the faster decline of  $^{137}\text{Cs}$  in agricultural products the contribution of wild products to the intake increased, and in 2007 their contribution was 77–97 percent of the ingestion dose. Currently the variation in consumption and origin of the wild foodstuffs are the main contributors to the dose variation in Finland. The ingestion doses calculated via data on foodstuffs were comparable to those received from the whole-body measurements or using data on mixed-diet measurements.

P16-22

### Investigation of Cs-137 redistribution within urban ecosystem

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It was studied the role of puddle sediments at the processes of horizontal migration and accumulation of Cs-137 in urban environment on the example of Ekaterinburg city, Russia. Ground of local depressed zones of forming puddles and puddle sediments are considered as final depots of nuclide concentration. Activity concentration of Cs-137 at puddle sediments was taken as a main object of the research. Regional deposition density by Cs-137 is assessed near 5.1 kBq/m<sup>2</sup> that associates with maximum concentration of upper 15 cm layer about 30 Bq/kg. It have been sampled 109 puddle sediments. The mean value of Cs-137 concentration in puddle sediments is 80 Bq/kg, maximum value is 540 Bq/kg. It is viewed the local migration of Cs-137 in urban environment which lead to its fourfold concentration in puddle sediments. The research has been made under the financial support of RFFR, project 10-05-96011.

P16-23

### Radioactivity in the environmental samples around the Cernavoda NPP

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The Cernavoda Nuclear Power Plant is dedicated to produce electrical & thermal power in a safe and efficient manner for at least 30 years, from nuclear power using CANDU technology. The factors presented below ensure that the public health and environment are adequately protected:

- source control;
- effluent control;
- effluent monitoring;
- environmental monitoring.

The Environmental Radioactivity Monitoring Program around Cernavoda NPP is designed to meet the following objectives under normal NPP operating conditions:

- to measure the radionuclide concentrations in environmental media;
- to provide an independent assessment of the effectiveness of the source control, effluent control and monitoring based on measurements in environment;
- to validate the models and parameters used in the calculation of the derived emission limits;
- to provide data to aid in the development and evaluation of models and methodologies which adequately describe the movement of the radionuclides through the environment.

The Environmental Control Laboratory of the Cernavoda Nuclear Power Plant, located in Cernavoda town, is equipped with modern analyzing systems to determine the natural and artificial radionuclide content in the following environmental samples from an area with 30 km radius around the NPP:

- airborne particles, iodine, aqueous vapours and deposition from air;
- surface water, deep ground water, infiltration water, drinking water;
- soil and grass;
- sediment and fish;
- milk, eggs and meat (chicken, pork and beef);
- vegetables, cereals and fruits.

The results of the monitoring program are annually compared with the results of The Preoperational Environmental Monitoring Program performed between 1984 and 1994. There were no environmental radioactivity modifications around the Cernavoda NPP comparing to the period before the NPP operation.

P16-24

**Radionuclides activity concentration in soil in Serbia**

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The soil is the basic environment for migration of radionuclides into plants, from where they reach people and animals through food. The type of soil affects the distribution of radionuclides in the soil itself and their transfer into plants, respectively. Systematic testing of soil radioactivity is performed on 10 locations in the Serbia, at particular time periods according to methods defined by regulations. Additionally to that program, undisturbed grassland soils were sampled at 33 different sites in Serbia. Several sites are located in a mountainous area in the west and central part of Serbia, several sites in a flat northern Serbia and several sites in the south Serbia. The samples were collected during 2006–2008, twenty years after the Chernobyl accident. At each site 5 cm thick sample layers were separately collected. The periods of sampling were spring and autumn. The soil samples were purified from plants and rocks. Each sample was dried in an oven at 105°C–110°C to constant weight during 24–48 h. The dry soil was crushed and sieved (0.5 mm). The resulting sample was weighed and transferred into a Marinelli beaker. The radionuclide activity of uranium and thorium series and <sup>40</sup>K, as well as the artificial radionuclide <sup>137</sup>Cs was determined. Radionuclide <sup>137</sup>Cs was present in all soil samples. High standard deviation and big difference between minimal and maximal activity concentrations of cesium suggested typical artificial pollutant. Given that its half-life is 30 years, it is distributed deeply into soil by washing out, and it will remain in ecosystem for a long time. Extremely high <sup>137</sup>Cs concentrations were recorded in the uncultivated soil of the mountain Zlatibor, what could be explained by first precipitations following immediately the Chernobyl accident. According to collected data, the activity of natural radionuclides was almost equal at all locations. There was no significant difference between radionuclide activity of cultivated and uncultivated soil.

P16-25

**Monte Carlo calculation of ambient dose equivalent from natural radionuclides in the soil of Vojvodina district in Serbia**

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Presented results are the part of the project financed by Ministry of Science and Technological Development, Republic of Serbia. As the main influences come from uranium, thorium and potassium we measured their concentrations in soil by radiometric techniques. Further we calculate external doses as well as effective doses for particular organs and specified tissues using Monte Carlo code. In this paper only the results for external dose equivalent at 1 m from the surface are presented. Two depths of the soil are taken into consideration, infinite and 15 cm. The results are given for the territory of Bela Crkva and Vrsac in Vojvodina district, Serbia.

P16-26

### Interpretation of radionuclide concentrations near detection limit for dose calculations

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When internal doses are assessed from concentrations of radionuclides present in air, water or food, activity concentrations in these media have to be known. Usually, since annual committed doses are to be assessed, annual averages of radionuclide concentrations are used. If the medium, which contribution to the dose is calculated, is sampled more frequently than once a year, the annual averages are calculated from individual measurements. It is important that the averaging is performed in such a way that the average value calculated does not depend on the conditions in which the measurements were performed. It follows that they must not depend on uncertainties and detection limits since these describe the quality of the analytical process and not the properties of the samples. In test reports measurement results appear in three forms:  $u(a) - < q(a) - [\text{blank}]$ . In the reports the first form appears if the concentration exceeds the limit of quantification. If the result exceeds the detection limit but does not exceed the limit of quantification, usually given as a relative uncertainty, or, if reporting of the detection limit is required, the result appears in the second form. The third form means "not detected". To calculate the average, consistently of the results appearing in all three forms must be treated on an equal footing. To do this, the following transformation is used:  $u(a) \rightarrow u(a) - < q(a) \rightarrow 0 \rightarrow q(a)/1.65 - [\text{blank}] \rightarrow 0$ , if the detection and quantification limits are given at  $k=2$ . When this transformation is used, the average value depends just on measurement results and the uncertainty of the average depends on the measurement uncertainties, detection limits and quantification limits. Systematic influences occur when the transformation is performed. They will be described and explained in the contribution. To compensate the influences to the largest degree it is necessary to keep the quantification limit as low as possible.

P16-27

### Environmental tritium monitoring techniques applied for a tritium removal facility

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Nuclear and radiological installations are subjected to the regulatory control throughout their life. A preoperational monitoring program must be designed to assess the background radioactivity level in the area impacted by any future nuclear or radiological activity and shall cover at least one year before the installation will start to be operated. The paper presents the analytical techniques that were developed, optimized and applied during such an environmental monitoring program which addressed the impact area of a pilot tritium removal facility. Since the radionuclide of concern was tritium, a difficult to measure radionuclide, various methods were applied to extract and purify the water from air, vegetation and food products, which are presented in the paper. Due to the low background tritium measurement method applied, a seasonal variability was exhibited as concerns the tritium in air concentration, which confirms the natural origin of tritium background.

P16-28

**Radioecological studies in the Barents Sea (results of expedition in 2007 – 2009)****Leppänen, Ari-Pekka<sup>1</sup>; Kasatkina, Nadezhda<sup>2</sup>;****Matishov, Gennady<sup>2</sup>; Solatie, Dina<sup>1</sup>**<sup>1</sup>STUK – Radiation and Nuclear Safety Authority, FINLAND;<sup>2</sup>Murmansk Marine Biological Institute, RUSSIAN FEDERATION

Murmansk Marine Biological Institute (MMBI) carries out annually scientific expeditions to the Barents Sea. The expeditions cover wide range of scientific disciplines (e.g. oceanography and radioecology). In 2007 and 2009 a scientist from Radiation and Nuclear Safety Authority (STUK) joined the MMBI's expeditions. The objective of this collaboration was to study the contemporary distribution of anthropogenic and natural radionuclides in the Barents Sea ecosystem. The route of 2007 – 2009 expeditions included the standard section number 6 (Kola section) in the central part of the Barents Sea and in Franz Josef Land area. Studies were primarily focused on eastern part of the Barents Sea in 2007 – 2008. The sections along the north-eastern Sea border, the territory near Novaya Zemlya western coast and troughs intersection in the south-east were investigated. In 2009 focus was on the western part of the Barents Sea, the studies were carried out on standard sections numbers 3, 19 and in Svalbard area. Sampling of sea water, bottom sediments and living organisms were carried out. Samples were analysed in laboratories in Murmansk and in Rovaniemi. The Cs-137, K-40, Ra-226, Th-228 activity was measured by HPGe gamma-spectrometer. Contents of Pu-238, Pu-239, 240 and Po-210 isotopes were determined by alpha-spectrometric method and content of Sr-90 was determined by beta-radiometric method after the corresponding radiochemical preparation of samples. The results of previous year researches show low levels of anthropogenic radioactivity in all components of the Barents Sea ecosystem. The average Cs-137 content in sea water was about 2 Bq/m<sup>3</sup>, and Sr-90 – 3 Bq/m<sup>3</sup>. The specific activity of Cs-137 and Sr-90 in bottom sediments varied within the range 1 – 8 and 0.2 – 4 Bq/kg dry weight. The analyzed ratio Pu-238/Pu-239 in the sediment samples showed that the plutonium is from the atmospheric nuclear weapons testing. Cs-137 content in fish was about 0.2 Bq/kg wet weight.

P16-29

**Experimental study of the radionuclides transport in soil and plants from waste dump****Bragea, Mihaela<sup>1</sup>; Aldave de las Heras, Laura<sup>2</sup>; Carlos Marquez, Ramon<sup>2</sup>; Cristache, Carmen<sup>3</sup>; Toro, Laszlo<sup>4</sup>**<sup>1</sup>Institute of Public Health Timisoara, ROMANIA; <sup>2</sup>European

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The transport of radionuclides through terrestrial environments is determined by a multiplicity of processes with time-scales ranging from a few minutes to many years. The importance of understanding and predicting the radionuclide migration from soils to vegetation arises from its potential radiological impact: slow migration has as result an increase availability of radionuclides for root uptake and gives rise to external doses for a long time. The transfer factors (TF) for natural uranium isotopes, thorium isotopes, and <sup>226</sup>Ra were obtained in plant samples (grass-pasture) growing in granitic soils around disused uranium mine located in the Ciudanovita region in the West of Romania. Affected and non-affected areas of the mine presented large differences in the activity concentrations of radionuclides of the uranium series. We also determined transfer factors for several stable elements (essential and non-essential). A set of statistical tests were applied to validate the data. The results showed that the transfer factors for both the natural radionuclides and the stable elements are independent of the two substrate types involved and also of the two areas considered in the study.

P16-30

### **HYDRUS-computer simulation of radionuclide migration in groundwater due to clearance of low-level waste from decommissioning**

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BfS Federal Office for Radiation Protection, GERMANY

Bulk amounts of cleared building rubble mainly arise due to decommissioning of nuclear power plants. Depending on the type of clearance, weakly contaminated rubble can be released to be deposited in landfills. Leaching of radionuclides is caused by infiltrating rainwater and may lead to migration of radionuclides through the landfill and the vadose zone into the aquifer where the contaminated seepage is mixed with groundwater. If contaminated groundwater is used for irrigation or direct consumption, the food chain may be affected (water pathway). Clearance levels for radionuclides have to be calculated in such a way that the water pathway is considered and the effective dose for an individual of the public is at most of the order of 10 micro Sievert per year.

In the wake of availability of inexpensive and fast computers the leaching of radionuclides, their transport through the various zones of rubble and soil and eventually the contamination of groundwater can be computed by means of sophisticated mathematical models. The software package HYDRUS constitutes an internationally established standard in contaminant transport modeling. We apply HYDRUS to problems of nuclide transport and water dynamics in landfills, the vadose zone and the aquifer. Calculations can be performed in one and three dimensions. Calculations in a one-dimensional geometry proved to be robust general assessments of an overall contamination situation. Typically, a simulation output includes peak contamination levels and the duration of a given contamination at a model well close to the landfill. Simulations can be refined by three-dimensional modeling, for example in a site-specific approach. It is planned to present the modeling procedure and the dynamics of well-water contamination levels calculated with HYDRUS. Radionuclides considered are characteristic for both the water pathway and the solid material from the dismantling of nuclear power plants.

P16-31

### **Radioactivity in Trinitite – a review and new measurements**

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Samples of Trinitite and soil from Trinity site were studied in the radioactivity measurements laboratory at the University of Bremen and at the authors' facilities in Anaheim and Edgewater. Gamma spectroscopy was used to identify and quantify radionuclides in Trinitite and to perform a radiometric characterization of soil at the Trinity site. Additionally, a similar material ("atomsite") formed during a soviet test at the Semipalatinsk nuclear test site was investigated. Fission products (<sup>137</sup>Cs, <sup>155</sup>Eu) together with activation products (<sup>60</sup>Co, <sup>133</sup>Ba, <sup>152</sup>Eu, <sup>154</sup>Eu, <sup>241</sup>Am) and <sup>239</sup>Pu were identified. A literature search including some publicly available archive sources was conducted and our data compared to previously published results. Obtained data on Trinitite were also compared to literature data on atomsite formed during atmospheric nuclear test in Algeria. Variability of radioactivity in Trinitite and relationship of distance from the ground zero and activation were discussed.

P16-32

**Human exposure at selected sites  
of the peaceful underground  
nuclear explosions in Russia****Ramzaev, Valery; Repin, Viktor; Khramtsov, Evgeny;  
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FEDERATION

During the period 2001 – 2009, eleven field expeditions have been conducted to seven selected sites of the peaceful underground nuclear explosions (PUNE), which were performed in the European and Asian parts of Russia in the 20th century. Those were: “Crystal” and “Kraton-3” (Yakutia); “Dnepr” (Murmansk region); “Angara” and “Quartz” (Hanty-Mansiysk region); “Globus-1” (Inanovo region); “Taiga” (Perm region). Evaluation of the current doses to representative individuals was one of the main aims of the radiological investigations at the studied areas. The present communication summarizes the key experimental data and the doses estimations given in the relevant original publications and the scientific reports prepared by the authors. The routine measurements of dose rates in air were performed in tandem with in situ  $\gamma$ -ray spectrometry and GPS mapping. Samples, taken for radiometric analysis, consisted of typical terrestrial and aquatic matrices such as soil, wild mushrooms and berries, water and fish. The external (from the  $\gamma$ -ray emitting radionuclides) and internal (from  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$  and  $^3\text{H}$ ) doses to a human from the PUNE sources were estimated using data of the in situ measurements and results of the laboratory radiometric analyses. Conservative and real quantitative estimations of the locations factors and the diet components for several mostly exposed groups of human population were used for model calculations of the doses. The estimated effective doses included contribution from the global fallout. It is demonstrated that for some PUNE sites and some scenarios the dose of interest may exceed the negligible limit of 10 microSv/year. At the same time, for all the sites the current doses were far below the value of 100 microSv/year, which is the threshold for a possible application of some countermeasures, accordingly the Russian legislation.



S17-01a

**Radionuclides and heavy metals bioavailability in a Norwegian area rich in naturally occurring radioactive materials**

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Recent study on environmental samples from thorium rich Norwegian area showed high gamma dose rate and significant transport of radionuclides into environmental compartments giving multiple stressors action in natural conditions. The main objective of this work was to investigate distribution and uptake of  $^{232}\text{Th}$ ,  $^{238}\text{U}$  and heavy metals such as Cd, Cu, Zn and Pb from soil and rocks into biota samples in natural conditions. Soil samples, plant samples of the most abundant species in area and earthworms were sampled on high gamma dose rate location in Fen (Norway). Radionuclides and metals were analyzed by ICP-MS. Soil analysis showed high level of radionuclides, 995 mg/kg and 9 mg/kg, for  $^{232}\text{Th}$  and  $^{238}\text{U}$ , respectively. Pb and Zn were in moderate high but comparable with levels in other Norwegian soils, Cd and Cu were in range of non contaminated natural soil. Among the plants collected, the highest uptake of both  $^{232}\text{Th}$  and  $^{238}\text{U}$  was found in moss. Distribution of these radionuclides was positively correlated with levels found in soil taken below. Different earthworms' species showed high levels of  $^{232}\text{Th}$ ,  $^{238}\text{U}$ , Cd and Pb what suggest bioconcentration from soil – worms' habitat and food. Despite that no high transfer factors were calculated from obtained numbers it was shown that these Fen invertebrates had significantly higher levels of several contaminants in comparison to those from chosen reference site in the vicinity. These preliminary obtained results will be the basis for future work in aspect of:

- determination of sensitive plant, fish, earthworm and mice species,
- determination of transfer factors and possible bioconcentration,
- investigation of different plant parts ability to concentrate naturally occurring radionuclides and study on dependence between uptake and change of natural conditions,
- investigation of target organs for radionuclides and metals deposition and possible biological effects, which will be presented in the conference.

S17-01b

**Radionuclides and heavy metals levels in environmental samples from thorium rich Fen area in Norway**

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Fen area in southern Norway is documented to be among the highest natural world reservoirs of thorium ore. It is geologically well investigated area with  $^{232}\text{Th}$  rich carbonatite rocks. Dose risk assessment and radon investigations, done in past, showed total effective dose up to 14 mSv/year. However, there is still huge lack of data considering environmental impact from the natural occurring material. Our paper is a result of first investigation phase on multiple stressors study that comprises identification of contaminants, distribution in natural compartments, biota uptake and total environmental impact assessment. Gamma dose rate measurements, done in 2008, gave the average dose rate 4.2  $\mu\text{Gy/h}$ , much higher than world's average dose rate of 0.059  $\mu\text{Gy/h}$ . Soil, rocks, water and plants samples were collected from 14 sampling points. Concentration levels of  $^{232}\text{Th}$ ,  $^{238}\text{U}$  and heavy metals such as Cd, Pb, Cu and Zn were analyzed by ICP-MS. Rock levels of radionuclides were consistent with previous findings and positively correlated with recorded gamma dose rates in area. Total soil analysis showed the values in range 20–1500 ppm for  $^{232}\text{Th}$  and 4–11 ppm for  $^{238}\text{U}$ . Concentrations of Cd and Cu in soil were higher than world average, but in range of Norwegian soil values. However, ranges for Pb 52–260 ppm and for Zn 205–706 ppm for Zn, suggested mobilization and distribution from rocks. Despite high soil levels, total and size fractionated water samples showed neither radionuclides nor heavy metals contamination. Size fractionation showed that  $^{238}\text{U}$  was more soluble and in low molecular mass fraction, while  $^{232}\text{Th}$  was in particulate phase and confirmed typical behavior in nature. Considering both radionuclides and heavy metals found in rock and soil from this area, our future work will be focused toward investigation of mobilization conditions, transfer to biota and biological effects of possible synergistic action of different radionuclides and heavy metals.

S17-02

**Thoron and its airborne progeny in Irish dwellings**

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During the period 2007–2009 long term indoor concentrations of thoron gas and airborne thoron progeny were measured using passive detectors in 205 dwellings in Ireland. Passive alpha track detectors of different types were used to make these measurements in the indoor air over a typical exposure period of at least three months. Thoron concentrations were measured using Raduets detectors supplied by Radosys, Budapest while thoron progeny concentrations were measured using passive detectors designed by the National Institute of Radiological Sciences (NIRS), Chiba, Japan. Radon concentrations were also measured in these dwellings using the standard alpha track detectors employed by the Radiological Protection Institute of Ireland (RPII). The main results obtained are given below. It should be noted that these results are not seasonally adjusted. The estimated annual doses for thoron progeny (ThP) and radon (Rn) were calculated using dose conversion factors (DCF). The DCF(ThP) used was based on the dosimetry models of Kendall and Phipps (2007) and of Ishikawa et al. (2007). Exposure to indoor air containing thoron decay products at a concentration of 1 Bq/m<sup>3</sup> EETC (Equilibrium Equivalent Thoron Concentration) was estimated to result in an annual effective dose of 0.75 mSv. For radon a DCF(Rn) of 1 mSv/year for indoor exposure under standard conditions to 40 Bq/m<sup>3</sup> was used. Thoron gas activity concentrations ranged from < 1 to 174 Bq/m<sup>3</sup> with an arithmetic mean of 22 Bq/m<sup>3</sup>. Radon gas concentrations ranged from 4 to 767 Bq/m<sup>3</sup> with an arithmetic mean of 75 Bq/m<sup>3</sup>. The corresponding estimated annual doses are 0.1 (min), 19.2 (max) and 1.9 (arith.mean) mSv/year. Thoron progeny ranged from < 0.05 to 3.8 Bq/m<sup>3</sup> (EETC) with an arithmetic mean of 0.47 Bq/m<sup>3</sup> (EETC). The corresponding estimated annual doses are 2.9 (max) and 0.35 (mean) mSv/year. In 14 dwellings doses from thoron progeny exceeded those from radon.

S17-03

**Radiation from geological samples in museums and showrooms**

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In the last two decades the international radiation safety communities e.g. IAEA, EC paid huge attention to naturally occurring radioactive materials (NORM) and technologically processed materials (TENORM). Exposures of workers handling such materials can be very high, in some cases even substantially higher than occupational exposures of workers dealing with the licensed radiation sources. Being aware of that the radiation safety community has published first safety standards related to NORM. The natural radioactive materials are mainly used in industry, while quite frequently also in research laboratories and educational institutions. Even more they are often present in museums and showrooms of minerals causing exposure of workers and public. The competent authority, the Slovenian Nuclear Safety Administration, identified in the last years many radioactive geological samples in geological institutions as well as in museums. The samples containing uranium and thorium can have different forms e.g. ores, minerals and petrified samples. Radiation safety requirements were ignored in most cases because the specimens were not identified by owners as radioactive materials. Recorded photon dose rates were occasionally a few orders of magnitude above the natural background and no provisions to avoid internal exposure were in place. Radiation safety requirements for such practices are analysed also in view of a lack of risk awareness. The paper focuses on the past and present requirements regarding the radiation practices. It analyses the practices in a view of international standards (EU BSS, IAEA BSS). The analyses of different national approaches from selected countries are given. Regarding the fact that external radiation and internal exposure due to radon are mostly neglected, the need for unavoidable action provided by a regulator is discussed in order to keep the system of radiation protection effective.

S17-04

**Natural radiation background  
time series from gamma  
detector stations in Iceland**

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We present here for the first time data from four continuously monitoring gamma detector stations in Iceland along with basic analysis. The results from all four stations show an average dose rate of 44–49 nSv/hr, and standard deviation around 5 nSv/hr (10 minute sampling cycle), with a distribution consistent with a Gaussian one.

P17-01

### Localities in Montenegro with elevated terrestrial radiation

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Based on geological evidence and findings of previous investigations of natural radiation in Montenegro, a research aimed to find localities with elevated terrestrial gamma-background and recognize sources of their radiation was conducted during the two-year period 2008–2009. For this purpose, 135 localities, which have geological formations known to contain minerals with potentially high concentrations of U, Th and K, were selected throughout the country for dosimetric survey. Knowing from earlier investigations that an average absorbed dose-rate in air, 1 m above the ground, in Montenegro is  $55 \text{ nGy h}^{-1}$ , it was arbitrarily adopted that only localities with absorbed doses at least 50% above this average value will be considered within this project as having elevated radiation background. Field measurements have shown that 43 localities, out of the 135 investigated, have such absorbed dose values (higher than  $80 \text{ nGy h}^{-1}$ ). Among 10 sites with the highest radiation background in Montenegro ( $110\text{--}192 \text{ nGy h}^{-1}$ ), two sites are on andesite volcanic rock (settlements Virpazar and Savnik), one on fluvio-glacial sand and gravel (near the town of Niksic), while the rest lie on bauxite deposits (near the town of Niksic). Compared to the other known areas of high natural radiation background in the world, all these sites in Montenegro have a moderately elevated level of radiation background.

From each of these 43 localities, soil samples have been collected for further radiation characterization of these sites. Using HPGe gamma-spectrometry, activity concentrations of radioisotopes  $^{40}\text{K}$ ,  $^{232}\text{Th}$ ,  $^{235}\text{U}$ ,  $^{238}\text{U}$ ,  $^{226}\text{Ra}$  and  $^{137}\text{Cs}$  were determined in soil samples. In this way, it was established that the main source of elevated radiation at the sites on andesite rocks was a high content of K (activity concentrations up to  $3341 \text{ Bq kg}^{-1}$ ), and high U and Th content at the sites on bauxite deposits (up to  $285 \text{ Bq kg}^{-1}$  of  $^{238}\text{U}$ , and up to  $201 \text{ Bq kg}^{-1}$  of  $^{232}\text{Th}$ ).

P17-02

### Identifying the presence of orphan radioactive sources in dwellings from the vicinity of former uranium mines (Portugal): a methodological approach

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For nearly one century, 61 uranium mines were exploited in central Portugal, generating 13 million tonnes of different kinds of wastes, accumulated normally in the vicinity of the exploitations. Over the years, some of these wastes were used as construction materials, usually in road construction, but sometimes also in residential buildings; in this last case, the dose rate increase due to the exposure to ionizing radiation can be significant.

To assess the possible use of mining waste in residential constructions, and the increase in dose exposure to the ionizing radiation associated, a methodology was developed in order to measure radiological levels, capable of being applied in buildings of different construction types, and producing a time/cost-effective procedure. The methodology accounts for the challenge of discriminating between high radiation levels of purely natural origin, since the region is also radon prone, and those induced by the possible presence of radioactive materials resulting from mining activities.

Thus, using as test cases two dwellings located in the vicinity of an old mining exploitation, indoor radon concentration were measured with CR39 passive detectors (90 days exposure time); this information was supplemented with data on exposure to gamma radiation (external radiation), gamma radiation flux from building materials, radon gas flux from the floors and radon concentration in sub-slabs.

The results showed important differences between the several parameters measured, reaching sometimes a few orders of magnitude. In one dwelling, radioactive waste was identified in the sub-slab, with the presence of these materials contributing to an excess of dose of about  $45 \text{ mSv/year}$ , assuming as background the values measured in the second dwelling where no radioactive waste was found.

The methodology developed may also play an important role in all the mitigation process, helping to reduce remediation costs.

P17-03

**Bioremediation of land contaminated by radioactive material****Koretskaya, Liubov**

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**Objectives:** Radionuclide pollution arises as a result of many activities, largely industrial, such as mining and the provision of nuclear energy. These pollutants are discharged into the atmosphere and aquatic and terrestrial environments and may reach high concentrations, especially near the site of entry for point source emissions, and/or be transported between different environmental compartments. Metallic radionuclide has also entered the environment as a result of weapons-testing and accidents such as Chernobyl. The effects of radionuclide in ecosystems are not well understood, although a degree of understanding exists over their fate; it is primarily concerns over transfer along aquatic and terrestrial food chains that are of current economic and public-health significance. Microbial biotransformations of metallic radionuclides are of great importance in the biosphere and several have additional applications for bioremediation. Reactions mediated by microorganisms include solubilization from organic and inorganic complexes, compounds and minerals by the production of acids or chelating agents. The aim of our study consisted in elaboration of the new biotechnological method for environmental pollution risk reducing.

**Methods:** Screening the importance of soil micro-organisms on radionuclides mobility have been performed.

**Results and conclusions:** The influence of microorganisms on the environmental fate of radionuclides was elucidated, using some non-pathogenic strains of *Penicillium* sp. and *Mucor* sp., active producers of extra cellular pectolitic enzymes. Higher degree of radio nuclides insoluble compounds solubilization, especially cobalt compounds, was observed under the influence of investigated strains in vitro (Invention nr. 3657 MD). Such mechanisms are important components of radionuclide biogeochemical cycles and should be considered in any monitoring analyses of environmental radionuclide contamination.

P17-04

**Establishment of research network for natural radiation exposure studies in Asia**

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A new project entitled gConstruction of natural radiation exposure study network h has been recently adopted in the Program of Promotion of International Joint Research under the Special Coordination Funds for Promoting Science and Technology operated by the Ministry of Education, Culture, Sports, Science and Technology of Japan. Eight institutions are involved in this project and the project will continue until March, 2012. The aims of the project are to assess the dose for natural radiation exposures using state-of-the-art measurement techniques in four Asian countries (China, India, Korea and Thailand) and their outcomes will be distributed worldwide. Conventional measurement techniques will be improved and be optimized. More scientific data and results will be obtained throughout this project. In particular, the following advanced technologies for inhalation exposures will be introduced:

1. Discriminative measurements of radon (<sup>222</sup>Rn) and thoron (<sup>220</sup>Rn) gases,
2. Evaluation of thoron decay products concentration,
3. Simple but effective particle size distribution measurements.

P17-05

### The measurement of the natural radiation background in a salt mine

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The Unirea Salt Mine is situated at a depth of 208 meters beneath the surface of the earth that corresponds to a water-equivalent thickness of about 560 meter. It has a remarkable stability of microenvironment, characterized by a constant temperature over the years of  $12.5 \pm 0.5^\circ\text{C}$  and a relative humidity of 60–65 %. In order to set up a calibration laboratory in this mine, for the measuring systems dedicated to the dosimetric measurements and environment, the natural radiation background had to be measured. The measurements were made using two different dosimetric systems: a. An AUTOMESS 6150 doseratemeter with an external scintillation probe; b. An TLD dosimetric system SD-TL type, which consists of the TL laboratory reader-analyse, 770 A type and thermoluminescent detectors by LiF:Mg, Cu, P. With the AUTOMESS 6150 we measured directly the ambient dose equivalent rate. With the TL dosimetric system we measured for times of 39 days, in different locations in the salt mine. The values of ambient dose equivalent rate were calculated from the results of these measurements; they are in the same range of  $1,5 \text{ nSv h}^{-1}$ – $3,8 \text{ nSv h}^{-1}$ .

P17-06

### Personal monitoring of aircrew exposed to cosmic radiation

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Everybody who flies frequently is exposed to elevated levels of cosmic radiation of galactic and solar origin and secondary radiation produced in atmosphere. The annual average radiation dose to aircrew may become similar or even large than that of other occupationally exposed groups. Determination of effective dose for aircrew members was performed by using programs EPCARD\*. Altogether about 180 pilots were monitored during 2007 year and about 500 air crew members were monitored during 2008 years. In 2007 annual average effective dose was 2.5 mSv and maximum personal dose was 4.0 mSv compared to next year annual average 2.2 mSv and maximum 3.7 mSv. Mobile Dosimeter Unit (MDU) Liulin Si spektrodosimeter and Exploranium GR 135 have been used for experimental measuring of levels of cosmic radiation on the airplane board. Additionally to personal cosmic radiation monitoring, small human study was conducted to monitor life style, nutrition and various clinical, biochemical, genotoxicity, immune and molecular markers from blood samples of exposed as well as control subjects and to investigate the possible effects of radiation exposure on human health.

**Acknowledgements:** \*Licence – program EPCARD (“European Program Package for the Calculation of Aviation Route Doses”), Helmholtz Zentrum München, Deutsches Forschungszentrum für Gesundheit und Umwelt (GmbH), Dr. Laschke and Dr. Nagel, Ingolstädter Landstrasse 1, 85764 Neuherberg, Germany. This work was supported by Ministry of Health SR 2005/42-SZU-20.

S18-01

**Progress with the revision of the EURATOM Basic Safety Standards and consolidation with other Community legislation****Janssens, Augustin**

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The revision of the EURATOM Basic Safety Standards (Directive 96/29/EURATOM) was undertaken to allow for the new ICRP Recommendations (Publication 103) as well as to consolidate all radiation protection legislation in a single BSS Directive. In line with ICRP the new Directive will allow for the three exposure situations: planned, existing and emergency. This required significant restructuring, together with the consolidation or recast. The new Directive will fully integrate all natural radiation sources, introducing more binding requirements for NORM industries, building materials, radon in dwellings and workplaces. The protection of the environment is now within the scope of the Directive. The Directive develops the concept of a graded approach to regulatory control, so that it is commensurate to the risk and to the effectiveness of such controls. In this context also the concepts of exemption and clearance have been worked out in more detail and new consideration is being given to the harmonisation of exemption and clearance levels. Further issues that emerged from the revision process are the definition and use of constraints and reference levels, as introduced by ICRP, and the principle of justification, in particular with regard to the deliberate exposure of people for reasons other than medical (e.g., for security screening). The revision and recast process is scheduled to be completed by mid 2010. Harmonisation with the International Standards (IAEA and co-sponsors) is vigorously pursued in view of co-sponsorship by EURATOM.

S18-02

**Comparison of current clearance standards and their brief history****Koskelainen, Markku<sup>1,2</sup>**<sup>1</sup>STUK – Radiation and Nuclear Safety Authority, FINLAND;<sup>2</sup>The University of Manchester, UNITED KINGDOM

Over the last 30 years, governments and the nuclear and non-nuclear industry have funded efforts to assess the potential for tightening of materials cycles and minimisation of waste containing hazardous levels of radionuclides. A number of studies have demonstrated the technical efficacy of converting various forms of radioactively contaminated materials into safe form and demonstrated that this can be achieved cost effectively and safely. However, until now clearance of materials considered safe has only occurred in small volumes, or within the nuclear industry for specific internal uses. In the near future large amounts of radioactively contaminated and activated materials will be generated by the decommissioning of first generation nuclear power plants and the historic case by case approach will not be sufficient to handle the associated volumes. To minimise the waste arising and encourage clearance of radioactively contaminated materials number of governments and international organisations have redrafted their regulations and guidance, allowing for a more fluent release of materials, from regulatory control. The current approach taken by the international organisations and national authorities is risk based. It intends to provide protection to workers, public and environment alike. Although the International Atomic Energy Agency (IAEA), European Commission (EC) and United States Nuclear Regulatory Commission (USNRC) recommendations are in general agreement on the principles of how clearance should be applied there is still some way to go before clearance values are harmonised. This study looks at the historic development of clearance standards over the last 30 years and compares the current risk based models and specific activity limits given by the IAEA, EC and the USNRC.

S18-03

**Current situation with application of new ICRP system of radiological protection in the Russian Federation: regulation and optimization issues****Shandala, Nataliya<sup>1</sup>; Kiselev, Mikhail<sup>2</sup>**<sup>1</sup>Burnasyan Federal Medical Biophysical Centre, RUSSIAN FEDERATION; <sup>2</sup>Federal Medical-Biological Agency, RUSSIAN FEDERATION

Current Russian basic regulative document, Radiation Safety Standards, needs updating, which must be carried out in accordance with common international practice. In the light of issuing of new ICRP principal recommendations in 2007, review of the IAEA Basic Safety Standards has been started. In compliance with the national practice, the IAEA member states implement the Basic Safety Standards in a form of national systems of laws, norms and rules. In fact, the current national radiation safety standards can be updated in Russia only after new IAEA standards issuing. Nevertheless, even today, we must take the contemporary principles of development of the radiation safety system postulated in the ICRP recommendations into account. There are no stricter hygienic regulations in ICRP Publication 103 in comparison with those established in Russia, but there are some new conceptual provisions and concepts in it. Publication 103 was being translated into Russia. The paper deals with the frame of national system of radiation safety regulation. Application of optimization and dose constraints in the course of Russian NPP operation is the specific case and its relevance is stressed in terms of future development of nuclear power. Using nuclear legacy regulation as an example, an importance of application of new exposure situations from ICRP Publication 103 has been shown. The safety levels reached due to the optimization principle application in the field of radiation safety and protection at the Russian NPPs and at the areas of their potential exposure to the public and environment can be recognized as rather good.

S18-04

**Stakeholder Involvement in Medical Practices – Report of the Heads of European Radiation Control Authorities (HERCA)****Levebvre, G.<sup>1</sup>; Kettunen, E.<sup>2</sup>; Godet, J.-L.<sup>3</sup>; Olerud, H. M.<sup>4</sup>; Sánchez, M.<sup>5</sup>; Trueb, Ph. R.<sup>6</sup>; Griebel, J.<sup>7</sup>; Stoop, P.<sup>8</sup>; Clarijs, T.<sup>1</sup>**<sup>1</sup>Federal Agency for Nuclear Control, BELGIUM; <sup>2</sup>STUK – Radiation and Nuclear Safety Authority, FINLAND; <sup>3</sup>Autorité de Sûreté Nucléaire, FRANCE; <sup>4</sup>Norwegian Radiation Protection Authority, NORWAY; <sup>5</sup>Consejo de Seguridad Nuclear, SPAIN; <sup>6</sup>Federal Office of Public Health, SWITZERLAND; <sup>7</sup>Bundesamt für Strahlenschutz, GERMANY; <sup>8</sup>National Institute for Public Health, NETHERLANDS

Radiation is used in diagnostic radiology to obtain anatomical images of the body and in nuclear medicine to visualize the function of an organ. In both cases, the radiation dose to the patient is an unwanted “side-effect”, unlike in radiation therapy where the dose is used to control cancer growth or as palliative treatment. Tremendous technological developments in both diagnostic and therapeutic applications have taken place over the last few years. The growing use of radiation related to these technological advances is of great benefit to patients as individuals and to society as a whole; it has however also led to a large increase in medical radiation exposure, which raises radiation protection issues. Only a close collaboration between all stakeholders will allow this dose increase to be understood and kept under control. A working group of HERCA has reviewed a large variety of stakeholder involvement practices in the member states. It has also looked into future stakeholder involvement, where the national radiation protection authorities must play a leading role. The authorities should take the initiative in bringing stakeholders together in order to solve today’s challenges in a concerted manner. These challenges have arisen from multimodal approaches (combination of new technologies) and/or new applications/practices involving different professional groups. Such examples can be found in radiation therapy (image guided radiotherapy, incident / accident management), in nuclear medicine (PET/SPECT-CT), in radiology (turning to digital systems, patient dose optimization), screening campaigns and the complex issues related to self-referral. Experts from member states of HERCA have discussed the role of authorities in the involvement of stakeholders, tried to identify relevant parties and given preliminary recommendations for radiation protection authorities and organisations, who need to improve their involvement, and examples of stakeholder involvement initiatives.

S18-05

**Health detriment and radiation protection management**

**Schneider, Thierry; Lochar, Jacques; Vaillant, Ludovic**  
CEPN, FRANCE

Introduced in 1977 by ICRP, the concept of health detriment is a complex construction based on scientific information and on expert judgement. It gives an estimate of the total harm to health to individuals and their descendants as a result of an exposure to radiation, assuming a linear-non-threshold dose-effect relationship. It allows to compare risks induced by different types of radiation exposure situations and to put into perspective with other health risks.

Understanding its meaning is not straightforward, even for experts. It is in fact necessary to analyse its components and associated value judgements, and their evolution to catch this meaning. In addition, the application of this concept for different exposure situations is still a matter of debates in the radiation protection community. For instance: Does it represent a potential number of health effects for an exposed population? Does it give an estimate of the probability of occurrence of a radiation-induced effect for an individual?

The aim of this presentation is to recall the basis of this concept and its evolution and to discuss the key stakes regarding its usefulness in the radiation protection system. For instance, for occupational exposures, although the radiation detriment is no more the central indicator for establishing exposure limits, it is still quite useful to compare the risk associated with these limits with the levels of risk associated with exposure to different carcinogens and with occupational injuries. In addition, it is a key element for addressing the probability of causation for occupational diseases associated with ionizing radiation. Its use is also a matter of debate regarding radioactive waste management or environmental exposures, for which the main concern refers to exposure of future generations and large populations. Nevertheless, this concept is useful in this domain for assessing the level of protection on the basis of the current radiological protection criteria.

S18-06

**Norwegian strategy to fulfil the OSPAR Radioactive Substances Strategy objectives**

**Natvig, Henning; Nilsen, Mette**  
Norwegian Radiation Protection Authority, NORWAY

At the 1998 Ministerial meeting of the OSPAR Commission, the Contracting Parties agreed a strategy with regard to radioactive substances, the OSPAR Radioactive Substances Strategy (RSS). It states that the ultimate aim is: substantial and progressive reductions in discharges and to achieve concentrations in the environment near background values for naturally occurring radioactive substances and close to zero for artificial radioactive substances by 2020. Several of the Contracting Parties are far from meeting the 2020 objective. The oil- and gas industry represent a substantial part of the TENORM-discharges to the North-East-Atlantic. A substantial part of the discharges come from the Norwegian sector. The Norwegian Radiation Protection Authority (NRPA) regulates the oil- and gas industry on the Norwegian sector. NRPA uses a variety of means to contribute to fulfil the RSS objectives by 2020. NRPA collaborate with the competent authorities from the other oil- and gas producing countries in the North Sea area to work towards a more harmonized regulation. The Norwegian zero discharge goal for the oil- and gas industries has been extended to contain radioactivity, It is also recommended to do a new consideration of injection of produced water on the two offshore platforms with the highest discharges of radioactive substances. We work towards a strengthened regulation of radioactive waste and discharges by a closer collaboration with the Norwegian Pollution Control Authority. As part of this work the legislation is currently under revision, and a new regulation based on the Pollution Control act is proposed. It is important to continue and develop the national monitoring programme of the industry, as well as investigate possible cleaning technologies and initiate cooperation between industry, regulators and researchers. Norway have at present special focus on TENORM. One of the first repositories for TENORM waste from the oil and gas industry was commissioned in 2008.

S18-07

### **The integrated management system – to ensure an overall safety**

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**Ham, Ulla; Lorenz, Bernd**

GNS, TZ, GERMANY

GNS (Gesellschaft für Nuklear-Service mbH) as a subsidiary company of the German utilities e.on, RWE, EnBW and Vattenfall is charged with ensuring the radioactive waste management for their nuclear facilities. Moreover GNS also provides its products and services to foreign customers.

“Safety first” – this is the key note of our vision to ensure sustainable radioactive waste management, meaning first of all the protection of people and the environment.

For this reason GNS has implemented an integrated management system strictly based on the requirements of the IAEA Safety Requirements GS-R-3 “The Management System for Facilities and Activities” in early 2009.

The management system integrates safety, health, environmental, security, quality and also economic elements.

Our company policy including the respective guidelines reflects the top-ranking of a strong safety culture within our management system.

An adequate organisational structure and the process organisation needed to fulfil the purpose of our company have been implemented always keeping in mind the meeting of the safety requirements. Continuous improvement of the organisation and processes is guaranteed, especially regarding the further development of our safety culture.

The paper presented in this abstract is to demonstrate in which way an integrated management system, strictly following the requirements of the above mentioned IAEA Safety Requirements, has been developed and implemented. The structure and the daily working of such an integrated system will be illustrated, benefits and advantages will be presented as well as the experiences gained up to the moment. But also challenges that appeared when developing such an integrated system with the emphasis on “safety first” will be addressed.

P18-01

**Possible implications of new Basic Safety Standards – a Swedish viewpoint**

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Lund, Ingemar<sup>2</sup>; Lund, Ingemar<sup>2</sup>

<sup>1</sup>Swedish Radiation Safety Authority, SWEDEN; <sup>2</sup>Swedish Radiation Safety Authority, Dept of International Affairs, SWEDEN

The 2007 Recommendations of the International Commission on Radiological Protection formally replaced the ICRP's former, 1990 Recommendations. The International Atomic Energy Agency and the European Commission presently update and review their Basic Safety Standards within their frameworks, jurisdiction and international roles. The Swedish regulatory system will be influenced and steered by these emerging documents, especially by the EU BSS since these are binding for the Member States. With the proposals existing as of spring 2010 as starting point, we will offer our view on the possible implications the new Standards will have on the radiation safety regulations of Sweden.

P18-02

**IEC standards for measurements of environmental radiation**

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This paper presents the IEC/SC 45B "Radiation Protection Instrumentation" and its 15 standards for measurement of environmental radiation that have been published or that are under development or revision. Two types of standards are considered: general standards for environmental measurement instrumentation and standards for airborne radioactivity measurements. The first type covers gamma radiation ratemeters for environmental monitoring (IEC 61017-1&2), equipment for monitoring of radionuclides in liquid effluents and surface waters (IEC 60861), mobile instrumentation for the measurement of photon and neutron radiation in the environment (IEC 62438) and in-situ photon spectrometry systems using a germanium detector (IEC 61275). The second types concerns equipment for continuous monitoring of radioactivity in gaseous effluents (IEC 60761 series), monitoring equipment of atmospheric radioactive iodines (IEC 61171) and radioactive aerosols (IEC 6117) in the environment, radon compensation for radioactive aerosol monitors (IEC 61578) and equipment for monitoring radioactive noble gases (IEC 62302) and airborne tritium (IEC 62303).

P18-03

### Investigation radiation hygienic monitoring in the Russian NPP vicinity

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Radiation hygienic monitoring is the system of the comprehensive and dynamic surveillance including the long-term continuous control of radiation hygienic situation parameters and doses of residents in the near-by areas of NPP. In the reference points of the NPP surveillance area and in the comparison area, the specialized rules are elaborated. These rules include the types of environmental media, scope and periodicity of sampling, methodological and technical requirements, etc. Investigation radiation hygienic monitoring has been implemented in a number of Russian NPPs including Kalinin, Volgodonsk and Novovoronezh NPPs. The radiation hygienic situation in NPP surveillance areas is generally satisfactory and stable:

- Outdoors gamma dose rate is in the range of background fluctuations for such territories;
- $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  specific activity in outdoor water reservoirs is in the range of radionuclide content in water reservoirs of the Central Russia;
- $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  burdens in drinking water is below intervention levels (NRB-99) for 135 and almost 300 times, respectively; total alpha and beta activity is below permissible levels;
- $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  burdens in foodstuff products and drinking water are 100–1,000 times below permissible levels;
- $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  burdens in foodstuff products and drinking water (NPP surveillance areas) are similar to these in other regions of the country.

The developed investigation radiation hygienic monitoring in the NPP vicinity should be the necessary part of the nationwide system of the public radiation protection regulation under nuclear renaissance, because it provides the opportunity to get the modern objective assessment of the NPP impact in the environment and population health.

P18-04

### Radio-ecological criteria and norms during remediation of the nuclear legacy facilities in the Russian Northwest

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Remediation of sites and facilities belonging to the sites of temporary storage (STS) of spent nuclear fuel (SNF) and radioactive wastes (RW) at Andreeva Bay and Gremikha village on the Kola Peninsula is one of the regulatory functions of radiation protection. After termination of operation of the ex-Navy serviced facilities, their infrastructure degraded resulting in radioactive contamination of some parts of the site. As one end-goal of remediation is putting STS into ecologically safe conditions, elaboration of quantitative radiation-ecology criteria and norms for STS site and facility conditions is urgent. Remediation criteria and norms defining requirements for radiation protection of workers, public and limits of environmental contamination have been developed for three main options: conservation, conversion (partial or overall renovation) and liquidation in the form of:

- dose limits and dose constraints;
- levels of radioactive superficial contamination of workshops and equipment inside them;
- specific activity of radionuclides in marine media, including fish;
- activity concentration of radionuclides in ground waters on-site STS.

The Environmental radiation monitoring findings served as a basis for the associated databank arrangement. The experimental results received have been plotted on the electronic map of the place. Further steps relate to generation of full geographic information system, which permits to carry out the computer calculation of the main indexes for simulation and prognosis of radio-ecological situation with the purpose of the radiation safety regulation.

P18-05

**Quality management system of  
in-vivo measurement (IVM) lab at  
Karlsruhe Institute of Technology  
(KIT) – accreditation and experience****Breustedt, Bastian; Mohr, Ute;  
Biegard, Nicole; Cordes, Gabriele**Karlsruhe Institute of Technology, Institute for Radiation  
Research, GERMANY

The in-vivo monitoring lab (IVM) at Karlsruhe Institute of Technology operates one whole body counter and three partial body counters. IVM is an approved lab for individual monitoring for incorporation according to German regulation. One of the requirements for the approval is a proof of competence via accreditation on ISO/IEC Standard 17025. In 2007 a web based quality management system has been set up and all the methods and procedures used at IVM have been described in a set of documents. Several document classes (e.g. standard operation procedures SOP) are used for this. For each class of document a template satisfying the formal requirements is used. The requirements of the ISO/IEC 17025 standard and their realization at IVM will be described. In 2007 several internal audits were used for fine-tuning the system before an external audit, which finally granted accreditation to the IVM, was held. The system is kept flexible and can thus be easily adapted to new situations (e.g. organisational changes). Only a sparse amount of the work time needs to be spent to maintain the running system. It also leaves enough freedom in the daily routine work at IVM and found acceptance by the employees, quickly. After two years of running the quality management we can say it was worth the trouble and time required in setting it up.

P18-06

**Setting up of a molecular imaging  
unit in biomedical research centres****Escudero, Rocio<sup>1</sup>; Mulero, Francisca<sup>2</sup>;  
López, Germán<sup>3</sup>; Pérez, Jorge<sup>4</sup>**<sup>1</sup>Centro Nacional de Investigaciones Cardiovasculares, Biosafety and Radiation Protection Service, SPAIN; <sup>2</sup>Centro Nacional de Investigaciones Oncológicas, Molecular Imaging Core Unit, SPAIN; <sup>3</sup>Globalpet, SPAIN; <sup>4</sup>Centro Nacional de Investigaciones Oncológicas, Biosafety and Radiation Protection Service, SPAIN

Molecular imaging techniques have become important tools for the clinical diagnosis of several diseases. These techniques are today in a highly mature state in the clinical field and are now being rapidly developed for use in biomedical (preclinical) research. Among currently available techniques are those allowing acquisition of high resolution anatomical images (CT, MRI), while others offer high sensitivity physiological/molecular imaging (PET, SPECT, optical). However, used separately each technique offers limited information, and therefore the emphasis of imaging applications for research is on multimodal imaging, wherein images from different techniques are combined to yield an image of high resolution and sensitivity. Although the use of radioactive isotopes in biomedical research is declining overall, their use in molecular imaging techniques is increasing. Currently, the most developed molecular imaging technique in research, and the most significant from the perspective of radiation protection (RP), is the microPET, combined with anatomical imaging, mainly by CT. In order to set up this technique (or others, such as SPECT) in a biomedical research centre, the RP requirements associated with the handling of high energy gamma sources (PET) and X rays (CT) must be met (equipment, shielding, dosimetry, waste management, training, etc). These measures also need to be evaluated and adjusted to meet the specific requirements of research centres in terms of biosafety, animal health and welfare, etc. This situation thus complicates RP in this kind of facility. The aim of this study is to briefly describe the most important imaging techniques and their application in biomedical research, and to present an example of the setting up of a unit or laboratory specialized in these techniques in centres dedicated to pure biomedical research (not associated with a healthcare centre). This study has been conducted by specialists from the RP and molecular imaging fields.

P18-07

### Testing of sealed radioactive sources at BAM

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GERMANY

Requirements and test programs for sealed radioactive sources are specified in international standards for safety in transport and in use. Sealed sources which are approved as special form radioactive material according to the Transport regulations, IAEA Safety Standards TS-R-1, must be able to withstand mechanical (9 m drop, percussion and bending) and thermal (800°C heat) tests without loss of radioactive content. The International Standard ISO 2919 provides a set of tests which classifies the sources for their safety in use. Performance tests specified in this standard are temperature (high and low), external pressure, impact, vibration and puncture tests. Each test can be applied at different levels of intensity depending on typical usage. As a criterion of passing or failing, leakage testing has to be done after each test. This poster will give an overview of BAM's comprehensive test equipment and experience in testing sealed radioactive sources.

P18-08

### Radiological criteria's for patients discharge following a radionuclide therapy or brachytherapy with implanted sealed radionuclide sources

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Dose criteria for limitation of exposure incurred by persons helping the patients or living with patients discharged from hospitals following radionuclide therapy or brachytherapy with implanted sealed radionuclide sources have been proposed for national Russian regulation. By means of a conservative dosimetry model, the values of operational radiological criteria for patient discharge from hospital are substantiated basing on the standards of permissible effective dose for population – 1 mSv and for persons helping the patient or living with him – 5 mSv. Two sets of whole body activity for radionuclides I-125, I-131, Sm-153 and Re-188 used in Russia for therapy, as well as dose rate near patient body were received. The smallest one was included in the new Russian Standards for Radiation Safety (SRS-99/2009). Observance of suggested criteria will ensure radiation safety of people in near environment (family, close friends et al.) of the discharged patient.

S19-01

**The new ICRP recommendations and the role of stakeholders**Lochard, Jacques

FRANCE

S19-02

**First lessons from the Montbéliard Radiation Protection Pilot Project: towards the development of a local expertise in radiation protection**Bataille, Céline; Lochard, Jacques; Schneider, Thierry

CEPN, FRANCE

Since 2004, the Montbéliard Urban Community (CAPM), in cooperation with CEPN, is engaged in a Radiation Protection Pilot Project whose main objectives are to improve the radiation protection of the inhabitants of the Montbéliard Country and to promote the creation of a pole of competence in the field of radiation protection in the territory. This Project is based on a global approach, addressing all aspects of radiation protection. It is divided into five sections: three ones are related to exposure situations (medical exposure, exposure to radon, exposure in case of radiological event), two others concern the development of the radiation protection culture. The Project is designed to promote active participation from various stakeholders at the local level, working in cooperation with national and international experts. In particular, local actors work in close relationships with major radiation protection experts in France: namely the French Institute of Radiation Protection and Nuclear Safety (IRSN) and the French Nuclear Safety Authority (ASN). Besides, the CAPM has entrusted the CEPN with a number of tasks to help manage and facilitate the project. In 2009, the main partners of this Project decided to analyse the feedback experience from this initiative. This paper will focus on the main results and perspectives of the Project and will present the first lessons that have been drawn. In particular, lessons about the possible involvement of territories in radiation protection topics will be developed. Some conditions needed to favour a local expertise in radiation protection will be discussed: for instance, the importance to benefit from local radiation protection experts, capable of initiating and guiding the various actions or the need to link radiation protection topics with local issues and stakes. Finally, a reflection on the modalities of articulation between local and national actors in the practical implementation of radiation protection will be proposed.

S19-03

### **Involvement of local stakeholders in the long-term surveillance of radioactive waste disposals**

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<sup>1</sup>CEPN, FRANCE; <sup>2</sup>IRSN, FRANCE; <sup>3</sup>MUTADIS, FRANCE; <sup>4</sup>ANCLI, FRANCE

The sustainability of radioactive waste disposals' surveillance systems is a key factor when it comes to long-term surveillance of these facilities. Local stakeholders have shown concerns on this matter, especially when dealing with intergenerational transmission of knowledge and memory of installations. As a European cooperative research program, COWAM in Practice (CIP) addressed these issues from a practical point of view. From 2007 to 2009, CIP involved a wide range of stakeholders from five countries, including members of NGOs and industry, elected officials, national experts and authorities. Among CIP outputs were the local stakeholders' expectations regarding long-term surveillance, and considering two main issues: on the one hand the long-term environmental and health surveillance, on the other hand the practical implementation of "reversibility" for geological disposal. The paper addresses the governance issues associated with the practical implementation of long-term surveillance systems. A sustainable surveillance system, involving local actors in the decision making process, should allow them to monitor the waste inventory, the disposal evolution, the implementation of 'reversibility', the potential environmental and health impacts as well as the financial aspects. Beforehand, an effective involvement requires the identification of concerned local stakeholders, their technical and political empowerment, as well as establishing cooperation between the local and national institutions involved in the surveillance. The radiation protection community has an important role to play to support local stakeholders' involvement in long-term surveillance, mainly in ways of training, skills and capacity building, but also by taking into account public concerns in the disposal design and for the organisation of its follow-up. Such a support would contribute to improve the sustainability of the surveillance system as well as that of the vigilance.

S19-04

### **Individual response to communication about the August 2008 <sup>131</sup>I release in Fleurus: results from a large scale survey with the Belgian population.**

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<sup>1</sup>SCK•CEN, SPS, BELGIUM; <sup>2</sup>SCK•CEN, University of Antwerp, BELGIUM; <sup>3</sup>SCK•CEN, SPS/PISA, BELGIUM

Lessons learnt from nuclear and radiological events highlight communication as one of the most important challenges in emergency management. There is a need to develop a better understanding of lay public responses to communication on emergency preparedness and protective actions.

In August 2008, a accidental release of 50 GBq <sup>131</sup>I occurred in Fleurus, Belgium. The population living in the surrounding was informed only 6 days after the onset of the incident. The Belgian nuclear emergency plan was activated and protective actions for the population were implemented. Consumption of vegetable products from local gardens was advised against. For public health and reassurance purposes, <sup>131</sup>I thyroid measurements on more than 1000 persons were performed. Communication to local authorities, local actors and population proved to be challenging during this crisis.

SCK•CEN organised a large-scale risk perception survey in the summer of 2009. The focus of the survey, realised through computer assisted personal interviews (CAPI) is nuclear risk communication, with one chapter focusing on reception and acceptance of messages during the Fleurus crisis. An additional sample of 100 persons living in the 5 km zone impacted by the Fleurus incident were added to the representative sample of the Belgian population sample.

This contribution focuses on the results of this questionnaire. It will discuss the perception and the evaluation at the local level of crisis communication items, and relate this to information sources and media use. We analyse the factors influencing the way in which people inquire and process risk information. Focus will be laid on the interaction between protective actions and information processing motivations and capabilities of the target population. Finally, we compare the data with more general results on nuclear emergency risk communication for the general population.

S19-05

**Science and values in radiation protection: Summary of two NEA workshops****Lazo, Ted**

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As part of its 2007 50th anniversary, the Committee on Radiation Protection and Public Health (CRPPH) published two forward-looking reports, summarising its views of emerging challenges in radiological protection policy, application and science. As follow-up, the Committee began more detailed exploration of the relationships between science and social values in RP decision making, leading to two workshops on Science and Values in Radiological Protection: the first in Helsinki in January 2008, hosted by the Finnish STUK (<http://www.nea.fr/html/rp/helsinki08/welcome.html>), and the second near Paris in December 2009, hosted by the French IRSN, the French ministry MEEDDM, and CEPN ([http://www.nea.fr/html/rp/vaulx\\_de\\_cernay09/welcome.html](http://www.nea.fr/html/rp/vaulx_de_cernay09/welcome.html)). The objective of this meeting was to develop a more shared understanding between the various stakeholders with regard to the mixing of science and its uncertainty with social values and their diversity in achieving decisions that are sustainable and acceptable when radiological risks are involved. The first Workshop studied this mixing process using three case studies with emerging scientific findings in the areas of non-targeted effects, individual sensitivity, and circulatory diseases. The focus here was more speculative in terms of “what if” research in these areas indicated changes, what magnitude of change would be needed before the system of radiation protection would need to be changed. The second workshop again used case studies to study how science and values are combined in making decisions, focusing on the management of exposure from radon, the management of medical exposures, and once again circulatory diseases. Given recent studies of cardiovascular disease, these topics were seen in the context of “what now”, again in terms of whether these findings would provoke changes in protection approaches. This paper will present the results of these two workshops, and will discuss how the CRPPH intends to take this work forward.

P19-01

### Lessons learned in radiological protection during the dismantling of nuclear facilities

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The Spanish radioactive waste management agency Empresa Nacional de Residuos Radiactivos (ENRESA) has carried out the dismantling of the Vandellós 1 Nuclear power Plant and of the experimental reactor and other research facilities at the Centre for Energy-Related, Environmental and Technological Research (CIEMAT). This article presents the lessons learned and the recommendations deriving from them in relation to Radiological Protection (RP) and the application of ALARA programmes during the performance of the dismantling projects. Likewise, the specific problems posed and the results of the solutions designed are identified. The aspects to be developed are as follows:

- Specific characteristics of dismantling operations: an analysis is made of the difference between RP during normal operation and that applied during dismantling, in relation to documentation, organisation and the necessary additional resources.
- Specific challenges posed: identification of the changes that will occur, such as:
  - Physical modification of the facility.
  - Continuous modification of the radiological configuration.
  - Modification of working techniques.
  - Modification of radiological risks, different from those existing during normal operation.
  - Adaptation of ALARA criteria to involved all the companies participating in dismantling.
  - Importance of the risk of internal contamination by alpha emitters, not considered during normal operation.
  - Adaptation of the RP training objectives and requirements of the workers.
  - Consideration of the interaction between radiological and conventional risks.
  - Extension of RP equipment and resources, both human and instrumental.

Finally, the solutions developed and successfully applied to the specific problems arising during the dismantling of Vandellós 1 and the CIEMAT facilities will be presented.

P19-02

### Remediation of TENORM residues: Professional risk assessment and public risk perception

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In the last three decades, members of different disciplines (such as sociology, radiation protection) have published a vast number of studies on risk perception and acceptance with respect to nuclear power plants and nuclear waste repositories. However, bridging the gap between what radiation protection experts consider to be an objective risk and the subjective risk perception by non-scientists is a challenging task. This is especially true for perception of radiation risks which might derive from so-called TENORM (Technologically Enhanced Naturally Occurring Radioactive Materials) during the remediation process of polluted industrial sites. In many cases, remediation of TENORM residues is affected by the people concerned facing inconsistent information (on the actual risks) and/or overlapping legal regulations. The remedial actions aimed at the protection of the residents often raise further concerns. As a consequence even the radiation monitoring required might cause distrust. This research project was established to elucidate the underlying reasons for communication problems between experts and affected members of the public. In case studies from two remediation sites in Germany (a residential area on a polluted former industrial site in Hanover and remediation of uranium tailings by WISMUT in Saxony) the risk assessment of experts and the risk perception of laypersons, resp., are analysed on the basis of interviews conducted with experts in the field of radiation protection and remediation, as well as with residents living on former industrial sites polluted with radioactive substances. Furthermore, primary sources including governmental documents and radiation protection regulations, and press coverage are investigated. The first results from the analysis of the data collected in this qualitative approach are presented here.

P19-03

**Thyroid measurement campaign after an accidental release of 45 GBq <sup>131</sup>I in Fleurus, Belgium**

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On August 22, 2008, a cloud of <sup>131</sup>I was released from the Institut des Radioéléments (IRE), a producer of medical isotopes located in Fleurus, Belgium. The peak of the release took place in the weekend of 23–24 August and was followed by a smaller, continuous release which lasted for several weeks. After reports of the incident in the press, concern grew among the local population about possible health effects of this release of radioactivity. As a consequence of this concern, the Belgian public health authorities organised a thyroid measurement campaign for the local public to reassure the public that no detectable dose was acquired in the thyroid, especially for small children and pregnant women. The Belgian Nuclear Research Centre SCK•CEN made a very substantial contribution to the thyroid measurement campaign. It provided 4 out of 5 measurement teams, each one equipped with a high-purity germanium detector and the necessary hardware and software. The University of Liège provided another team with a NaI detector. All detectors had been calibrated in advance and were checked regularly during the measurement campaign. The thyroid measurement campaign took place on Monday September 1st and Tuesday, September 2nd 2008 in the village of Lambusart close to Fleurus. More than 1000 people were measured, including all children from the local schools. No thyroid contamination was detected. This paper elaborates on the preparation of this measurement campaign and the practical execution. It draws important lessons for the preparedness for similar situations in the future, both with respect to public information and technical and organisational aspects.

P19-04

**Designing of stakeholder meetings for consensus development through the stakeholder involvement in the field of nuclear energy utilization**

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<sup>1</sup>Japan NUS Co. Ltd., JAPAN; <sup>2</sup>Tokyo Institute of Technology, JAPAN

In order to develop trustful relations and to harmonize with society for the use of nuclear energy and the operation of nuclear facilities, it is essential for the state governments and electric power utilities to design the appropriate measures for communication and dialogue with stakeholders. The one-way information distribution should be avoided and the two-way information exchange system should be build up between the administration and the public.

In this paper, we focused on the designing of the stakeholder meetings and comparatively studied the cases in Japan and in France. As the result, it is found that there are differences in the selection of stakeholders and the designing of the meetings. These differences are probably relating with the social backgrounds and cultural differences in the countries. The experiences in the French system would be informative for the Japanese stakeholder meetings.

In Japan, one of the biggest issues has been the finding of the candidate site for the high-level waste disposal facility. Nuclear Waste Management Organization of Japan (NUMO) has been in charge of disposal business. Toyo town in Kochi prefecture applied to NUMO as the candidate, for the first time in January 2007. The Japanese government approved the initiation of preliminary literature investigations to survey the previous records of the earthquakes and so on. However, due to the strong opposition movement developed in Toyo town and Kochi prefecture, the application was cancelled. Based on the results of this case, we considered the problems of the stakeholder involvements and the differences in the designs of the stakeholder meeting between the existing nuclear facilities and the planning facilities.

P19-05

### Information technologies in radiation protection legal regulative of Serbia

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Books, documents, laws and other regulatory papers were accessible only for the limited number of users. Development of information technologies enable easy and quick access to radiation protection regulatory as well as to the other documents not only to the experts but also to the public. In this paper we gave example of information technology application in radiation protection regulative of Serbia.

P19-06

### 30 years of the Croatian Radiation Protection Association

Krajcar Bronić, Ines<sup>1</sup>; Miljanić, Saveta<sup>2</sup>;

Ranogajec-Komor, Maria<sup>2</sup>

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The 30th anniversary of the Croatian Radiation Protection Association (CRPA, [www.hdzz.hr/](http://www.hdzz.hr/)) is an opportunity to review the work of the society and to point out the main goals for the future. CRPA was founded in 1979 in the frame of the Yugoslav Radiation Protection Association. Since 1991 CRPA is an independent organization and in 1992 became a regular member of the International Radiation Protection Association (IRPA). CRPA is a public organization with the purpose of promoting and developing scientific, educational and cultural activities in the field of radiation protection and related fields of science with 185 members from of various areas of radiation science. One of the main activities of CRPA is a regular organization of national symposia. Seven national symposia of CRPA with international participation were organized after 1991. All presentations were published as full papers in printed Proceedings. In 2001 CRPA organized the IRPA Regional Congress in Dubrovnik, Croatia. Members of CRPA frequently take part in organization of regional, European and world IRPA congresses and in the work of IRPA General Assembly. CRPA has been actively involved in the meetings of the European radiation protection societies since 2004. The organization of the 6th meeting of this kind (Zagreb, October 26, 2009) was entrusted to CRPA. On the celebration of the 30th birthday of CRPA the first award for best work in the field of radiation protection will be given to the young scientist who will then compete for the first European award for young scientists. In future CRPA will continue to organize regular national symposia and encourage its members to participate at IRPA congresses. It will increase the efforts in organization of lectures for both scientific community and general population. It will also keep its presence in various international activities of radiation protection societies with emphasis on improvement of cooperation with the societies in the neighbouring countries.

P19-07

**Public acceptance of  
radiocontamination in food  
products: what can we learn for  
a better decision-making?**Turcanu, Catrinel<sup>1</sup>; Carlé, Benny<sup>1</sup>;Perko, Tanja<sup>2</sup>; Schröder, Jantine<sup>1</sup><sup>1</sup>Belgian Nuclear Research Centre SCK-CEN, BELGIUM;<sup>2</sup>University of Antwerp, Faculty of Political Sciences, BELGIUM

After a nuclear event with subsequent contamination of the environment, one of the most important issues to be dealt with is the management of contaminated food production systems. The main challenges are to mitigate the health effects to the population consuming such products and to bring social reassurance, while limiting the economic loss and restoring normal life.

This contribution focuses on consumer's risk perception and attitude towards food products containing residual radioactivity. It is assumed that the products under discussion satisfy the legal norms concerning the maximal allowable levels of radioactive substances in food and therefore they can be freely marketed. The data for this study originate from a large-scale public opinion survey that carried out in Belgium in the summer of 2009 on the basis of computer assisted personal interviews (CAPI).

This work aims at gaining a better insight in consumer's attitude and thus contributes to a more efficient decision-making. Previous research suggests that the acceptance of legal norms for food products plays an important role in adopting a risk-accepting attitude towards food products with residual radioactive contamination. Alongside with acceptance of legal norms, a number of additional factors that could influence consumer's attitude are explored in our study: attitude towards nuclear energy, and some psychometric factors such as dread and unknown.

The results are interpreted in the context of practical implications for emergency management and for the decision making process.



WS1-01

**Lifetime health risk of paediatric exposures to ionizing radiation**

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Blettner, Maria

GERMANY

WS1-02

**Radiation protection of embryo-foetus in diagnostic imaging**

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Applegate, Kimberley

Image Gently

WS1-03

**Justification and optimization of paediatric CT**

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Owens, Cathy

European Society of Paediatric Radiology

WS1-04

**Radiation protection in paediatric radiology: a comprehensive approach**

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Malone, Jim

IAEA

WS1-05

**Nordic and Baltic experiences of  
justification and optimization  
of paediatric CT**

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Seuri, Raija

Helsinki University Hospital, FINLAND

WS1-06

**Good practice in the digital  
paediatric radiography**

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Mannila, Johanna

Helsinki University Hospital, FINLAND

WS1-07

**Optimization of protection  
in paediatric PET-CT**

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Holm, Søren

Rigshospitalet, DENMARK

WS1-08

### Unjustified CT examination in young patients: a survey at Oulu University Hospital

Oikarinen, Heljä; Meriläinen, Salme; Pääkkö, Eija; Karttunen, Ari; Nieminen, Miika; Tervonen, Osmo  
Oulu University Hospital, Department of Diagnostic Radiology, FINLAND

**Purpose:** The doses of radiation from computed tomography (CT) are relatively high, yet CT is being increasingly utilized. Furthermore, the radiation-induced lifetime risk of cancer mortality is higher at younger age. The basic aim of the study was to find out whether previous CT examinations done on young patients were justified, and if not, whether another, more justifiable imaging modality had been available.

**Methods and materials:** Fifty CT examinations of the head and CT examinations of the lumbar spine, cervical spine, abdomen, nasal sinuses and trauma, 30 each, done on patients under the age of 35 years in 2005, were evaluated retrospectively by using electronic patient files and the referral guidelines for imaging recommended by the European Commission. As a consequence of the study, new interventions and follow-up of the lumbar CT were introduced.

**Results:** Seventy-seven per cent of the CT examinations of the lumbar spine, 37% of the abdomen, 36% of the head and 20% of the nasal sinuses were unjustified. Three out of 21 CT examinations performed on children were unjustified. Most of the unjustified examinations could have been replaced by magnetic resonance imaging. Justification of the lumbar CT could be clearly improved by new interventions, education, use of referral guidelines and increased MRI capacity.

**Conclusion:** Justification of CT examinations in young patients seemed to be inadequate. However, justification could be improved by education, use of referral guidelines and increased MRI capacity.

WS1-09

### Screening or selective imaging in paediatric dentistry: from panoramic to CBCT

Horner, Keith  
University of Manchester, School of Dentistry, UNITED KINGDOM

Dental radiography is one of the most frequent forms of medical X-ray imaging. A large proportion of examinations are performed in the paediatric age group, principally for the detection of dental decay (caries) and developmental anomalies. While most dental X-ray examinations have a very low radiation dose, the introduction of Cone Beam CT (CBCT) brings a higher dose range to dental imaging. Clinical screening of children is good practice, but radiographic screening cannot be justified. Referral (selection) criteria for imaging have been developed by various authorities and organisations, but these have a variable basis upon scientific evidence and uncertain acceptance amongst dentists. Provisional evidence-based referral criteria for CBCT are available through the European SEDENTEXCT project. Considerable research is needed to refine the existing referral criteria for dental radiology and to monitor their adoption in primary dental care.



WS2-01

**The IAEA OSART programme and radiation safety related findings during recent OSART missions**Lipar, Miroslav

IAEA, AUSTRIA

The IAEA operational safety review team OSART for nuclear power plants in Member States have been reformed responding to the changes of the environment of both the industry and Member States needs. The IAEA safety standards for Operations are being applied when conducting the Agency's safety services. Our goal is to ensure that the issues and trends resulting from industry operating experience and the Agency safety services can be effectively communicated to Member States and be used to further reform our safety standards and services. Radiation Protection is an important area of OSART review. The relevant Safety Guide serving as a basis for this area is "Radiation Protection and Radioactive Waste Management in the Operation of Nuclear Power Plants", IAEA Safety Standards Series No. NS-G-2.7. The objective of this presentation is, by referring to the above Safety Guide, to discuss the various findings, recommendations, suggestions and good practices from recent OSART missions in different countries that should be considered in order to improve Radiation Protection in the Operation of NPPs. The following RP areas are assessed during OSART mission: Organization and function, Radiation work control, Control of occupational exposure, Radiation protection instrumentation, protective clothing and facilities, Radioactive waste management and discharges and Radiation protection support during emergencies.

WS2-02

**Radiation safety in new build**Alm-Lytz, Kirsi; Vilkkamo, Olli

STUK – Radiation and Nuclear Safety Authority, FINLAND

STUK reviewed the utility Teollisuuden Voima Oyj's (TVO) application for the Construction Licence of the Olkiluoto 3 nuclear power plant unit in 2004–2005. Based on this review STUK prepared its statement on safety together with a safety assessment report of the new plant to the Government. STUK has continued reviewing the detailed design during the construction of the new plant unit. By virtue of the Nuclear Energy Act (990/87) and the Government Decree on the Safety of Nuclear Power Plants (733/2008), Radiation and Nuclear Safety Authority (STUK) issues detailed regulations, YVL Guides, concerning the safety of nuclear power plants. Several YVL Guides deal with radiation safety (site, abatement of releases, worker radiation protection, emergency arrangements, etc). The paper will discuss some radiation safety related requirements in the design of a new Finnish NPP and their implementation in the licensing documentation.

WS2-03

**The New IAEA Basic Safety Standards (BSS) and their implementation for the Operation of Nuclear Installations****Lorenz, Bernd<sup>1</sup>; Schwarz, Wolfgang<sup>2</sup>; Holl, Matthias<sup>3</sup>**<sup>1</sup>GNS Gesellschaft für Nuklear-Service mbH, GERMANY;<sup>2</sup>E.ON Kernkraft GmbH, Kernkraftwerk Isar, GERMANY;<sup>3</sup>RWE Power AG, GERMANY

After the issue of ICRP 103 now the process of revising the IAEA BSS started. It follows the policy to adopt all the new ICRP considerations as far as possible. This should not be a problem as the ICRP itself stated “stability and continuity” as the headline for its new recommendations. Indeed, there are few changes in ICRP: the risk factors are nearly the same and became even smaller, the dose quantities remain and, what is essential, the three basic principles justification, optimization and limitation endure. But there are changes. The process based approach is no longer used, there is new terminology and dose constraints were seen as central part of RP not corresponding to the long lasting practice. The revision of the BSS triggered a lively discussion in which the operators of nuclear installations participated. The large number of comments shows that some remains to be done. Clarifications were already possible during the joint meeting of RASSC and WASSC in November 2008. It was e.g. made clear that not an optimized state has to be assured but the process of optimization. Unfortunately this decision was now cancelled, a situation which is not acceptable. It was also revealed that sometimes it was not yet clear who is responsible and what is a requirement and what a guideline. We can be optimistic that in the next reformatted drafts there will be even more clarity. However, a precise study of the new text will be mandatory. For operators of nuclear facilities it is essential that changes in the BSS lead to higher safety and not to higher bureaucracy only. The demand for dose constraints for all sources that could be drawn from the text formally would be an example for that. The drafting of the new BSS is in the hands of the IAEA and its co-sponsors. The operators need to focus on the discussions in the Safety Standards Committees and on comments. This is an important part of the process and we noticed that experience from practice is welcomed.

WS2-04

**Radiation protection culture in the nuclear industry****Le Guen, Bernard**

Électricité de France, FRANCE

WS2-05

**Occupational radiation exposure  
– an overview of the exposure  
of the workers in facilities of  
the nuclear fuel cycle**

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**Kaulard, Joerg; Schmidt, Claudia; Strub, Erik**Gesellschaft fuer Anlagen- und Reaktorsicherheit (GRS) mbH,  
GERMANY

Workers are subject to radiation exposure in several industries. This contribution will provide an overview of the exposure of workers in nuclear installations. The contribution will address the exposure in nuclear power plants in operation, as well as under decommissioning and in facilities of the nuclear fuel cycle. Based on recent data, trends in the exposure of workers will be discussed and examples will be given on how experiences contribute to improvements concerning the exposure of workers.

WS2-06

**Radiation protection issues  
in fuel-manufacturing**

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**Mellander, Hans**

Westinghouse Fuel Sweden, SWEDEN

WS2-07

**Floating nuclear power reactors  
– Fiction or future?****Reistad, Ole<sup>1</sup>; Hansell, Cristina<sup>2</sup>**<sup>1</sup>Norwegian Radiation Protection Authority, NORWAY;<sup>2</sup>James Martin Center for Nonproliferation Studies,  
UNITED STATES

Russia's current floating nuclear power plant (FNPP) plans were initiated nearly 20 years ago, with a competition to develop small-scale power plants for the Russian Arctic. While the locations where the first plants will be sited have been altered several times, the basic design of the prototype plant remains the one that won the competition in 1994: a variant of the Russian icebreaker reactor. This paper describes the development in the Russian plans for building floating nuclear power plants (FNPP), and the status for the ongoing construction project. There have been two major changes since 1994: Russia has promised to fuel the reactors with low enriched uranium (LEU) fuel — whereas icebreakers use 36 – 90% enriched uranium fuel — and exporting FNPPs has become a key goal for its developers. The project now under realization has also been redesigned to increase safety. Attention to proliferation-resistance has also been highlighted in many Russian presentations on the FNPPs, making a switch back to HEU less likely. Redesigns to increase safety have also been widely touted. While there are many detailed reports about the fuel design, though, there is no data on performance — indeed, it is not clear that performance has indeed been sufficiently demonstrated. There are reports (without data) that testing of the fuel has occurred in other Russian reactor types, however, and Russian designers appear satisfied with the current fuel design. Russian has also approached the IAEA in order to have the Agency involved in assessing the safety of the plant design. Despite these developments, though, there are still several major questions about Russia's FNPP plans that raise concern. Much of the FNPP project remains shrouded in secrecy. Economic calculations, which will surely effect expenditures on safety, security, etc., are unknown—the total cost estimates given vary widely, and do not appear to include security, transport, or back end costs.

WS2-08

**Assessment of potential consequences  
of hypothetical radiological  
incidents in the seas of North-West  
Region of Russian Federation****Krylov, Alexey; Pavlovski, Oleg**Nuclear Safety Institute of Russian Academy of Sciences,  
RUSSIAN FEDERATION

There are the sites for the storage and decommissioning of the retired nuclear submarines, their nuclear reactors, spent nuclear fuel and radioactive waste, located in Northwest Russia. Many of those sites are not isolated and protected. There are also nuclear shipbuilding facilities, naval objects and nuclear powered vessels (submarines, icebreakers) in the seas. All these sites present potential threat of radiological releases. This was the reason for implementation of the International Project "Enhancement of Radiation Monitoring and Emergency Response System in the Murmansk Region" (Project), managed by the European Bank for Reconstruction and Development. The Nuclear Safety Institute (NSI) of the Russian Academy of Sciences was the main executor of the Project. Possible scenarios and consequences of accidental radioactive contamination of coastal waters of Northwest Russia are discussed in this work. The scenarios assume the location of the potential accidents in the White Sea and in one of the Bays of the Barents Sea. The modelling of possible consequences of radiological accidents was implemented for water objects that strongly differ in size (from 5 to 300 kilometres), tides, currents and characteristic times of water exchange with the Arctic Ocean. The modelling of migration of the radioactive substances was carried out with the use of computer model developed by the NSI specialists. This model is based on the well-known three-dimensional Princeton Ocean Model.

R01

**ICRP Publication 103 and beyond**

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**Clement, Christopher**

ICRP, CANADA

This paper focuses on ICRP *Publication 103*, the 2007 Recommendations of the International Commission on Radiological Protection, which lays out the system of radiological protection for all exposure situations and exposure types. In addition, subsequent ICRP publications which delve more deeply into specific aspects of this system are reviewed to some extent, including: ICRP *Publication 104* Scope of Radiological Protection Control Measures; ICRP *Publication 105*, Radiological Protection in Medicine; ICRP *Publication 108*, Environmental Protection – the Concept and Use of Reference Animals and Plants; ICRP *Publication 109*, Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations; and an ICRP publication in press titled Application of the Commission's Recommendations to the Protection of People Living in Long Term Contaminated Areas After a Nuclear Accident or a Radiation Emergency.

R02

**Radiation protection metrology and measurements**

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**Maringer, Franz Josef**

BEV – Federal Office of Metrology and Surveying, AUSTRIA

Quantitative assessments of external and internal exposure need reasonable state-of-the-art physical / biological / ecological models and reliable quantities and measurement methods and instruments. Fundamental basis for dose and activity measurements are solid instruments and adequate measurement methods. In this paper, the appropriate quantities and units as far as necessary measurement chains to assure traceability from international primary standards to end-user measurement facilities are given. The basic concepts and practical implementation of uncertainty assessments in activity and dose measurements methods are presented. Finally main aspects of quality assurance in the field of radiation protection measurements are discussed. The target group for this information are newcomers as far as experienced radiation protection experts, radionuclide and dosimetry metrologists and end-user of measurement instruments in radiation protection.

R03

### **External dosimetry and individual monitoring**

**Stadtman, Hannes**

Seibersdorf Labor GmbH., Radiation safety and application,  
AUSTRIA

Individual monitoring is required by international regulations to demonstrate the compliance of dose limits. This paper gives an introduction which types of personal dosimeters are in use and how these dosimeters are calibrated in the operational dose quantities Hp(10) and Hp(0.07). In addition type test requirements for different dosimeters stated in recent international standards (IEC) are summarised and compared.

R04

### **Radiobiology – Evaluation of health risks after ionising radiation**

**Streffer, Christian**

University Clinics Essen, GERMANY

For radiological protection two classes of effects are grouped: deterministic and stochastic effects. Deterministic effects with threshold doses are mainly tissue effects, dose response is well-known from clinical experience and animal experiments. For stochastic effects (cancer and hereditary effects) no threshold dose is assumed. The knowledge of mechanisms is necessary for solving these open questions. DNA damage and its repair, apoptosis, adaptive response, bystander effects, genomic instability are important in this connection and will be discussed. Radiations with different LET as well as biological systems with different sensitivities like prenatal development and genetic diseases will be of high interest.

R05

**Clinical auditing and quality assurance****Järvinen, Hannu**

STUK – Radiation and Nuclear Safety Authority, FINLAND

In the jungle of the concepts of quality management, with a diversity of approaches and procedures in order to improve and maintain high quality, the meaning of concepts can easily be confused with each other and this has been particularly true for clinical audit. Clinical audit is a systematic review of the procedures in order to improve the quality and the outcome of patient care, whereby the procedures are examined against agreed standards of good practices. While it certainly is an important part of the overall quality assurance activities, it should not be confused with either overall quality assurance or quality control programmes. It should neither be confused with external quality assessments such as accreditations or certification of quality systems, or with regulatory inspections. In Europe, the Council Directive 97/43/EURATOM introduced the concept of clinical audit to medical RADIOLOGICAL (diagnostic radiology, nuclear medicine and radiotherapy) procedures. Recently, the European Commission has published further guidelines on clinical audits (Report Radiation Protection 159). In this refresher course, the purpose, scope and methods of clinical auditing are presented in accordance with the EC guidelines. The role of clinical audit as a part of overall quality assurance is explained and its relation to the concepts of quality management clarified.

R06

**Natural radiation environment and NORM****Markkanen, Mika**

STUK – Radiation and Nuclear Safety Authority, FINLAND

We are exposed to natural radiation all the time and everywhere. However, the types and levels of exposure vary considerably from “insignificant background” to situations where workers or members of the public receive doses which would not be accepted in any planned uses of radiation sources. In some cases, human activities have modified or even caused new pathways of exposure to natural radiation sources.

The refresher course will introduce the most common sources of natural radiation, as well as, types and levels of exposures delivered to workers and the members of the public. It will also highlight key aspects and challenges in reducing exposures and in introducing regulatory requirements for e.g. radon in workplaces, natural radioactivity in building materials and industries involving NORM (Naturally Occurring Radioactive Material).

The aim of the refresher course is to provide a general overview on natural radiation environment and NORM and to highlight practical aspects in managing related exposures.

R07

**Internal dosimetry and individual monitoring****Etherington, George**

Health Protection Agency, CRCE, UNITED KINGDOM

A description is given of the main principles and methods of internal dosimetry. Factors that are unique to internal dosimetry (e.g. protraction of doses over time) are discussed, and the implications for the dose quantities used in internal dosimetry are explained. The principles underlying the use of biokinetic models are discussed, and ICRP's models of the respiratory tract and human alimentary tract described. As an example of the current approach to systemic modelling of the elements, the biokinetic model for plutonium is described. Lastly, the use of individual monitoring for the retrospective assessment of internal doses is discussed.

R08

**Optimisation of radiation protection for pediatric and adult patients in radiography and computed tomography****Geleijns, Jacob**

Leiden University Medical Center, Radiology, NETHERLANDS

The need for optimization of radiation protection of patients in diagnostic medical imaging became clear already some 30 years ago. Scientists that pioneered in radiation protection observed that large variations in radiation exposure of patients existed for one and the same diagnostic examination. This triggered many national and international field studies. The field studies that have been carried out in the United Kingdom are particularly well known, and the observed steady reduction of third quartile adult patient dose values from three reviews of UK national patient dose data for the mid-1980s; the year 1995; and the year 2000 illustrates that improvements in acquisition protocols and imaging equipment resulted in substantial optimization of radiation protection. The need for optimization of radiation protection of young patients became evident when the number of clinical indications for CT examination of children grew rapidly mainly due to the enhanced speed of the CT scanners around the year 2000. It was observed in the United States that many CT scans of children were performed with acquisition protocols that were developed for adults, and that used too high exposures for small children. This led to special efforts worldwide in optimization of pediatric CT examinations; the Alliance for Radiation Safety in Pediatric Imaging of the United States of America (USA) encourages on its website [[www.pedrad.org](http://www.pedrad.org)] increased awareness of opportunities to lower radiation dose in pediatric CT procedures.

R09

**Radiation epidemiology**

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**Blettner, Maria**

GERMANY

R10

**Radioecology and environmental exposure pathways**

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**Strand, Per; Dowdall, Mark**

Norwegian Radiation Protection Authority, NORWAY

Radioecology (“radiation ecology”) is the scientific field encompassing the relationships between ionizing radiation or radioactive materials and the environment or subunits thereof. Radioecology and its study constitutes an important component of radiological protection of both humans and environment mainly, although not solely, through its relevance in understanding and describing environmental exposure pathways and quantifying radionuclide transport along them. Such pathways can be described as the route radioactive substances take from their source to their end point and how humans or biota can be exposed to the substance. This lecture introduces the basics of radioecology and discusses the role of radioecology with respect to environmental exposure pathways for radioactive contaminants. It presents the fundamental concepts of radioecology, the tools used by radioecologists with respect to the study of exposure pathways and future directions of research in the field.

R11

### **Malicious events: scenarios, consequences and response**

Prosser, Lesley

Health Protection Agency, UNITED KINGDOM

The potential use of radioactive materials by individuals with malicious intent has become an area of increasing international concern in recent years. This refresher course session will cover a number of key areas:

- Consideration of a range of potential scenarios and consequences both in the short and longer term;
- Examination of how lessons identified from past accidents can be used to develop preparedness in this area;
- Discussion of the key elements of planning arrangements required to respond effectively to a scenario of this nature; and
- Reviewing the key international planning guidance that is available to assist in the preparation for such scenarios.

R12

### **Indoor radon sources, remediation and prevention in new construction**

Arvela, Hannu

STUK – Radiation and Nuclear Safety Authority, FINLAND

Soil permeability and foundation structures and their impact on radon entry are the key factors in both radon resistant new construction and indoor radon remediation. Examples on construction practices which either promote or prevent radon entry will be presented. In radon remediation active methods Active Sub-slab Depressurization (ASD) and radon well are most efficient. Different approaches for varying house structures and national standards or guides will be presented. Remediation methods based on sealing entry routes, improvements of ventilation and decreasing of underpressure also have an important role in remediation work. Radon resistant construction practices are based either on preparatory ASD implementation or on sealing practices e.g. using plastic membranes as radon barriers. The results available from passive and active soil ventilation as well as from membrane use will be presented.

R13

**Radiation exposure of space and aircrew**

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**Hajek, Michael**

Vienna University of Technology, Institute of Atomic and Subatomic Physics, AUSTRIA

Cosmic radiation and its secondaries created in interactions with planetary atmospheres, shielding structures and the human body constitute one of the most important hazards associated with space and air travel. Crew members are facing exposures to radiation levels that may easily exceed those routinely received by terrestrial radiation workers. To assess the significance of potential biological implications on the health of space and aircrew, it is necessary to discuss the characteristics of the cosmic-ray environment and its dependencies on altitude and geomagnetic latitude. Exposure of space and aircrew to cosmic radiation will be reviewed, and recommended dose limits for astronauts working in low-Earth orbit will be dealt with in comparison with radiation protection guidelines of aircrew personnel.

R14

**Stakeholder involvement and engagement**

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**Koskelainen, Markku**

STUK – Radiation and Nuclear Safety Authority, FINLAND

One of the greatest challenges facing radiation protection professionals today is, how to include the society in radiation protection decision making. In response to this issue, internationally accepted guiding principles for radiation protection professionals on stakeholder engagement have been published by the International Radiological Protection Association (IRPA). IRPA goal is to ensure that consensus on directions for improvement of stakeholder involvement programmes is reached among radiation protection professionals, and that these guiding principles are taken into account during the development of future stakeholder involvement programmes.

R15

### **Decommissioning and waste management**

**Thierfeldt, Stefan**

Brenk Systemplanung GmbH, GERMANY

Decommissioning of nuclear installations is associated with dismantling contaminated and activated systems, structures and components as well as with decontamination and further handling of these large quantities of materials. Decontamination and demolition of buildings takes place in later phases of decommissioning projects.

This refresher course gives an overview of the various techniques used for dismantling and for decontamination and puts them into context with aspects of waste management, including the resulting quantities of radioactive waste and material eligible for clearance.

The aim of the course is to provide an overview of current issues and available techniques in the field of decommissioning and waste management and of their range of applicability, benefits, and mutual interdependence.

R16

### **Non-ionising radiation**

**Matthes, Rüdiger**

Bundesamt für Strahlenschutz, GERMANY

Technological development in modern societies cause an ever increasing exposure of people to non-ionising radiation in all situations of life. Examples include new technologies for diagnosis and treatment in medicine, wireless communication technologies at home and in the office, and high power devices for material processing in industry. The health implications of such exposures have been investigated quite intensively, but remain an issue of public concern. The relevant mechanisms and health effects are different throughout the non-ionising electromagnetic spectrum. Nerve excitation and tissue heating are well established examples. Cancer induction especially in children or from very long chronic exposure is still under investigation. The International Commission on Non-Ionizing Radiation Protection has issued guidance on limiting exposure to static, low, and high frequency electric and magnetic fields, that are regularly reviewed.

IOF-01

**The WHO Programme on radiation and health**

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Neira, Maria

WHO – World Health Organization

IOF-02

**Challenges in radiation protection – views from the IAEA**

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Amaral, Eliana

IAEA – International Atomic Energy Agency

IOF-03

**ILO's activities in radiation protection of workers**

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Niu, Shengli

ILO – International Labour Organization

IOF-04

**Future direction of the work of UNSCEAR**

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Weiss, Wolfgang

UNSCEAR – United Nations Scientific Committee on the Effects of Atomic Radiation

IOF-05

### **The activities and considerations of the ICRU on selected radiation protection topics**

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Paretzke, Herwig

ICRU – International Commission on Radiation Units and Measurements

IOF-06

### **International Commission on Radiological Protection – recent publications, current initiatives and future work**

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Clement, Christopher

ICRP – International Commission on Radiological Protection

In 2007, after almost a decade of development and worldwide, open consultation, the International Commission on Radiological Protection (ICRP) published its latest fundamental recommendations describing the overall system of radiological protection in the 2007 Recommendations of the International Commission on Radiological Protection. These replaced the 1990 Recommendations of ICRP published almost two decades earlier. Since then ICRP has focused primarily on developing publications that support or further elaborate elements of the system of radiological protection as described in the 2007 Recommendations. This paper describes these publications, as well as ongoing and planned future efforts with the same objective.

IOF-07

### **The Euratom programme of research and training on low doses of radiation**

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Jouve, André

European Commission, Directorate General for Research

The Euratom programme of research and training on the risks associated with low doses of radiation will be closely aligned to priorities identified in the Strategic Research Agenda (SRA) of MELODI and the Transition Research Agenda (TRA) to be implemented through the project DoReMi funded as part of the 7th Euratom Framework Programme. These research agendas are aimed at integrating the European research effort on low dose, at opening this effort to the wider scientific community and at promoting and facilitating the sustainable integration of key research institutions in European Member States.

IOF-08

### **New Build, environment and waste – application challenges for the 'new' RP**

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Riotte, Hans

Organisation for Economic Co-operation and Development / Nuclear Energy Agency – OECD/NEA

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# Programme outline

	13 Sunday June	14 Monday June	15 Tuesday June	16 Wednesday June	17 Thursday June	18 Friday June
8:00						
8:30		Registration desk opens	<b>R3 – R6</b> Refresher courses 3 – 6 (four parallel lectures)	<b>R7 – R10</b> Refresher courses 7 – 10 (four parallel lectures)	<b>R11 – R13</b> Refresher courses 11 – 13 (three parallel lectures)	<b>R14 – R16</b> Refresher courses 14 – 16 (three parallel lectures)
9:00		NOTE WORKSHOP: Implications of non-targeted effects for radiation protection	Opening ceremony IRPA history / Geoffrey Webb	<b>S01</b> Biological and health effects of ionising radiation	<b>S04</b> Dosimetry	<b>S14</b> Non-ionising radiation protection
9:30		RADON mitigation and prevention, VISIT to Tampere		<b>S02</b> Medical use of radiation	<b>S07</b> Education and training	<b>S16</b> Radiation in the environment
10:00		TECHNICAL VISIT at Olkiluoto and EPR and geological repository for high level nuclear waste		<b>S03</b> Radon	<b>S10</b> Nuclear and radiological emergencies and incidents	<b>S18</b> Radiation protection recommendations, standards and regulations
10:30			Coffee	Coffee / Technical exhibition	Coffee / Technical exhibition	Coffee / Technical exhibition
11:00			<b>PL1 – PL3</b> Plenary lectures 1 – 3 (each 20 min) Highlights in European radiation protection	Poster session	Poster session	<b>S15</b> Radiation protection of the public
11:30			Lunch	<b>S01</b> Biological and health effects of ionising rad.	<b>S04</b> Dosimetry	<b>S17</b> Natural radiation
12:00				<b>S02</b> Medical use of radiation	<b>S11</b> Nuclear security and non-malevolent use of radiation	Summaries Young scientist award Closing
12:30				<b>S03</b> Radon	Lunch	
13:00				Lunch		
13:30			<b>PL4 – PL6</b> Plenary lectures 4 – 6 (each 20 min) Highlights in European radiation protection			
14:00				<b>ASF</b> Associated Societies Forum	<b>S05</b> Waste management and decommissioning	
14:30			Coffee / Technical exhibition	<b>WS1</b> SPECIALIST WORKSHOP I	<b>S08</b> Radiation protection of workers	
15:00	Technical visit Travel to Olkiluoto by bus			<b>WS2</b> SPECIALIST WORKSHOP II	<b>S11</b> Radiation detection technologies and radionuclide analytics	
15:30			<b>IOF</b> International Organisations Forum	Coffee / Technical exhibition		
16:00		DoreMi Forum		<b>WS1</b> SPECIALIST WORKSHOP I Towards safer and more effective use of radiation in paediatric healthcare	Coffee / Technical exhibition	
16:30				<b>WS2</b> SPECIALIST WORKSHOP II Radiation protection issues in nuclear industry	Poster session	
17:00			Poster session		<b>S06</b> Naturally occurring radioactive materials – NORM	
17:30					<b>S09</b> Radiation protection of the biota	<b>S13</b> Medical response in radiation accidents
18:00						
18:30		Accommodation and sightseeing in Rauma				
19:00			Reception and concert at Finlandia Hall	Reception by City of Helsinki at Town Hall		
19:30						
20:00					Congress dinner at Hotel Hilton Kalastajatorppa	
20:30						

