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Encouraging Sustainability in Radiation Protection

Book of Abstracts

IRPA 2018 Book of Abstracts

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IRPA 2018 Book of Abstracts

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Communication

Subject: Communication

Questions and answers: the experts of the Spanish society of radiological protection communicate with the public

Eduardo Gallego

One of the strategic lines of the Spanish Society of Radiological Protection (SEPR) is dedicated to relations with society. The aim is to "approximate the SEPR to society, enhancing the existing communication channels and implementing new lines of media coverage"; it is proposed (1) to develop and maintain dissemination products for the general public and the mass media; (2) to carry out a detailed analysis on the ways of enhancing the dissemination of the SEPR messages through the Internet, the new technologies and social networks and (3) to develop an action plan to establish communication channels with the media (press, radio and television) to disseminate articles or news related to current issues prepared by the SEPR, which contribute to the dissemination of the SEPR as a scientific and independent society. Within this objective, the section called "Ask the SEPR" was launched in 2013 on the website https://sepr.es, through which the intention it to respond to the doubts and concerns of those who visit the site. The consultations are answered by volunteer experts, having classified them according to a few main topics, also including small introductory documents to each thematic area. The topics considered include general information on radiation and its effects, radiation of natural origin (including radon and NORM), the use of radiation in medicine, considering both the radiological protection of patients in diagnosis and therapy, and that of health workers. It also addresses radiological protection in nuclear energy, radiological protection of the public and the environment, as well as questions about other radioactive sources and the management of radioactive waste. Non-ionizing radiation also has its own section, classified essentially in mobile telephony and antennas, domestic appliances such as microwaves, induction, etc., as well as uses in medicine and other fields. With this initiative, an interactive service has been put at the service of the Spanish-speaking community through which to answer the public's doubts about our profession.

Subject: Communication

Communicating Nuclear Power Energy in a Newcomer Country

Diana Kathini Musyoka

Nuclear power plant projects have over time faced unique challenges with regard to public understanding and acceptance. This has been exacerbated by nuclear accidents in the past which have fueled fear amongst the public because they have been associated with release of radiation to the environment. Another limiting factor is concern on radioactive waste produced in nuclear power generation which causes controversy whenever nuclear facilities of any kind are proposed. Radiation is viewed as an invisible hazard whose health effects are dreaded by the majority of the public. It is important to note that a proposal to develop a nuclear related facility will inevitably result in considerable debate, first nationally then locally when specific sites have been identified. Therefore, a communication strategy and plan are key in addressing communication and awareness on a nuclear power programme in a newcomer country. In the initial stages of nuclear programme implementation, the government and the NEPIO - 'nuclear energy programme implementing organisation', are the organisations with major roles. Specifically, the NEPIO should conduct surveys to determine the public's knowledge and receptiveness to nuclear power and consequently develop public information tools that respond to the results of the surveys. Kenya Nuclear Electricity Board (KNEB), the equivalent of a NEPIO in Kenya, has employed a number of tactics of stakeholder involvement and communication. A national poll carried out in 2015 indicated that awareness of nuclear energy is low among the Kenyan public. The respondents who showed support to nuclear energy did so due to perceived benefits such as reliability, affordability and environmental friendliness. On the other hand, those in opposition indicated perceived environmental and health hazards such as radiation and possibility of proliferation. The Kenya nuclear power programme has advanced considerably since 2015 and is in its Phase two according to the IAEA guidelines. Therefore, stakeholder involvement initiatives also have to change. For example, in Phase two, a preferred site for Kenya's first nuclear power plant has to be selected as well as alternative sites. This creates a need to enhance public acceptance and support amongst the local community in the preferred site. While it may not be possible to begin these efforts by KNEB as a NEPIO and not owner/operator, KNEB can develop their strategies to include educating and creating awareness in the regions that have potential to host the first nuclear power plant during preliminary site selection.

Subject: Communication

The European Health Physics mailing lists RADSAFE-EU and RADSAFE-D - a means of communication in radiation protection since more than 20 years

Peter Hill

In 1997 the radiation protection mailing lists RADSAFE-EU and RADSAFE-D were initiated by Forschungszentrum Jülich GmbH. The imitative drived at using the internet to better communicate in matters of radiation protection both in the German-speaking regions as well as on a more European level. The chosen way of communication should enable an interaction between the participants. They also should supplement the international mailing list RADSAFE.

In earlier days radiation protection mailing lists as electronic communication media provided the somehow unique feature of interactive exchange in professional matters. With the establishment of electronic networks (e.g. Facebook, Xing) this uniqueness is gone. Nowadays radiation protection mailing lists are just one of several pillars of professional electronic communication. However they are not out of date. This is shown clearly by the persisting interest of users. In the most recent years the number of members in the mailing lists has levelled out at ~400 for RADSAFE-EU (English-speaking) and ~200 for RADSAFE-D (German speaking).

The subscription to the mailing lists is quite easy. All it takes is to send an email to radsafe-eu-subscribe@fz-juelich.de (radsafe-d-subscribe@fz-juelich.de resp.). The body of the message might remain empty.

The international mailing list RADSAFE presently sponsored by an US university still persists and is doing well. For Spanish-speaking people a few years ago the list RADIOPROTECCION has been created on the initiative of members of the Peruvian Health Physics Association. This list grew quickly up to a large number of participants and has been followed up and supplemented by a Facebook account.

Overall it can be concluded that health physics mailing lists are still a valid option for communication in radiation protection. Though some of them already exists since over 20 years it is always worth to participate.

Subject: Communication

Towards Guiding Principles for IRPA Communication and Engagement with the Public: The Work of the IRPA Task Group on Public Understanding of Radiation Risks.

Pete Cole

Context: The Task Group on Public Understanding of Radiation Risk was established in 2014 with the aim of encouraging and supporting Associate Societies in the development of effective means of enhancing public understanding of radiation risk through the sharing of good practice, ideas and resource materials.

Work done: Up to now the group's endeavours have focussed on promoting the study of public (including media) engagement with radiation protection issues and publication of articles thereon plus the development of a library of good practice activities which have been made available on a dedicated IRPA webpage.

Ongoing activities: The time is now right for the group to move forward on another two milestone undertakings:

1. Developing the IRPA guiding principles for communicating and stakeholder engagement with the public. The proposed work plan is:

> a. To develop methodology and protocol for engaging with IRPA membership in order to garner 'guideline' ideas.
>
> b. To organise and host international and regional workshops specifically on 'communication and stakeholder engagement of IRPA' to collect good practices, explore ideas and identify needs for inclusion in the 'guidance' at different radiation protection events.
>
> c. To conduct the first of these workshops at the RICOMET 2018 conference in Belgium, and improve the workshop methodology.
>
> d. Present results from these workshops and first draft guidance document at IRPA EC 2019
>
> e. To revise the first draft of the IRPA Principles based on feedback to a second draft which will be presented to IRPA 2020 in Korea for approval and subsequent launch.

2. The development of a 'soft skills' tool pack to facilitate IRPA AS to hold training sessions for radiation protection professionals on communicating with the public and stakeholder engagement.

It is essential that radiation safety professionals obtain some rudimentary skills in communicating the concepts of risks and benefits to non-specialists including the media. Such 'tool packs' will need to take into account a variety of languages and cultures but may include slide sets, desktop exercises, case studies, links to expert science communicators, and feedback questionnaires.

Invitation: In the case that you wish to organise a national or international workshop in the context of IRPA' communication and engagement with public, kindly contact dr. Hiroko Yoshida, president of the TG public understanding at hiroko@m.tohoku.ac.jp

Subject: Communication

Local concerns & media attention vs. experts in environmental remediation: Two Belgian case studies

Tanja Perko

Decisions related to environmental remediation (ER) of NORM sites (Naturally Occurring Radioactive Material) or areas affected by mixed contaminations (e.g. from radium production) cannot be isolated from the socio-political and cultural environment. Although their importance in ER project planning and implementation is emphasized by experiences of the affected populations, decision-makers, as well as opinion makers in radiation exposure situations, the socio-political, ethical and cultural aspects have not been empirically or systematically studied. Stakeholder's views, concerns and uncertainties have not been collected and analysed. Our research addresses this gap.

In order to identify and collect the views, challenges and uncertainties of different stakeholders, specifically people living in the contaminated areas, we conducted a mixed methods study, including media analysis (newspaper articles published in the last 15 years), questionnaires with members of the population and interviews with key information sources for two contaminated sites in Belgium.

Our study highlights main public concerns, stakeholders' uncertainties, media attention points and information sources. In-depth analysis shows that affected population, remediation experts and mass media are concerned about different issues and therefore express or are confronted with different uncertainties. For instance, mass media frame the problem as "radiological contamination", experts as "mixed contamination" (chemical and radiological) and people living in an affected region as "pollution".

Findings from this empirical and systematic analysis are central to improving risk communication and formulating stakeholder engagement objectives for NORM contaminated sides and related remediation processes, since successful risk communication should primarily address the risk perception, concerns and views of affected population rather than focus on technical scientific facts. Recommendations related to stakeholder engagement in remediation processes will be drawn from the cases analysed.

Acknowledgement: The research has been conducted in the context of the TERRITORIES project, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 662287.

Subject: Monitoring

New CSN web-based application for the public consultation of the Spanish radiological environmental monitoring data

Sofía Luque

Article 2 of the Law of creation of the CSN states that this Body is responsible for "Monitor the radiological quality of the environment" as well as "Inform public opinion on matters within its competence". To fulfil the former, in Spain, two main monitoring networks are established:

• The environmental radiological monitoring programs around nuclear and fuel cycle facilities, carried out by licensees.

• The national monitoring network throughout the country, carried out by 21 university laboratories through agreements with the CSN.

All of these data are kept in an Integrated management system of environmental radiological data, known as “Keeper”, which until now had four different interfaces depending on its user:

1. Licensees and laboratories, responsible for inputting and validating the data in the database.
2. CSN experts in charge of assessment, who can use statistical and graphical tools to evaluate the data.
3. Other CSN experts, who can consult the data in a map interface.
4. A module to automatically generate the information required by the European Commission in accordance with Articles 35 and 36 of Euratom Treaty, in an appropriate format.

The public information function has been fulfilled, for more than 20 years, by the yearly publication of a report to the Spanish Congress and Senate which contains a summary of the results obtained by the system of environmental radiological surveillance in Spain, and a technical report with the detailed results. Both documents are available online on the CSN website.

Law 27/2006, of July 18, which regulates the rights of access to information and public participation in environmental matters, stated that the public has the right to access to environmental information held by public authorities, encouraging the latter to ensure its dissemination and to make it easily available through electronic formats within public telecommunication networks.

To comply with this requirement, the CSN has launched an application that opens access to Keeper which constitutes the fifth and last interface of the system. This tool has a user-friendly interface that uses a Google Maps based map of Spain and a selection panel, from where the different environmental radiological values can be queried, with the possibility of filtering the selection by installation, sample type, radionuclide, sampling period or station.

The objective of this poster is to present this application that can be accessed from any internet access point at the following address https://www.csn.es/valores-radiologicos-ambientales-pvra-rem.

Decommissioning

Subject: Decommissioning

Decommissioning Dounreay – Radiological Protection Challenges, Solutions and Lessons Learned

Deborah Clark

Dounreay is situated on the north coast of Scotland and is operated under contract to the UK's Nuclear Decommissioning Authority (NDA) by Dounreay Site Restoration Limited (DSRL). DSRL is a wholly-owned subsidiary of the Cavendish Dounreay Partnership Ltd, a consortium of Cavendish Nuclear, CH2M and AECOM.

Dounreay site was instrumental in the development of fast breeder reactor technology in the 1950s. The large and complex site houses a number of unique plants including two fast reactors, a materials test reactor, metallurgical laboratories (with fume cupboards, glove boxes, and shielded cells), fuel reproccessing plants, post irradiation examination (PIE) facilities, and waste handling, processing and storage facilities.

Working to deliver the site closure programme, Dounreay is now a site of decommissioning, demolition, construction, and waste management. The experimental nature of some of the now redundant facilities means that the clean up and demolition of the site requires innovative thinking as well as great care in order to safely remediate the land and restore the site.

We have encountered many technically challenging projects during the decommissioning programme so far. Along with the technical aspects come radiological protection considerations which must be commensurate with the task risks as well as being practical to implement.

Some of the challenges include high gamma and beta gamma dose rates in heavily shielded facilities where man access is not possible, high levels of extremely mobile loose radioactive contamination including alpha and beta emitting radionuclides, alkali metal contaminated components, ageing facilities which were not designed with decommissioning in mind, and loss of operational experience due to an ageing workforce.

The innovative solutions to these challenges include the use of mock ups to replicate the work place in non active areas so that operability can be tried and tested without the radiological hazards, the use of unique tools designed for remote working, and the design of local shielding which is quick and easy to deploy at the work area, and the training and mentoring of new staff to continue the decommissioning work.

This paper discusses some of the projects, the novel designs and techniques, the radiological aspects and lessons learned.

These projects include a unique facility designed and built to retrieve and condition breeder fuel elements from the Dounreay fast reactor (DFR), the decommissioning of heavily shielded PIE facilities, fuel reprocessing plants, and waste handling and disposal facilities.

Subject: Decommissioning

Radiological characterization of activated material at accelerators

Reiner Geyer

Materials inside and around accelerators get activated by the irradiation fields caused by the primary beam particles and their interactions with matter. Because of the complexity of these irradiation fields, the radiological characterization of materials for clearance from regulatory control or disposal becomes a challenging procedure. Different particle types contribute. Their energies may vary by orders of magnitude from energies of thermal neutrons to Tera electron volts. The intensities of the fields may change rapidly over relative short distances. Furthermore, the activation products depend strongly on the chemical composition of the objects. Hundreds of different radioactive nuclides may be produced, while typically a significant part is not easily detectable by simple spectroscopy or count rate measurements. In view of these challenges and the change of the Swiss exemption limits in 2018, the radiation protection groups of the European Organization for Nuclear Research (CERN) and the institute of radiation physics of Lausanne University Hospital (IRA) are developing new characterization techniques, which shall allow for efficient radiological controls based on in-situ measurements with reasonably compact and mobile devices.

One key element in the development of the new techniques is a software tool named Radiological Workstation (RAW). RAW facilitates the characterization of objects by combining measurement results from high purity germanium detectors or count rate monitors with pre-computed predictions from ActiWiz/FLUKA simulations. The detected activities can be complemented with those, which are difficult to measure, using these simulation results. This is an essential tool to avoid more complex measurement techniques like radio chemical analysis. The latter are very cost and time-expensive and cannot be used in daily operation. The correctness of the simulation can be validated by comparing the measured activities with their predictions. This self-consistency check is also sensitive to other assumptions like the chemical composition of the characterized material.

The basic ideas of the approach will be illustrated in this contribution by using the example of two accelerators, a proton cyclotron for the production of radio pharmaceutics in the environment of a hospital and a high-energy proton-synchrotron accelerator for physics research at CERN. The benefits as well as the limitations will be discussed and summarized.

Subject: Decommissioning

Dose assessment for critical group due to radioactive effluents release as a result of a nuclear research reactor decommissioning

Carmen Tuca

The study presents the analysis of the potential doses received by the members of the critical group (infants and adults located in the Magurele city, starting with 1 km distance from the reactor), as a result of the gaseous and liquid radioactive effluents release in the decommissioning process of the VVR-S nuclear research reactor of NIPNE, Bucharest, Romania. The cutting of activated and contaminated components and structures and also the demolition of the concrete biological shielding generate the gaseous effluents. Processes such as the emptying of the pools for long term storage of the nuclear spent fuel, cutting of metallic or concrete components or decontamination of the workers and equipment's, generate the liquid effluents. Thus, the maximum annual effective doses for a critical group member due to the release of one Bq activity of the radionuclide on the release path air and water were calculated. The methodology for dose calculation takes into account the dose constraint - 50 µSv / year for the critical group members - imposed by the regulatory body for decommissioning activities of the reactor. It is considered reasonable to apply for each member a weighted average of an equivalent dose that does not exceed the equivalent dose limit. The dose received by an individual varies according to the age, weight, metabolism and nutrition habits. The released activities of gaseous effluents are much lower than the derived emission limits (DELs) for gaseous effluents' assigned value of 10 µSv/year (for 2014, 2015 and 2016) and these constraints are fully accomplished. The most restrictive dose values for air are for the adults as a result of 152Eu and 60Co release. On the contrary, for the liquid effluents the released activities are systematically higher than the DELs for the most radionuclides. In 2014 and 2016 these arriving up to 39 times, respective 165 times for 90Sr, the most significant beta pure emitter. The effective dose constraint of 40 µSv/year for critical group is not accomplished and the effluents must be treated as liquid wastes. The most restrictive dose values are for the adults due to the potential release of 238U. Similar values were obtained for: 235U ,60Co ,90Sr, 137Cs and 134Cs. For infants the most restrictive dose values are due to potential release of 235U and also from 137Cs, 241Am and 90Sr

Subject: Decommissioning

On the decommissioning of activated concrete

Gilles Moerdijk

At the Technical University of Eindhoven in the Netherlands, a project was recently completed on the decommissioning of supporting concrete beams of a former accelerator home. The work was started by taking drilling cores at several supporting beams which were sawn into 2 cm thick samples for a quick total gamma analysis using a NaI-detector. A typical example of the count rate as a function of the material depth in two different cores is shown in Fig. 1. Some samples were additionally analysed by a (HP)Ge semiconductor detector to identify the responsible radionuclides, i.e. Co-60, Eu-152 and Eu-154 in the concrete and Co-60 in the reinforcing steel. Per sample an index is determined by dividing each identified radionuclide by its clearance value and summing over all nuclides. In formula:

$$\text{Index}=\sum_i A_i / A_{i,c}$$

in which A_i is the activity concentration of radionuclide i and $A_{i,c}$ is the clearance level of radionuclide i (according to Dutch legislation 2016). When the index is equal to 1 or lower, the material can be treated in the same way as non-contaminated ones. The well agreement between the index and the count rate is demonstrated in Fig. 2. Based on this information a decommissioning plan was made up and submitted to the competent authority.

A total of 360 tonnes of concrete were crushed to release the reinforcing steel. The granulates were stored in 321 half-filled 1-m3 big bags. From each bag a sample was analysed by gamma ray spectrometry to evaluate the activity concentrations. The frequency diagram of these 321 samples (Fig. 3) shows an average value for the clearance summation index of 0.03, which is well below the clearance level of 1. The mean activity concentrations of Eu-152 and Co-60 were 0.07 and 0.02 Bq/g, respectively. The concrete granulates were reused to level up a local parking space.

The amount of reinforcing steel was determined at 13 tonnes, representing a total Co-60 activity of 3.3 MBq. The steel was transported to a smelter in Germany. Processing the steel delivered 24 ingots which were released to be 100% recycled. After processing a residue of 200 kg remained, which was deposited at COVRA, the national organization for the storage of radioactive waste.

Subject: Decommissioning

Cyclotron decommissioning at the Vrije Universiteit Amsterdam: "The beginning of the end"

Andy van Driel

Since 1963 a 30 MeV cyclotron has been used for research purposes at the Vrije Universiteit of Amsterdam. In the early '90s the unit has been used for the production of isotopes for medical imaging. After a stand-by period the system has been shut-down in May 2014. From that moment onwards it was no longer an operating cyclotron with a concrete bunker for shielding purposes but 140 tons of activated steel and 600 m3 of activated reinforced concrete. Being located in a building with 3 operating cyclotrons and a GMP facility for the production of medical isotopes, the decommissioning of this cyclotron comes with its own specific challenges.

The decommissioning of the cyclotron and cyclotron supporting structures have been put under a separate license in order to create a clear and transparent decommissioning project.

I will outline the setup of the project, the time-line and will both illustrate our decommissioning process in action and the problems we encounter (like measuring large amount of samples with a low amount of radioactivity, retention of system knowledge, recycling of radioactive materials and the consequences of the implementation of EU-BBS) and how we think to tackle them.

During the project it became clear that finding a solution for re-use of concrete and steel is preferred over final disposal in the radioactive waste depository.

I will conclude the presentation with possible scenarios for the re-use of "large" amounts of radioactive concrete in the Netherlands.

Subject: Decommissioning

Clearance of the concrete blocks from the dismantling of the DIORIT experimental reactor at the Paul Scherrer Institute

Isabel Sierra Perler

While the old Radiation Protection Ordinance in Switzerland was still in place (till 31.12.2017), materials from the dismantling of the DIORIT experimental reactor at the Paul Scherrer Institute were cleared. The 94 concrete blocks from the former biological shield consisted of different proportions of baryte and colemanite concrete and steel. The sealing cords around pipes were asbestos-containing in most cases.

Proof of compliance with the guideline ENSI-B04 resp. limit values for clearance of the concrete blocks was given in two ways:

1. Compliance with the requirements listed in Art.1StSV is proven:

• LE values have fallen below with appropriate application of the sum formula,

• dose rate at a distance of 10 cm does not exceed the value of 0.1µSv/h after deduction of the background,

• CS values for surface contamination are not exceeded.

2. Compliance with the requirements listed in Art.2(2) StSV is proven:

• LE values have fallen below with appropriate application of the empirical formula,

• At no time people will accumulate an effective dose higher than 10µSv per year as a result of disposal of the blocks.

The proof of keeping the dose criterion was given by referring to the proof of German clearance values for landfill, which are higher than the Swiss values. The specific activity was determined by probing and laboratory analysis as well as by in situ gamma spectrometry measurements on each individual block. By sampling, the existing nuclide vectors were confirmed or adapted after special nuclide analyzes as well as the relaxation length was calculated. This is a prerequisite for the determination of the total activity in the individual blocks by means of in situ gamma spectrometry measurements (calibration). It was proven for each concrete block individually, that the mass-specific limit value stays below the admissible limits by using in situ gamma spectrometry measurements. The respective total activity of a concrete block, obtained by in situ gamma spectrometry, was compared to the inactive release criteria for the net mass. This procedure of case-by-case analysis resulted in comparatively large effort (high number of samples and detailed evaluations as well as additional measurements), which is not case in the routinely applied ENSI guideline B04. In the end the inactive release of 90 concrete blocks (about 70 tons) could be realized with the disposal to a landfill, which is suitable for the acceptance of asbestos.

Subject: Decommissioning

Release from Regulatory Control of Concrete Construction Waste from the Facilities DIORIT and SAPHIR at PSI

Isabel Sierra Perler

The Paul Scherrer Institute (PSI) is the largest national research center in Switzerland. Its multidisciplinary research is dedicated to a wide field of natural science and technology as well as particle physics. The research reactor facilities of the institute (DIORIT, SAPHIR) are currently at the advances stage of decommissioning. Significant quantities of the construction waste, particularly concrete, were produced during the dismantling process. According to the results of radiological characterization, the concrete waste created during decommissioning was subjected to the process of exemption from regulatory control. Approximately 70 tons of concrete have been reprocessed, sampled, characterized and studied. Measurements in the RTM644lnc large clearance box monitor were performed in order to officially release the material from regulatory control.

Initially, the material under study consisted of a mixture of large concrete fragments and concrete rubble. A specific material processing facility was constructed and commissioned at PSI in order to reprocess and homogenize the material.

The technical aspects of the material processing, the radiological characterization method, statistical studies as well as the official measurement procedure in accordance with Swiss legislation are discussed in the present work. The current study is helpful to establish and facilitate a procedure of release from regulatory control of concrete construction waste.

Subject: Decommissioning

Project feedback experiences in decommissioning Low Flux Reactor

Karlijn van der Wagt

The Low Flux Reactor in the Netherlands was operated for approximately 50 years for research and education purposes. In 2010 the reactor was taken out of business for economic reasons. After a period of 6 years of preparation in which the radiological inventory was determined, the decommissioning license was received, and working procedures were established, the actual decommissioning started in 2016 with the removal of the operating console.

The decommissioning approach was to divide the decommissioning into discrete work packages. Each work package consisted of a detailed work plan, a Task Risk Assessment (TRA) and a radiological risk inventory & evaluation (RI&E) including expected dose the workers will collect. The actual work started with a kick-off meeting and daily toolbox meetings. After the completion of each work package the activities were evaluated and the lessons learned were applied in the next activities. To perform such a graded approach in decommissioning project good arrangements with the authorities is necessary. To facilitate the decommissioning process NRG developed a sensitive measuring system and a 'track and trace' device in-house to characterize and track all waste resulting from decommissioning LFR. The radioactive waste was declared with the central waste management organization in the Netherlands (COVRA) by using the fingerprint method and radiochemical analyses for confirmation. The majority of the waste is stored in Konrad containers which is new in the Netherlands. The reactor was completely removed, the reactor hall released and all radioactive waste transferred to COVRA in spring 2018. In this presentation these subjects will be treated with a focus on radiation protection during the performance of the project.

Subject: Decommissioning

Decontamination of buildings in the dismantling of José Cabrera nuclear power plant

Teresa Ortiz

Tasks for decontamination of walls, floors and large pieces, along with the restoration of lands and demolition of buildings, constitute the main works in progress and until completion of the dismantling project. The walls decontamination plan includes two processes depending on the degree of penetration of the contamination, the removal of the contaminated layer using techniques such as dust mopping, sucked or scarifying, in the case of surface contamination, and cutting and chopped of the concrete if the contamination has penetrated deeper or there is activation of the material.

The decision to apply one or the other technique is based on the results of the characterization of the walls, the expected efficiency, radiological optimization and the volume of radioactive waste. The set of actions to perform, their control, obtaining and processing of final data constitute the basis on which it will make the decision declassification applying, as a base, MARSSIM methodology and procedures developed on the basis the experience of decommissioning of Vandellòs I and PIMIC project. The complexity of your application will be conditioned by the operational history of the plant, the available information and the wisdom in working methods.

Subject: Decommissioning

Definition of the clearance levels of Italian nuclear plants and possible changes for adoption of the Council Directive 2013/59/EURATOM

Francesco Mancini

In Italian law the art. 154, paragraph 3-bis, of Legislative Decree 230/1995 establishing that levels of clearance from nuclear installations must meet the criteria for the exemption of radiological practice, in particular the effective dose expected to be exposed the members of the public must be equal or less than 10 µSv per year.

The same law establishes that the definition of the levels must take into account the directives, recommendations and technical guidelines provided by the European Union.

The current clearance levels have been defined taking into account the European Commission publications: Radiation Protection 89 (metallic materials), Radiation Protection 113 (cement materials) and Radiation Protection 122 part. I (other materials) , re-evaluated for radionuclides with levels greater than 1 Bq/g to the value of 1 Bq/g, that is the level of exemption provided by Italian law for all radionuclides.

The present work aims to provide a general overview of the current clearance levels of nuclear installations in decommissioning of Sogin (4 Nuclear Power Plants: Trino, Caorso, Latina and Garigliano, 4 nuclear research plants: Eurex, Opec, Ipu and Itrec and 1 fuel plant: Bosco Marengo) and provide a critical study on the possible changes in the concentration levels following the implementation of Directive 2013/59/ EURATOM.

In particular, there are two issues introduced by Directive 2013/59/EURATOM which could result in a significant change in the clearance levels:

1. The definition, for large quantities of materials, not only of the exemption levels but also of the clearance levels;

2. The adoption of the Safety Standards Series IAEA No.RS-G-1.7 for definition of the exemption and clearance levels for large quantities of materials.

The first point, if the values of Table A part I of the Directive are completely adopted, would allow to have clearance levels above 1 Bq/g for the radionuclides with low radiological risk that currently have values equal to 1 Bq/g (H-3, Fe-55, Ni-63, ..) because they cannot exceed the exemption levels of 1 Bq/g of the current Italian law, the second point could have instead repercussion for the clearance levels of "other materials" that are currently defined according to the Radiation Protection 122 part. I and not according to the Standards Series IAEA No.RS-G-1.7.

Education

Subject: Education

IRSN's Information and Education Strategy for the Public to enhance their Radiation Protection and Nuclear Safety Culture

Fabrice Ecrabet

In France, the legal framework has been recently reinforced in order to have a better compliance with the safety features of nuclear installations but also a relevant communication with the public about the nuclear risks and the nuclear decisions. Starting with the Nuclear Safety Transparency law of 2006 defining transparency in the nuclear field as "the set of provisions adopted to ensure the public's right to reliable and accessible information on nuclear safety", afterwards reinforced by the Law on Energy Transition and Renewable Energy in 2015. This law reinforced the transparency provisions, requiring not only transparent one way information but also public participation.

IRSN, way before these transparency requirements, made it one of their priorities to develop different methods and tools for the improvement of communication between Experts and Public promoting visibility and trustworthiness. Thanks to the new legal framework, the development of new tools to inform and engage citizens is accelerated. The traditional tools available are annual reports, newsletters, websites, magazines, Press data center, press conferences, etc…Today completed with new tools such as social media..

In addition, IRSN developed ways and tools promoting direct contact with the public, such as the Exhibition about Nuclear and Radiation risks, covering all topics and every question raised by the public including health aspects and medical use. The exhibition called "RADIOACTIVITY" has been designed, in collaboration with the French regulatory body ASN, to inform the Public. The exhibition is not only used by IRSN "Open Days" or Emergency drills but travels also around the country to schools, hospitals, museums dedicated to science (e.g. in Paris "la cite des Sciences et de l'Industrie"), community centers etc…often accompanied by our experts. The Exhibition proved to be an important tool offering the public a better understanding of what is at stake, enlighten their choice as citizens and provide basic knowledge in case of a radiological accident. In addition the Exhibition proved to be inspiring for the young generation to pursue a scientific career, hence avoiding a shortage of scientific and technical competences in a way to ensure radiation protection and nuclear safety for a long period of time

Today the Exhibition is therefore considered as a valuable asset of our "Information and Education Strategy for the Public" to enhance their Radiation Protection and Nuclear Safety Culture.

Subject: Education

Radiation protection training in updated Slovenian legislation: what is improvement and what is not

Matjaž Koželj

Before joining EU, Slovenia had to harmonise legislation in the field of protection against the dangers arising from ionising radiation. In the year 2002 Ionising Radiation Protection and Nuclear Safety Act was approved. In the following years, second-level legislation was introduced, also regarding required education and training of exposed workers and other persons involved in the implementation of radiation protection in practice. These are persons responsible for radiation protection, which are appointed by employers and are in fact radiation protection officers. Staff members of the radiation protection units in nuclear facilities also perform tasks of radiation protection officer. While persons responsible for radiation protection were introduced with the harmonised legislation, radiation protection units were already operational in nuclear facilities for more than two decades at the time.

In the relevant Rules, there were seventeen different courses defined, and for each course, additional training for a responsible person for radiation protection was defined as a short addition dedicated mostly to familiarisation with legislation. Requirements for training of staff members of radiation protection units in nuclear facilities were also defined. Authorised radiation protection experts in authorised institutions should perform training for all these groups.

Last year new Rules were approved (still based on Act from 2002!) that changed the system of radiation protection training considerably. The number of different courses has been reduced, the required length of training was reduced for most workers except those in nuclear facilities and industrial radiography, and the requirement for additional training of persons responsible for radiation protection has been cancelled. While most of these changes could be justified, or supported with some arguments, it is our opinion that the last one will reduce radiation safety in Slovenia.

Recently (in December 2017), new Ionising Radiation Protection and Nuclear Safety Act based on the new Council Directive 2013/59/EURATOM was approved in Slovenia. Consequently, all second-level legislation must be updated in the near future. While some Decrees and Rules updated and approved in last two years are in many details already compatible with the new Directive, we think that Rules related to radiation protection training are not and should be updated significantly to ensure a higher level of radiation protection. In our contribution, we will compare Directive and the new Act with the current system of radiation protection training to identify and reveal problems and weaknesses that should be solved in the updated Rules.

Subject: Education

Sustaining radiological protection inspection capability through graduate and nuclear associate training and development

Laura Macintosh

There are a number of nuclear industry graduate schemes around the UK which offer structured training and experience to help graduates on their way to becoming Radiological Protection (RP) professionals. This includes company specific RP schemes and the 'nuclear graduates' scheme which recruits graduates into a wide range of disciplines, including RP; each graduate having a dedicated sponsor organisation from the nuclear industry.

To help meet increasing regulatory demand and demographic challenges, the Office for Nuclear Regulation (ONR) has chosen to 'grow its own' through graduate and nuclear associate recruitment. ONR has been a sponsor of the nuclear graduates scheme since 2014 and supports graduates through the two year programme to develop personally and professionally, working towards a relevant chartered status and to develop the skills required to succeed within ONR. Whilst on the scheme graduates undertake secondments in the nuclear industry to gain practical experience and develop technical knowledge as well as completing technical and behavioural training. ONR's nuclear associate role is for those who have completed the graduate scheme or for those joining ONR with some experience in their relevant discipline. For staff at all levels, ONR offers a comprehensive training and development programme focussed on providing new recruits with the knowledge, skills, and attitudes they will need to undertake their roles in a nuclear regulatory capacity.

ONR began recruiting nuclear associates in 2013 and graduates in 2014 from a range of disciplines. Six of these new recruits have joined the RP and Criticality specialism in ONR and are following tailored programmes of training and experience to become specialist inspectors. This will ensure ONR continues to have suitable resource to ensure that workers and members of the public are adequately protected from ionising radiation arising on nuclear licensed sites.

ONR also recognises the importance of engaging with young people through Science, Technology, Engineering and Maths (STEM) activities and actively supports staff who wish to volunteer whether this is through ONR or by supporting professional bodies such as the Society for Radiological Protection (SRP). STEM activity is also an integral element of the nuclear graduates programme. RP professionals in ONR have engaged with schools and universities through career talks and by providing practical support, playing a vital role in inspiring future generations of scientists and engineers who may choose to follow a career in Radiological Protection.

Subject: Education

Development of Radiation Research Capacity in Ireland

Lorraine Currivan

Ireland's Environmental Protection Agency, EPA, is the national competent authority for the protection of workers, members of the public and the environment against the hazards associate with ionising radiation and has a role in maintaining, growing and building national capacity in radiation science. Evidence indicates that the current capacity nationally in terms of the availability of skilled radiation scientists is insufficient to meet future staffing requirements for EPA in this field. It is acknowledged that a programme to build radiation research in Ireland is a strategic priority for the EPA in its 2016 – 2020 Strategic Plan under the heading "Implement the EPA Research Strategy and leverage national co-funding and EU funding opportunities to help build environmental and radiological protection research capacity in Ireland and improve the dissemination of research outputs". This paper presents the vision, approach and successes towards reinvigoration of radiation research in Ireland to attract the next generation into this field of science and to achieve the following objectives :

• To stimulate the Irish radiation research community so as to develop national radiation research capacity

• To support high standards and broad horizons in radiation research by facilitating engagement with national and international research groups.

• To address knowledge gaps on radiation matters relevant in Ireland and internationally and aligned with the EPA Corporate Strategy.

• To build expertise and facilitate knowledge sharing by engaging with a network of stakeholders.

• To inform EPA and national policy by addressing the knowledge needs of governmental and non-governmental stakeholders, both nationally and internationally and providing evidence based solutions with an emphasis on continually improving nuclear safety and radiation protection

Subject: Education

The Status of Radiation Safety (RS) Culture within the Higher Education, Research and Teaching (HERT) Sectors in the UK: An Initial Assessment.

Jim Hunter

OBJECTIVE: To attempt to assess the state of radiation safety (RS) culture within the Higher Education, Research and Teaching (HERT) sectors in the UK with a view to informing the development of strategies and tools to improve RS culture in these sectors.

METHODS: The UK Working Group (WG) for RS Culture in HERT Sectors developed an on-line survey, using a questionnaire consisting of 35 questions organized into 6 sections – participant roles, training, incidents, personal dosimetry, personal protection, and general awareness. The questionnaire response was anonymous. The link to the questionnaire was disseminated via (a) websites of SRP and AURPO, (b) announcements at conferences/meetings, and (c) word of mouth and e-mail.

RESULTS: So far the survey results have revealed a number of noteworthy insights including:

1. 54% of students and 41% of academics/researchers felt that they were not involved in the planning of changes to RS procedures that affected them and 17% of participants overall said they did not receive RS updates from line managers. This is indicative of poor communication between management, RS professionals and workers. Better methods for involving all stakeholders in RS decisions must be developed.

2. 24% of participants felt that RS was not considered to be as important as other objectives such as teaching and research in their organisations. This may suggest inadequate RS training, lack of resources for RS, or poor awareness of RS importance in management.

3. Over 11% students felt that their RS training was inadequate to enable them to work safely, and 5% did not know who to contact in the event of a radiation incident. This suggests that every university course that involves some radiation work should include an obligatory session on RS. 21% of students received their initial RS training via an on-line training package, suggesting that any improved training methods may benefit from being more practical in nature, e.g. rehearsals of contingency plans. Nevertheless, e-training will be useful for regular refresher training especially where there are no alternatives, or training resources are limited.

INTERIM CONCLUSIONS: Results so far strongly suggest that communication and training are key areas to focus on when aspiring to improve RS culture in these sectors.

Subject: Education

The European Radon Association (ERA)

Jose Luis Gutierrez Villanueva

The European Radon Association (ERA) was established in May 2013 at the ROOMS conference held in Bouillion (Belgium). The aim was to bring together radon professionals from different sectors: scientists from academia, experts from commercial companies, public health, national authorities, policy makers, etc.

The interest in radon issues and ERA has increased during the period of implementation of the EURATOM BSS directive in the EU member states. But ERA is also cooperating with organizations like IAEA. ERA is also working together with the radon associations in US and Canada through a network called COIRA.

There are 20 private companies working on the radon field supporting ERA and more than 100 individuals are active ERA members. The association has hosted five workshops over the last years dealing with different aspects on radon matters: public health approach, risk communication, legislation, etc. In addition to that, ERA has organised radon training courses.

This presentation will show the main objectives and a summary of the activities of ERA up-to-date and the importance of an organization like ERA as a way to share knowledge and experience and improve best practice and quality.

Subject: Education

Education and training in radiation protection: results of the ENETRAP III project

Michèle Coeck

For a vast amount of nuclear applications in industry, healthcare, research and other sec-tors, a good understanding of radiation protection (RP) is fundamental in order to protect workers, the public and the environment from the potential risks of ionizing radiation. Effective education and training (E&T) is a critical element helping to prevent the decline in expertise and to meet future demands for RP competences.

The 7FP ENETRAP III project added new and innovative topics to existing E&T approaches in RP. It further developed the European reference training scheme with additional spe-cialized modules for Radiation Protection Experts working in medical, geological disposal and NPP.

In addition, ENETRAP III also introduced a unique train-the-trainer strategy, with modules available in French and English.

All pilot sessions were open to young and more experienced students and professionals.

A web-based platform containing all relevant information about E&T in RP facilitates an efficient knowledge transfer and capacity building in Europe and beyond. A database is available to connect all training events and other opportunities, and can be linked to other E&T databases, increasing efficiency of searches for the end user.

ENETRAP III also produced a guidance document for implementing E&T for Radiation Pro-tection Experts and Officers, hereby providing extremely important assistance to all Member States who were expected to transpose the Euratom BSS requirements into their national legislations.

Moreover, ENETRAP III will demonstrate the practical feasibility of earlier developed con-cepts for mutual recognition and thus provide leading examples in Europe demonstrating effective borderless mobility.

For all these activities ENETRAP III strongly connected with all stakeholders, i.e. end-users, E&T providers, legal authorities, and to other relevant international organizations, groups and networks dealing with E&T in radiation protection.

This presentation will highlight the achievements and discuss the future actions to be taken beyond the project duration.

Subject: Education

Implementation of the radiation protection expert and radiation protection officer from the European basic safety standards in the Netherlands

Barbara Godthelp

In the European basic safety standards a clear distinction has been made between the different roles and responsibilities of experts and services involved in radiation protection. The radiation protection expert (RPE) and the radiation protection officer (RPO) have been introduced in the European basic safety standards for this purpose. A comparison of the roles and responsibilities of the radiation protection expert and radiation protection officer laid down in the basic safety standards with those laid down in the Dutch Radiation Protection Decree for the Dutch experts revealed that they (partially) overlap.

In the Dutch legislation, three types of experts were recognized: the “general coordinating expert”, the “coordinating expert” and the “supervisory expert”. The Dutch coordinating expert was highly comparable with the radiation protection expert from the basic safety standards. The general coordinating expert had additional tasks. In the new Dutch Decree basic safety standards radiation protection that will be in force the 6th of February 2018 the term RPE has been implemented literally, whereas the RPO has been implemented in the new Decree basic safety standards radiation protection as supervisory employee radiation protection. The learning outcomes and registration requirements for the RPE are similar to those already in force for the (general) coordinating expert and are laid down in the new Dutch legislation.

The Dutch supervisory expert is partially comparable with the radiation protection officer from the basic safety standards. However, the technical competence relevant for a given type of practice that is demanded in the basic safety standards for the radiation protection expert as well as the radiation protection officer is lacking. To comply herewith, the Dutch system of radiation protection had to be modified. Therefore, the branches in collaboration with the teaching institutes have drafted learning outcomes for the new application specific training for the supervisory employee radiation protection. This is done for nine specific applications namely: 1) medical applications, 2) dentistry, 3) veterinary applications, 4) nuclear fuel cycles, 5) open sources, 6) naturally occurring radioactive materials, 7) accelerators, 8) industrial radiography (including non-destructive testing and exploration research) and 9) gauging techniques. These approved learning outcomes for the nine application-specific courses for the supervisory employee radiation protection have been incorporated in the new ministerial rule basic safety standards radiation protection.

Subject: Education

Learning outcomes for the RPO responsible for Dispersible Radioactive Material.

Andre Zandvoort

In 2015, the Authority for Nuclear Safety and Radiation Protection (ANVS) requested stakeholders to revise the training system for Radiation Protection Officers in The Netherlands. The core of these revisions which derive from the European Basic Safety Standards (EU-BSS) is that the training for Radiation Protection Officers should be application specific. The University of Groningen chaired a workgroup whose task was to formulate the qualification descriptors for the training of Radiation Protection Officers of Dispersible Radioactive Material (RPO-DRM).

The workgroup formulated a gradual approach, demanding three different levels of RPO-DRM, the required knowledge and competences increasing as the risk of the application increases. For pragmatic reasons it was proposed to hold to the limits of the former Dutch Guideline for Radionuclide Laboratories (laboratory on B, C or D level), which in any case adheres to the gradual approach for regular applications. The three proposed levels were: RPO-DRM B for radionuclide laboratories at B-level, RPO-DRM C for radionuclide laboratories at C-level, and RPO-DRM D for radionuclide laboratories at D level.

Because the required level of knowledge of the RPE is comparable with the level of knowledge needed for the responsibility for a laboratory on level B it was suggested that the RPE training is adequate for the RPO-DRM B and no separate training is needed. Complying with the decreasing risk level, the learning outcomes for RPO-DRM C and D are simplified learning outcomes of RPO-DRM B. The RPO-DRM D learning outcomes are compatible with the former Dutch `level 5B` training, apart from the supervising tasks.

The workgroup recommends using the course for RPO-DRM D as training for the workers in radionuclide laboratories as used to be the case with the former 5B course. Using a well-defined set of learning outcomes like the RPO-DRM D learning outcomes for the instruction of workers prevents uncertainties in the level of knowledge when moving from one institute to another. Besides the gradual level of knowledge, the workgroup also strongly suggested that the RPO-DRM can supervise encapsulated radioactive sources for e.g. calibration purposes.

In this contribution the process of establishing learning outcomes for RPO-DRM in The Netherlands will be discussed along with the main results.

Subject: Education

Learning outcomes for E&T programs for RPOs responsible for open radioactive sources – A German-Dutch comparison

Jan-Willem Vahlbruch

Building on earlier work the Universities of Hannover and Groningen collaborated in comparing the new Dutch learning outcomes with the current and possible future German requirements for RPOs for open radioactive sources. This bilateral project aimed at providing advice to the Dutch Authority for Nuclear Security and Radiation Protection (ANVS) and the German Bundesamt für Strahlenschutz (BfS) to formulate the final learning outcomes for or harmonizing E&T programs for these RPOs. Furthermore – as the lowest level of these programs will also be suitable for radiation workers (RWs) – the project also aimed at facilitating employers in both countries in mutually recognizing the instruction programs for RWs.

The results of the German-Dutch comparison show that the learning outcomes differ primarily with respect to the national legislation. The analysis clarifies especially the impact of German legislation references and explains the thematic equalization of the German-Dutch subjects. Significant expertise discrepancies occur e.g. for the various waste management systems for radioactive material. Furthermore, the comparison of keywords identifies missing topics. All relevant expertise discrepancies are summarized by an additional training advice.

Subject: Education

Radiation in medicine: application for android devices

Cristian Candela

PURPOSE

The purpose of this application is to familiarize users with the effects of ionizing radiation used in diagnostic imaging, both in radiology and nuclear medicine. Although dose reference levels (DRLs) can be found in official national and international documents, usually patients do not know their existence or how to get to them. The most relevant and updated information has been summarized for adults, children and pregnant women. It is included a summary about the magnitudes and units used in radiological protection, as well as the dose limits for exposed workers and members of public.

MATERIALS/METHODS

The application has been developed for Android devices, from Jelly Bean versions (Android 4.1) to the most recent. Java and Android Studio are the language and the integrated development environment (IDE) used. The documents used to collect the information are the Spanish DOPOES and DOMNES projects, the 2011 version of Spanish Protocol for Quality Control of Radiodiagnosis, the document “Recommended procedures for energy X-ray dosimetry between 20 and 150 keV in radiodiagnosis” of the Spanish Society of Medical Physics (SEFM), and documents 52, 80, 84, 103 and 106 of the International Commission on Radiological Protection (ICRP).

RESULTS

There are different sections in the main menu of the application: “Images”, “X-Ray”, “Nuclear Medicine”, “Pregnant women”, “Natural Radiation”, “Personal History”, “References” and “More information”. In “Images” section we have include original drawings used to explain some of the procedures realized in diagnostic imaging. In “X-Ray” section there are four subsections, for adults, children, CT and other procedures, where it is indicated the average effective dose received in each test. The “Nuclear Medicine” section has been divided according to the different organs involved in each process. The “Pregnant Women” section is a summary of the document 84 of the ICRP. The map of the “Natural Radiation” section shows information of the Spanish Dosimetry National Center (CND), which displays the distribution of the environmental radiation in µSv / month. In "More information" we have added a brief explanation of the magnitudes and units used in Radiological Protection.

CONCLUSIONS

We have developed a simple and intuitive application for Android devices, in which the most relevant and updated information on Radiological Protection can be found based on the Spanish Legislation, the national projects DOMNES and DOPOES and the most recent documents of the ICRP related with radiological protection in pediatric radiology, radiopharmacy and pregnancy.

Subject: Education

Intervention by Intervision: Radiation Safety Culture in The Netherlands

Bert Metz

Following the initiative by IRPA to promote and improve Radiation Safety Culture worldwide, the Dutch Society for Radiation protection (NVS), in collaboration with the Nuclear Research and Consultancy Group in Petten (NRG), has started a project to investigate the possibilities to stimulate Radiation Safety Culture in The Netherlands.

In parallel to the more traditional way of disseminating information on safety culture, by means of lectures and courses, an alternative way of directly engaging radiation protection experts was investigated. As a means to achieve this goal the applicability of the method of intervision was proposed, where intervision stands for a learning method for a group of equals guided by a process supervisor, focusing either on improving personal functioning or on improving working processes.

This active method of exchanging information seemed well-suited to improve radiation safety culture, and fulfils a number of possibilities that IRPA mentions in its “Guiding Principles for establishing a Radiation Protection Culture”:

1. Modelling, reinforcing and coaching safety behaviours;

2. Creating positive and total awareness about Radiation Protection at working places;

3. Establishing adequate and proper communication processes among all the practitioners involved.

For an intervision training to be successful, IAEA in its Safety Report ‘Performing Safety Culture Self assessments’ recommends that participants should feel free to speak about problematic work situations.

4. Therefore, a psychologically safe environment, a so-called ‘shared space’ should be created.

To test the possibilities that intervision sessions may provide, two successive pilot workshops were organized in collaboration with trainers from De Federatie in Amsterdam. The pilot workshops were attended by 10 radiation experts from different organisations in The Netherlands.

The first workshop started with an introduction about Radiation Safety Culture and was followed by parallel sessions where participants in groups could practice communication techniques and discuss safety behaviour. Following the workshops, the participants were asked to apply and experience the new communication skills in their own organization. During the second workshop, they presented their experiences, and additional training was given, based on their requests.

From the initial feedback we carefully conclude that intervision is useful tool, in particular to learn from safety related events in other organizations and also for the improvement of personal communication skills.

In relation to the IRPA and IAEA recommendations mentioned above, we conclude that each of these can be fulfilled to some degree by the method of intervision.

Measurements

Subject: Measurements

Smartphones as Dosimeters

Hendrik Erenstein

Introduction: Because of the inherent dangers of ionising radiation it is important for professionals to keep the doses to a minimum. Real-time dosimetry has been proven to be a valuable instrument in encouraging radiation awareness to reduce personal radiation dose. The equipment used for this is however rather expensive and therefore not readily accessible. Smartphones running dedicated detection apps could lead to a breakthrough as these are widespread available and cheap. However at this moment very little is known regarding the reliability and accuracy of smartphones as dosimeters.

Methods: A total of five smartphones was tested against Philips Dose Aware and against a Raysafe X2 in combination with the R/F detector which functioned as a gold standard. These tests were performed for multiple energies, distances and angles in order to ascertain a good overall view of smartphones as real-time dosimeters for measuring radiation dose and dose rates. In addition to the initial measurements calibrated measurements were performed to assess the effect of calibrations on the reliability and accuracy of smartphones as real-time dosimeters.

Results: The percentage deviation from the gold standard varies from 45 % to over 500 % for the uncalibrated data. However, after calibration the percentage deviation was reduced to 0,38 % to 53 % for the measurements. Under optimized conditions the majority results in a percentage deviation which is well within the internationally accepted 30 % accuracy. Two apps used showed no significant difference from the gold standard in 33 % and 56 % of all cases. The relative standard deviation ranged between 1,56 % and 4,98 %, also well within the accepted limit of 30 %. The overall dose rate correlation seems to be linear in comparison to the gold standard. While the energy sensitivity has more deviation for the LG G2, LG G3 and Samsung Galaxy S4. Directional sensitivity however shows similar results for all smartphones with a clear distinction for Philips Dose Aware.

Conclusion: It is possible to use smartphones as real-time dosimeters with only minor reliability and accuracy deviations. However, it is important to keep in mind limitations such as the need for calibration and the large directional sensitivity as misuse could lead to unnecessary worries or a false sense of security.

Subject: Measurements

Factors Influencing the Accuracy of Gamma Spectrometry in Paid Service Measurements vs. Scientific Measurements

Martin Heule

Gamma spectrometry is the favourite analysis technique to quickly measure a wide range of radionuclides with only minimal sample preparation. However, when it comes to accurately quantifying results, a variety of contributions of measurement uncertainties have to be considered.

The contribution will provide an assessment of quantification quality and calibration approaches for practical measurements when providing gamma spectrometry as a paid service versus the scientific application of gamma spectrometry.

The factors to be considered are a combination of instrument-based properties and of course properties of different types of samples.

On the instruments side, solid-state detectors fundamentally need high quality efficiency curves. These are unfortunately not independent of the sample, since they also are highly dependent on the size and shape of the samples, i.e. the geometry.

On the sample side, there may in addition be a wide range of activities leading e.g. to increasing detector dead times, nuclide combinations with overlapping lines in the gamma spectrum or self absorption within a real-life sample may play a substantial role.

In applied cases, additional boundary conditions due to commercial considerations like sample processing capacities and throughput times have to be considered.

In literature, one of the above-mentioned factors is usually characterised individually while all other conditions are kept at a perfectly constant level. Practical experience shows, however, that one often has to deal with several factors at once influencing a sample measurement.

Also, a synopsis of several recent interlaboratory studies in which the radioanalytics laboratory at PSI participated will be used to gain insight into the level of quantification accuracy that can be expected from a wider number of analysis laboratories.

More time has to be allowed for measurements with more stringent scientific requirements. For these cases of use, characteristics of traceability chains derived from standard materials, sample and geometry variations and the use of mathematical compensation methods for geometry compensation will be discussed in light of every day’s use and best practices will be identified.

Subject: Measurements

A Rapid, Robust and Sensitive Detector for the Quantification of Fast Pulsed Ionizing Radiation at CERN

Hamza Boukabache

CERN designs and operates a wide number of accelerators to probe the matter and to understand the fundamental laws of the universe. These activities may generate stray radiation in localized zones due to the interaction of high energy particles with stable matter. Accurately measuring these mixed radiations behind shielding requires very specific instruments capable to react to various particles (neutrons, pions, muons, electrons, photons, protons …) through wide energies and with different time-based dynamic. This paper gives a general description of the newly designed Cern Radiation Monitoring Electronic (CROME) system. Conceived and manufactured for radiation protection, CROME is a novel solution for radiation assessment capable of measuring very low dose rates down to the background noise, whilst being able to measure radiation over an extensive range of 9 decades without any auto scaling.

This paper further concentrates on the analytical calculation of the CROME' front-end response and the mathematical model used to estimate the ambient dose equivalent. In that respect, it addresses on the one hand, the electro-physical phenomenon used to measure mixed ionizing field and on the other hand, it describes the calculated transfer function used to quantify pulsed ionizing radiations.

Finally, we demonstrate the measurement capabilities of the system to both semi-static and dynamic stimulus. The experimental responses of CROME detector to various radiation fields acquired under controlled conditions are then correlated to the theoretical results.

Subject: Measurements

Rapid method for low level Sr-90 determination in seawater

Suputtra Visetpotjanakit

Determination of low level Sr-90 in seawater has been widely developed for purpose of environmental monitoring and radiological research since Sr-90 is one of the most hazardous radionuclides released from atmospheric nuclear weapon testing, nuclear waste discharge and nuclear accident. Liquid extraction technique using bis-2-etylhexyl-phosphoric acid to separate and purify Y-90 and Cherenkov counting using liquid scintillation counter to determine Y-90 in secular equilibrium to Sr-90 were developed to monitor Sr-90 in our Asia Pacific ocean. The analytical performance was validated for the accuracy, precision and trueness criteria. Sr-90 determination in seawater using various low concentrations in a range of 0.01 – 1 Bq/L of 30 liter spiked seawater samples and 0.5 liter IAEA-RML-2015-01 proficiency test sample were performed for statistical evaluation. The results had relative bias in range from 3.41% to 12.28%, below accepted relative bias of 25% and passed the criteria which could confirm our analytical performance of low level Sr-90 determination in seawater. Moreover the approach is economical, non-laborious and fast to analyse Sr-90 in seawater.

Subject: Measurements

Calibration Procedure for Clearance Measurements of Bulk Material with Dedicated Traceable Sources

Malgorzata Kasprzak

The calibration of a clearance box measurement system using directly the bulk material to be free released was found in the past to be more precise compared to the calibration with multipurpose phantoms. In the common calibration procedures issues arise from geometry differences and an inhomogeneous activity distribution. Consequently, we developed a procedure to calibrate a clearance box monitor by using real cleared materials (gravel and concrete) and adding dedicated Co-60 sources.

As the radioactive calibration sources are mixed with the bulk material, harsh mechanical treatment of the sources cannot be excluded. Therefore, the calibration sources needed adequate robustness as well as accurate metrological characterization. 10 µg of a Co-60 solution traceable to international standards were injected into the centre of a nylon sphere with a diameter of 9 mm. The nylon sphere was then sealed into a 20 mm diameter stainless steel (SS304L) sphere with a wall thickness of 5.5 mm. The spheres were sealed using a matching custom made threaded plug.

Due to the wall thickness of the heavy-duty sources, attenuation in the source material had to be taken into account to provide a reference activity value to use for the calibration of the clearance box monitor. The attenuation was determined experimentally using high resolution gamma-spectrometry and validated numerically with Monte-Carlo calculations.

Using the attenuation corrected apparent activity, 30 of these heavy-duty sources were used to successfully calibrate a RADOS RTM644lnc clearance box monitor for 300 kg of gravel and 700 kg of concrete debris. Due to unique properties of the Co-60 sources we were able to obtain uniform distribution of radioactivity in the material resulting in the increased accuracy of calibration. The natural activity of the cleared material was taken into account and the calibration factors were derived for the geometry corresponding exactly to the geometry of the measurements significantly improving the precision of the clearance procedure. In this contribution we will present the details of the Co-60 sources' preparation and explain the calibration technique.

Subject: Measurements

Investigation of Bayesian Statistical Techniques at the Decision Threshold

John Brogan

Statistical analysis of a radiation measurement traditionally relies upon the use of the frequentist (Classical) statistical test. In the case of radiation measurements, a statistical analysis is carried out on the assumption that the calculated background distribution comprised of a series of measurements is accurately representative of the true background distribution. Use of the frequentist statistical test for radiation detection and measurement arises from the necessity to separate signal from background. ISO 11929 defined the decision threshold, y^*, which is considered an investigatory level and does not provide any information regarding detection capabilities; the detection decision is purely based on this value. However, problems arise when applying traditional decision rules to very low count rate data due to the assumption that the experimenter has an extremely accurate estimate of the mean and standard deviation of the background. Accounting for the uncertainty in background fluctuations while simultaneously improving the decision threshold is a considerable undertaking in frequentist statistics. Bayesian data analysis could supply the tools to approach this problem. The study presented investigates applications of Bayesian data analyses to the decision threshold. The posterior distribution of a Bayesian model contains all available information and uncertainty about the true value of a parameter of interest. The challenge lies in developing a model such that decisions can be made on sample measurements similar to frequentist decision theory. The model is tested on measurements taken in controlled settings in a laboratory using both static and variable background. Ultimately, a successful decision threshold developed through Bayesian data analysis will be easy to implement and improve true detection rates under lower false positive rates when compared to the traditional statistical tests used for radiation detection.

Subject: Measurements

Utilizing Data Patterns in String Measurements to Enhance Radiological Detection Capabilities

Alexander Brandl

The detection of a signal embedded in background in counting experiments customarily utilizes a fixed decision threshold determined from previous measurements of background data to distinguish signal from background events. Standardized methods to calculate this decision threshold assume that the distribution of the background data follows a normal distribution, which can be characterized by the mean and the standard deviation of the data. For the analysis of data at low signal-to-background ratios, the assumption of a normal background distribution may not always be valid. The approach to calculating the decision threshold has been generalized and the statistics of string measurements have been evaluated. Binomial statistics can be utilized to describe data patterns in string measurements which frequently occur in a variety of operational radiation protection applications, such as continuous laboratory or environmental contamination surveys or in the search for orphan sources. The analysis of those data patterns allows for the identification and detection of a signal at a lower signal-to-background ratio, resulting in higher detector sensitivity or, conversely, in a lower false positive detection rate. Results are presented for data pattern analyses of gross count / count rate instruments as well as of spectroscopic measurements. Enhancements in radiological detection capabilities for these instruments have been observed in laboratory measurements for string measurement gross count data and sequential spectroscopic data. The binomial statistics approach has also been tested in low-fidelity spectral data analysis and provided similarly enhanced detection capabilities. Statistical algorithms have been developed which utilize the analysis of patterns in the data strings to enhance the test statistic for the decision on the absence or presence of a radiological source. Null hypothesis test performance and source detection efficacy have been shown to improve compared to the traditional method of achieving a detection decision by the comparison of a measured value to a fixed decision threshold.

Subject: Measurements

Monte Carlo Simulations and Experiments to Detect Radioactive Sources in Steel Scrap

Tobias Hein

“Orphan” radioactive sources in steel scrap represent a topic of continuous concern. They endanger workers and may contaminate steel products. Initial PENELOPE Monte Carlo simulations by the German Federal Office for Radiation Protection (BfS) were aimed at identifying ways to better detect radioactive sources in scrap and to estimate possible detection thresholds. Based on this work, the BfS has commissioned Brenk Systemplanung GmbH (Brenk) to compile a report on radiation incidents involving orphan sources in the scrap metal economic cycle. This investigation is part of the German effort to implement the Council Directive 2013/59/EURATOM and carried out by BfS and Brenk on behalf of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, BMUB).

The emphasis of this study is to determine the current detection limits for Co-60, Cs-137 and Am-241 sources in scrap metal as well as identify possibilities to improve the detection. In order to assess the current situation in Germany, a survey was carried out to determine typical measurement technology of the involved companies. This survey also identified the typical geometry and loading of a scrap container for the German market.

Based on the final results of the survey, a realistic model of a scrap container filled with approx. 2000 metal brackets was established. Monte Carlo simulations based on the MCNP6 software package were performed on this model to determine the detection limits for typical and widely used detection devices under standard conditions. Thus, the photon fluxes of Co 60, Cs 137 and Am-241 sources and also the neutron fluxes of different neutron sources were simulated outside the container for different source positions inside the scrap container. The results of these theoretical investigations were compared to those of the homogeneous density approximation and confirmed by experiments under realistic conditions.

Medical

Subject: Medical

Influence of lead aprons in the response of personal dosimeters worn by medical staff in fluoroscopy guided procedures

Cristian Candela-Juan

Fluoroscopy guided interventional procedures provide remarkable benefits to patients. In these, the medical staff working near the scattered radiation field has to wear shielding devices such as lead aprons and be monitored with personal dosimeters. In particular, it is an acceptable practice to derive eye lens doses from a dosimeter placed above the apron or collar. Nevertheless, the backscattered radiation for a dosimeter worn above a lead shield differs from that generated during calibration with a water slab phantom. The aim of this study is to evaluate which correction factors should be applied to the dose calculation algorithm when a passive personal thermoluminescent dosimeter (TLD) is worn over a lead shield.

The dosimeter characterized is based on a card with four TLD-100 detectors, sandwiched in between the following filters: copper, aluminium, plastic and air (Figure 1). The photon energy is estimated from the readings of the four detectors and a calibration factor is applied to obtain Hp(10) and Hp(0.07), taking into account their energy dependency and filter attenuation. The Monte Carlo code PENELOPE was used to simulate the dosimeter. After its validation, the simulated dosimeter was irradiated with a realistic photon beam scattered by a patient from an interventional radiology procedure. This was used with different setups, which consider different lead thicknesses and incident beam angles.

As a result, when the dosimeter is intended to be used above an apron, the reading below the copper filter must not be considered because its angular dependency is too steep. On the other hand, the readings of the other three detectors remain almost independent of the incident beam angle, but require a correction factor of 0.75 due to the lack of backscattering. The modified dose calibration algorithm was applied to 30 dosimeters that had been worn above aprons in interventional radiology departments. The comparison is overwhelmingly in favour of the new algorithm, with improved energy estimation for all dosimeters and the median standard deviation between the three doses (after attenuation correction) being reduced from 12.4% (previous algorithm) to 4.3% (modified algorithm).

In conclusion, personal dosimeters that are not shielded from backscatter radiation may require a specific characterization if they are going to be worn over a lead apron. The backscatter effect may result in a systematic error, leading to an underestimation of doses to unprotected soft tissues such as the eye lenses.

Subject: Medical

Implementation of regulation for quality control of medical uses of ionizing radiation in Korea

Sang Hyun Park

Medical exposures have been dominant part of individuals' exposure against ionizing radiation. Among the medical uses of radiation, radiotherapy and nuclear medicine deliver relatively higher exposure to patients, whole body or target organs (or tissues) as well. Therefore, for these procedures, quality control (QC) has been very essential part in view of radiation safety. In this study, regulatory practices and approaches for QC of radiotherapy and nuclear medicine procedures were introduced.

The regulation of QC required licensee to maintain the exposure dose or administered activity as prescribed by medical doctors. For radiotherapy, there were more specific provisions, for example securing qualified expert for QC of radiotherapy machines, establishment of comprehensive QC program and independent external audit. According to reported data, total number of designated experts were 232 persons from 91 medical centers by July 2017. Items, methods and acceptance criteria for QC program of each type of radiotherapy machine were described in a technical standard issued by the Nuclear Safety and Security Commission (NSSC) to support the regulation. Since 2015, on-site external audit has been conducted for 22 medical centers and confirmed that most of centers have maintained their machines within tolerances. For a long-term perspective, postal audit has been started from 2017. Postal audit were designed to verify output and check mechanical isocenter of radiotherapy machines using glass dosimeter and film.

In nuclear medicine practices, the accurate assay of activity of radiopharmaceuticals prior to administration is important process to assure that patients receive the correct prescribed dose. Dose calibrators (or radionuclide activity calibrators) have been used as the principal instruments to assay activity before administration. In 2017, the Korea Institute of Nuclear Safety (KINS) surveyed status of usage and QC of dose calibrators to design appropriate regulatory approach. Totally 211 licensees (with 336 dose calibrators) participated in the survey voluntarily. According to the survey, only 46 licensees has conducted regular basis QC and 52 licensees secured calibration sources. KINS, through periodic inspection, will guide licensees to conduct minimum performance check, such as daily basis constancy and response check using solid type check source. Also research and development programs have been started to provide calibration sources and technical supports to field instrument users.

Subject: Medical

Using Receiver Operating Characteristics and Nomograms for Justifiying Medical Imaging and Communicating Benefits and Risks to Patients.

Jim Thurston

All diagnostic tests including medical imaging can be characterised by their Sensitivity - the number of True Positives detected relative to the number of False Negatives, and their Specificity - the number of True Negatives relative to False Positives. Such analysis was first described in the early 1950s when these sensitivity and specificity rates were plotted as "Receiver Operating Characteristics" curves for considering the effectiveness of radar systems in detecting enemy aircraft / missiles. It was subsequently applied to medical imaging, and further developed in the 1970s when the use of Nomograms was first suggested. However, during the decades since then, the use of ROC and Nomogram analysis has fallen out of favour.

This paper will present worked examples on revisiting ROC curves and Nomograms to analyse modern diagnostic medical imaging, to consider whether it can be used to predict the effect on a population undergoing such imaging in terms of the impact on prognosis (mortality and morbidity) versus a non-imaged population. It will discuss how such an approach could thus be used to determine the overall benefit of such imaging to be directly compared to the risks, including from the radiation exposure, for the purpose of Justifying the exposure. Finally, the presentation will consider how these same measures of benefit and risk can then be communicated to the patients in getting informed consent.

Subject: Medical

Eye lens dosimetry for interventional procedures in cardiology

Grażyna Krajewska

The eye lens is one of the most sensitive organs for radiation injury and exposure might lead to radiation induced cataract. Recently, the International Commission on Radiological Protection (ICRP) recommended a reduction in the annual dose limit for occupational exposure for the lens of the eye from 150 to 20 mSv, averaged over a period of 5 years, with the dose in a single year not exceeding 50 mSv. These recommendations are introduced in the European directive 2013/59 (EURATOM,2013).

This prospective study investigated eye lens dosimetry in two medical institutions in Warsaw (Hemodynamics Laboratory and Center for Cardiac Catheterization and Angiography) during a routine year of professional activity. The radiation exposure measured in a normal working schedule of a intervention radiologists during 3 months and this cumulative eye lens dose was extrapolated to 1 year. Body and skin dose measurements were also performed, estimating Hp (10) and Hp (0.07) values.

The eye lens doses were measured in terms of the dose equivalent H p(3) with the eye dosimeter with thermoluminescent detectors, close to the left eye (placed on the temple). The estimated annual eye lens doses for 50 radiologists , range from a minimum of 0.1 mSv to a maximum of 3.0 mSv with an average dose of 1.0 mSv

This study demonstrated that the estimated annual eye lens dose is well below the revised ICRP's limit of 20 mSv/year. However, we demonstrated high maximum and average doses during invasive cardiovascular diagnostic tests and therapeutic treatments in the field of cardiology and interventional radiology procedures. The interventional radiology causes the radiation risk exposure of eye lens doses have been registered both in persons directly performing treatments and the accompanying persons too.

There is probably the correlation between doses on the skin (measured by the ring termoluminescent dosimeter) and doses on the eye lenses of the staff (numerical numbers not captured due to too few results), but further research is required.

With radiation induced cataract being explained as a possible stochastic effect, without a threshold dose, radiologists and anesthesiologists who regularly work in a radiological environment should remain care and vigilant. This persons should also maintain radiation safety standards at all times, which includes adequately protective equipment, keeping distance, routine monitoring and periodic training in occupational safety.

Subject: Medical

State of Digital Radiography Reject Analysis in Dutch Hospitals

Ischa de Waard-Schalkx

In the past decades Dutch radiology departments have shifted from conventional to digital radiography. In digital imaging, it is easier to remake an image and delete the previous ones. This means that there are more but more complex options for quality assurance for the diagnostic images. From a radiation protection perspective every additional image carries a radiation risk for the patient and should be avoided when possible.

In the time of conventional imaging films that could not be used for diagnostic purposes (and were rejected) were collected in a special blue trashcan. When full, the rejected films were analyzed and recommendations for improvements in imaging were made to avoid the same mistakes in the future. A similar analysis of digital images is more complex and there are indications that these analyses hardly take place anymore even though several software tools have become available to perform these. The Dutch Healthcare Inspectorate therefore asked the National Institute for Public Health and the Environment (RIVM) to investigate the current state of reject analyses in digital imaging. For carrying out this assignment RIVM contacted Inholland University (InhU)of Applied Sciences. Radiography students from InhU were involved to collect data during their internships in several Dutch hospitals.

To investigate the current state of the art a literature study was conducted and a questionnaire was set up. Questions included the frequency of reject analyses, the procedures and the software tools used, the amount of rejected images and the registration of these. The questionnaire was used for guidance during interviews with quality managers at radiology departments in 20 Dutch hospitals. Radiography students from InhU collected approximately half the questionnaires as a part of their internships at radiology departments. The other half was gathered by RIVM researchers to have a balanced selection of departments throughout the Netherlands.

Taken together the 20 interviews with radiology departments throughout the Netherlands constitute a significant sample from the approximately 80 hospital conglomerates in the country. Preliminary results indicate that few radiology departments still carry out reject analyses. Software tools that are available for such an analysis of digital images seem to be only used sporadically. For radiation protection purposes it is recommended that radiology departments put more effort in collecting rejected images for educational purposes and to avoid similar mistakes in the future.

Subject: Medical

Eye lens doses of medical staff incurred in interventional procedures in Poland

Agnieszka Szumska

The rapid development of imaging technology has contributed to the growth of interventional radiology in recent years. Because of the introduction of new techniques and equipment and the ever-increasing use of radiation in medicine, it is important to continue to assess the doses resulting from medical exposure to radiation. Also the attention devoted in recent years to eye lens dose assessment was increased and recent studies have proved that radiation induced cataracts do not exclusively result from very high doses, and even no dose threshold for radiation-induced eye lens injuries even claimed that there is no threshold. According to ICRP recommendations and the new EURATOM directive 2013/59, for occupational exposure in planned exposure situations, an equivalent dose limit for the lens of the eye of 20 mSv in a year. Implementation of a reduced dose limit for the lens of the eye will require accurate dosimetry to determine eye lens exposure.

Personal dose equivalent in terms of Hp(3) for two most common interventional cardiology procedures (coronary angiography - CA and intervention - PCI) were evaluated for operators, nurses and technicians accrued over 60 interventional cardiology procedures. The EYE-D™dosimeter developed within the Optimization of Radiation Protection for Medical–ORAMED EU project was applied, using high-sensitivity MCP-N (LiF:Mg, Cu, P) detectors. Also annual doses to the lenses of the eyes were calculated by combining the doses per procedure recorded for the workers with their annual workloads.

In general, doses received by the staff performing PCI procedures were found to be systematically higher than those after CA procedures, by some 30% or more. Within the medical team, operators always received the highest doses, followed by nurses and technicians. Maximum eye lens doses, skin doses and whole body doses were 165 µSv, 962 µSv and 30 µSv per procedure, respectively.

64% of workers are likely to receive an annual dose above 3/10th of the annual limit and 21% exceed the dose limit of monitoring. Furthermore, there are 8% of the workers that could even get an annual dose above 20 mSv.

The findings of this study clearly indicate the necessity of Hp(3) measures during the interventional procedures, particularly in light of the reduced ICRP and EU eye dose limit.

Subject: Medical

An Assessment of Radiation Doses for Breast, Ovaries and Uterus while Investigating the Head, Chest, and Abdomen- Pelvis Using CT

Niculescu Florentin

Introduction

The Computerised Tomography (CT) has changed the medical imagery by providing a tri-dimensional image of the organs or places of interest. An increase in the frequency of applying this diagnosis means has a great impact on the patients and the population in general. Medical exposures through CT represent about 14% of the total radiological investigations used for diagnosis. In women's case, the most frequent examinations were for pelvis (56.1%), abdomen and chest (51.8%).

Objectives and Methodology

The aim of the study is to assess the organ dose in women for the radio-sensitive organs (breast, ovaries, and uterus) through three CT procedures (head, chest, and abdomen-pelvis) The study was carried out on two types of CT, both with 64 rows on a number of 60 patients for each CT (20 patients for each procedure). Following the data about the patient's identity, the exposure parameters, the CTDI and DLP values for each patient, the organ doses were estimated both by using the calculation model published in RP 154 and the Impact Dose software.

The Results

In the medical exposure for the head, the value of the average dose on breast was of about 0.036±0.012 mSv, 0.001 mSv for ovaries, and 0.000 mSv for the uterus. In the medical exposure for the chest, the value of the average dose was of about 28.86±11.79 mSv for breasts, 0.365±0.27 mSv for ovaries, and 0.310±0.28 for the uterus. In the abdomen-pelvis investigation, the average values of the doses varied like this: 12.74±6.98 for breasts, 59.94±7.72mSv for ovaries, and 60.38±7.43 for the uterus. The estimated values for the two CTs were comparable.

Conclusions

The organ doses were higher in all the investigation procedures compared to other studies carried out in countries such as Germany and England. We found a variation of the organ dose depending on more factors, such as the investigation parameters, the radio-protection measures for patients, and the radio-protection training of the technologist. It is necessary an increased attention in optimising protocols leading to a decrease of doses especially in the organs with a high radio-sensitivity. We must also pay special attention to the team-work of all the specialists implied in these procedures.

Subject: Medical

Assessment of patient doses from PET/CT examinations in the Russian federation

Larisa Chipiga

The aim of the current study was to determine the structure of PET diagnostics by performing a patient dose survey in PET/CT departments and to suggest possible methods for optimization in PET diagnostics in the Russian Federation.

The data collection was performed on 27 PET scanners in 10 PET departments and 9 PET centers, in 12 regions of Russia: Saint-Petersburg, Moscow, Republics of Bashkortostan and Tatarstan, Belgorod, Tumen, Tambov, Kursk, Lipetsk, Orel, Sverdlovsk regions and Primorsky krai in 2012-2017. The total patient doses, from combined PET and CT examinations, were calculated as the sum of the effective doses from internal exposure (administered radiopharmaceutical) and external exposure (CT scan). For each PET/CT scanner the internal dose from the radiopharmaceutical was estimated using conversion coefficients (ICPR publ. 128), for typical administered activities. The external dose from the CT scan was estimated using the CT-Expo software, based on the typical DLP and tissue weighting factors from ICRP (ICPR publ. 60).

The most common PET/CT examination in Russia is whole-body (WB) examination with 18F-FDG; performed with administered activities from 200 to 390 MBq. Moreover, PET/CT examinations of the brain with 18F-FDG (mean administered activity of 170 MBq), WB or pelvis examinations with 11C-choline (mean administered activity of 380 MBq) or 18F-choline (mean administered activity of 310 MBq) are performed; other examinations are less frequent in Russia. The CT scans performed as a part of WB PET/CT examinations are associated with doses that varies from 400 to 1700 mGy·cm, and for PET/CT examinations of the brain the doses varies from 40 to 1700 mGy·cm. Multiphase CT scans, with contrast agent, increase the patient doses by a factor of two. The total patient doses for WB CT examinations varies from 17 to 38 mSv and the CT scan composes up to 70 – 95% of the total patient dose from the PET/CT examinations. The total patient dose for brain examinations vary from 4 to 6 mSv. For optimization of patient doses in combined PET/CT examinations low-dose CT protocols as well as justification of diagnostics and multiphase CT protocols should be considered.

Subject: Medical

Dose reduction from accurate proton energy loss prediction with dual energy CT in proton therapy

Emiel van der Graaf

Proton therapy is part of radiotherapy and increasingly applied in treatment of cancer, especially for children and patients with tumours in the head and neck region. With proton therapy the tumour can be irradiated with less damage to the surrounding healthy tissues and critical structures compared to irradiation with photons. To optimally exploit this benefit of protons, the energy transferred by the protons to the tissues (the dose distribution) must be calculated very accurately. For this, the specific energy loss of the protons for each tissue is determined based on x-ray computed tomography (CT) imaging. In clinical practice, a phenomenological model is used based on an image obtained with a single x-ray spectrum (single energy CT, SECT). The predictions of this model are not patient specific and very inaccurate for materials which differ in composition and density from the materials used for determination of the model parameters. We have developed a method using two x-ray spectra (dual energy CT, DECT). With this method the electron densities and effective atomic numbers, which determine the specific energy loss of protons in a material, are derived from two images on basis of fundamental theory of the interactions of x-rays. This method provides patient specific predictions with an accuracy better than 2%. This is a large improvement in accuracy and stability of the method with respect to the clinically applied SECT method and can reduce the risk of high doses to healthy tissue or low doses to the tumour due to inaccurate prediction of proton energy loss in the tissues on the beam path.

Subject: Medical

Paediatric brain irradiation with spot scanning proton therapy reduces the out-of-field doses compared to photon radiotherapy – a EURADOS WG9 antropomorphic phantom study

Filip Vanhavere

Children are more sensitive to the effects of ionising radiation and have more chances to develop secondary cancer in their lifetime. Therefore, reduction of secondary out-of-field doses in child radiotherapy is an important radioprotection concern. Proton therapy (PT) allows to reduce unnecessary dose to the surrounding organs however the formation of secondary neutrons is considered as a major disadvantage of PT over conventional radiotherapy.

In this work the out-of-field doses were measured in child anthropomorphic phantoms (representing 5 and 10 year-old child) treated for brain tumours using proton spot scanning and three photon radiotherapy techniques; 3D Conformal RadioTherapy (3D-CRT), Intensity Modulated RadioTherapy (IMRT) and Gamma Knife (GK). Different passive dosimetry systems (thermoluminescent (MTS-7, MTS-6, MCP-n), radiophotoluminescent (GD-352M, GD302M), bubble (BD) and polyallyldiglycol carbonate (PADC) track detectors were used to assess the complete stray irradiation.

Brain irradiations with photon therapy techniques revealed most pronounced radiation to the out of-field organs using GK. Number of isocenters is an important factor defining the level of out-of-field doses during GK. IMRT, using coplanar fields, revealed the lowest out-of-field organ doses except for non-target brain and eye dose for which 3D-CRT, using non-coplanar fields, was somewhat lower. This was explained by the different treatment configurations while the use of mechanical wedges during 3D-CRT affects the out-of-field organ doses at larger distances.

The out-of-field photon doses, as measured with TLDs and RPLs, are significantly lower using proton spot scanning technique compared to photon techniques. This difference becomes even larger with increasing distance from the brain, ranging from one order of magnitude, close to the brain, to more than two orders of magnitude further away from the target. In PT the neutron doses are lower than secondary photon doses close to the target while neutron dose becomes larger than secondary photon doses further away from the target. The neutron equivalent doses, as measured with BD and PADC, range from 1mSv/Gy close to the field edge to 0.01mSv/Gy at 20 cm from the field. Altogether still significantly reduced out-of-field doses are observed for PT spot scanning compared to photon therapy.

To conclude, PT reduces the out-of-field doses while an accurate evaluation of the secondary neutron component is needed in the assessment of out-of-field doses during PT.

Subject: Medical

Evaluation of staff member radiation exposure of ^{90}Y selective internal radiation therapy

Maartje Lotz

Introduction

Selective internal radiation therapy (SIRT) has been developed in recent years for the treatment of liver tumors. SIRT consists of x-ray guided pre-SIRT radioembolization procedure using 99mTc-macroaggregated albumin followed by the administration of therapeutic amounts of 90Y-microspheres. During SIRT, staff members are exposed to ionizing radiation both from angiography and used radioactivity. Aim of this study was to measure the total staff dose and compare this to the dose calculated for the a priori risk-analysis.

Materials and methods

The a priori determined staff radiation exposure resulting from the angiography procedure was calculated based on a X-ray scaled scatter fraction at 80 kV and dose-area-product (DAP) values of 3.4·E2 Gy·cm2 and 1.3·E2 Gy·cm2 for pre-SIRT and SIRT respectively, as reported in literature. The 90Y (99mTc reported in parentheses) radiation dose was determined by assuming an administered activity of 3000 MBq (150 MBq).

In total, 24 pre-SIRT and 19 SIRT procedures were performed on a Philips Allura system. Staff members wore real-time personal dose meters (Philips DoseAware), which measured the radiation exposure. The exposure was automatically coregistered with the angiosystems dose output (DAP) in a patient and staff dose monitoring system (Philips DoseWisePortal).

Results

The calculated staff dose resulting from the angiosystem was 1.6 mSv and 0.62 mSv for pre-SIRT and SIRT respectively. The calculated dose for 90Y (99mTc) was 2.1·E-3mSv (1.2·E-3mSv) and was considered negligible.

Compared to the DAP-values reported in literature, we observed more than twofold lower DAP-values (1.3·E2 Gy·cm2 and 0.61 Gy·cm2 for pre-SIRT and SIRT respectively) and thus lower calculated radiation dose (0.91 mSv and 0.29 mSv).

In contrast, the average measured radiation dose was 5.5·E-2 mSv and 2.4·E-2 mSv for the pre-SIRT and SIRT procedure respectively, meaning tenfold lower values compared to the calculated radiation dose. This difference might be explained from the application of additional radiation protection measures (additional lead-shielding, leaving the room when possible) during the angiography procedure.

Conclusion

The measured staff dose during SIRT is more than tenfold lower compared to a priori calculated values. Staff dose was primarily due to X-ray angiography. This study indicates the importance of performing radiation dose assessment based on local procedures and equipment used and verifying the calculated dose by performing measurements in clinical practice.

Subject: Medical

Patient & Staff Dose Management Software – can it make a difference?

Sian Vaughan

Patient dose management systems are now widely available from many different vendors. This work investigates the utility of using one of these software packages that also collate real-time staff dosimetry in the area of interventional cardiology.

The software captures staff dose from a solid-state dosimeter worn outside the cardiologist's thyroid collar thus giving an indication of dose to critical organs such as the eye. This data is merged with the patient DICOM Radiation Dose Structured Report [RDSR] that gives patient and equipment information for every radiation event during a procedure.

This work will show early data [e.g. uploaded heat map 1, contribution document 1] that shows at which angulation of the x-ray equipment the cardiologist receives the maximum amount of dose by procedure type, thus enabling targeted interventions for radiation protection. This work also shows how the practice of each cardiologist is captured both in terms of procedural conduct and also radiation hygiene [e.g. use of the ceiling suspended Pb shield for face/eye protection].

This investigation has also attempted to correlate the doses from the solid-state dosimeter with those passive dosimeter results from UK legally required staff radiation dose monitoring, indicating the difficulty of this comparison.

The investigation has also shown, qualitatively, that feedback to cardiologists increases their interest in their dose and practice, but the built-in reports from this software are inadequate in conveying the required information, leading to potential increased confusion amongst the cardiologists.

Although this is very early work in the field, the exciting possibilities lead the authors to conclude that this is a fruitful approach to the optimisation of radiation safety for a key 'at risk' medical staff group that warrants much further investigation.

Subject: Medical

Case-based practical training in radiation safety for medical interventional teams

Marijn Rolf

Introduction

At the cardiac catheterization laboratory of the Rijnstate Hospital (Arnhem, the Netherlands) the collective team dose (Hp10) of the cardiologists and the technicians increased more than could be explained from the increase in procedures. After initial investigation a radiation safety training seemed the best solution.

Method

Kolb's experiential learning theory was applied to each topic that needed to be addressed in the training. Kolb's learning cycle consists of four stages: active experimentation, concrete experience, reflective observation, and abstract conceptualization. Effective learning is best facilitated by short cycles through all stages.

Each topic was presented by a small case from daily practice. The team was then asked to indicate the best solution. Next, their proposed solution was tested in practice on a phantom, with feedback provided by active dosemeters (DoseAware, Philips Medical). This enabled them to reflect on their expectations and the concrete experience. In the last stage, the team members were facilitated by the medical physicist in understanding the underlying radiation physics concepts. To also learn by repetition the training ended with more complex cases where all the concepts could be applied and tested again.

Effect of the training was objectively measured by the cumulative team effective dose. Subjectively the effect was gauged by reactions of the participants.

Results

The collective team effective dose over the years is shown in figure 1. The training started in September 2013 and all team members were trained by the end of January 2014. From 2012 to 2014 the collective dose decreased by 30%, whereas the number of patients treated stayed stable. This indicates a strong dose reducing effect from the training. Long term effect (2015) showed a stable team dose despite an increase in number of patients treated.

Initial reactions of the particpants can be summarized by a quote of one of them: "to my surprise this training was both fun and useful". Long term effects as reported by the team: a better cooperation within the team, better awareness on radiation dose, and better contact with the medical physicist for advice. These are all elements of a good safety culture, indicating that this practical training also has a positive effect on the radiation safety culture.

Conclusions

A case-based practical training was very well received by the cardiologists and technicians. This resulted in a significant and long term reduction of their effective dose and a better safety culture.

Subject: Medical

Visualizing simulated x-rays with the Microsoft HoloLens to enhance medical staff's understanding of 3D radiation patterns.

Tessa Klunder

Introduction

The ALARA principle (As Low As Reasonably Achievable) encourages hospitals to keeping radiation doses for staff and patients as low as possible. Fluoroscopy not only exposes the patient to radiation, but also the specialist and other personnel in the room. Staff from the interventional radiology and cardiology department of the Albert Schweitzer hospital in the Netherlands expressed their concerns about radiation exposure. Not being able to see radiation patterns made them question the optimal position during operations. What if they could see the X-rays in 3D inside the operating room? With mixed reality this becomes possible. The Microsoft HoloLens (2016) is a mixed reality headset, that can project virtual objects (holograms) in the real world.

Method

We developed a HoloLens application to simulate and visualize scatter radiation levels during a fluoroscopy procedure in an operating room. Our objective is to use holograms to improve the understanding of interventional cardiologists, - radiologists, and technologists of radiation patterns and to support them in identifying positions with high and low radiation levels. This project is a collaboration between Utrecht University, Capgemini Netherlands and the Albert Schweitzer hospital. The scatter radiation is simulated by raytracing photons and simulating Compton scattering using the Klein-Nishina formula. The application offers functionalities allowing users to change the C-arm position, turn on lead shielding and dynamically see the effects of these interventions.

Results and Conclusion

We conducted a first series of user tests on the prototype HoloLens application in the radiology and cardiology departments of the Albert Schweitzer hospital to assess the effect of the visualization on the understanding of the radiation patterns in the operating room. The personnel of both departments responded mostly positively to the visualization and the HoloLens. Our results cannot yet statistically confirm that users experience a learning effect, but do show that they performed better at identifying unsafe positions inside the operating room. Additionally we learnt the importance of emphasizing differences in radiation levels, as some participants were not able to see the subtle changes in intensity levels in the current version. Our research concludes that mixed reality shows promise for safety training purposes in hospitals. Improvements in visualization techniques and interaction with the Hololens may contribute to the learning effect of the current application and therefore deserve further research.

Subject: Medical

Local diagnostic reference levels in paediatric interventional radiology procedures

Luis Alejo

Introduction: Due to the Council Directive 97/43/EURATOM, is obligated to promote the establishment and use of DRLs as a strategy for optimization. The aim of this work is to obtain an approximation to local DRLs in the most common paediatric interventional procedures performed in a paediatric University Hospital, and highlight the problems encountered.

Materials and Methods: The interventional radiology rooms considered are equipped with Philips fluoroscopic systems: Integris 3000, Integris Allura and Allura Xper FD20. During a 1-year period (November 2016 - October 2017), Ka,r and Pka, fluoroscopy time, number of images and age data were collected from the equipments using DOLIR automatic dose management software. Weight and percutaneous approach data were collected during procedures and registered in a database. All the dose values were corrected using a flat-ionization chamber duly calibrated. The approximated DRLs were obtained using the third quartile of the population data.

Results: 146 procedures were analised from a total of 220. The missing procedures were usually consequence of data loss of patient weight or procedures classification. For the time period considered, data of 11 studies exclusively diagnostic were collected (phlebography, arteriography, lymphography and indirect portography), obtaining a Pka of 44.1 Gy·cm2 for ranges [15.0-52.5] kg and [32-172] months of age. For 25 percutaneous transhepatic cholangiography procedures (PTHC), the Pka obtained was 20.2 Gy·cm2 for ranges [9.5-26.0] kg and [17-117] months. For 35 central venous catheter procedures (CVC), 1.0 Gy·cm2 was obtained for ranges [10.0-35.0] kg and [22-143] months. For embolization of congenital arteriovenous malformation (n=43), 15.7 Gy·cm2 was obtained for ranges [19.5-54.8] kg and [75-147] months. If we considered all the therapeutic procedures (n=135), including PTHC, CVC, MAV embolizations and transjugular intrahepatic portosystemic shunting (TIPS), then we can obtain DRLs for the conventional paediatrics ranges: 1.4, 14.5, 19.9, 70.4 and 61.9 Gy·cm2 for (0-5], (5-15], (15-30], (30-50] and (50-80] kg; 7.0, 15.5, 14.5, 58.1, 57.3 Gy·cm2 for (0-1], (1-5], (5-10], (10-15] and (15-18] years of age.

Conclusions: Strong variations can be observed in paediatric patient doses due to the great variability in patient size and weight. A wider regional survey should be conducted.

Subject: Medical

Technology to reduce or even prevent harmful radiation effects on the skin.

Ad den Boer

With the development of pulsed fluoroscopy in 1992 we got the opportunity to develop new medical intervention techniques, with prolonged treatment- and fluoroscopy times.

After the development of a real-time entrance dose monitoring system in 1999 we were able to follow up the health status of patients with (very) high local skin dose after cardiological percutaneous interventions.

We studied various patients with pulsed X-ray entrance doses over two gray, those patients showed no deleterious effects to the skin.

Hereafter we performed a pig-skin study. Using continuous X-ray fluoroscopy skin reactions were seen as expected.

However, no harm was seen after using pulsed radiation.

These differences cannot be explained by differences in dose, dose-rates and (extra) beam filters, these were identical, continuous

X-ray: 480 nGy/s, (110kV-12mA)- pulsed X-ray: 475 nGy/s, 38 nGy/p (110kV-120mA at-12,5 pulse/s and-8ms/pulse).

An in vitro (skin)cell survival study with 6 gray radiation, using continuous fluoroscopy, showed LQ curves with a survival rate of <1% (these finding fit with data from radiobiologic literature). On the other hand, pulsed radiation showed a cell survival of more than 80%.

It was concluded that a cellular adaptive response was found: cells can repair or prevent the expression of radiation damage within milliseconds if pulsed radiation is applied.

This is very reassuring for patients and for operators, occupationally exposed to high levels of X-ray radiation.

While pulsed X-ray radiation does not exist in nature, (it is man-made since 1992), until now this phenomena has never been examined at cellular level.

The presentation focus on various questions about the (absence of) harmful biological response to pulsed X-ray, as seen in practice in interventional radiology and cardiology.

It is stressed that further research should be done to (skin)dose response relationship and to the optimization of the pulsed X-ray technique in radiology and cardiology.

Subject: Medical

Measurement of skin dose and radiation-induced skin reactions during breast cancer radiotherapy.

Erik Tesselaar

Radiation therapy increases local and regional control and overall survival with breast cancer, but the vast majority of patients develop acute skin reactions as a result of radation-induced microvascular changes. The aim of this work was to determine the dose distribution to the skin of the breast or thoracic wall by film dosimetry and to study correlation between skin dose and local changes in microcirculation in the skin in breast cancer radiotherapy.

Gafchromic EBT3 films were used for dose measurements and scanned using an Epson Perfection V600 scanner. Films were calibrated for different energies and effects of film size, and spatial and temporal variations in film readout on the calibration curve were investigated. Measurements were done in male and female phantoms and in 5 patients undergoing breast cancer radiotherapy (1 breast-conserving and 4 mastectomy patients). Between 16 and 21 films (2x1 cm2) were placed on the skin at sites within and adjacent to the radiation fields (Figure 1). Phantoms and patients were irradiated with a prescribed dose to target of 2 or 2.66 Gy with two opposed 6MV and/or 15MV fields.

Regional changes in mean blood perfusion and in mean red blood cell concentration (RBCC) at the end of the treatment, compared to baseline, were measured using laser speckle contrast imaging (LSCI) and polarised light spectroscopy (PLSI), both in treated and untreated breasts.

While films showed a very minor energy dependence (0.59%), a 2.2% variation in calculated dose between different film sheets was observed. Also, dose calculation was affected by spatial variations of the scanner (4.5%) and variations in readout time (up to 1.5% between 24h and 7 days).

It was observed that between 45-64 % of the prescribed dose was deposited at the skin. A good agreement was found between skin dose in phantoms and patients. There was no significant correlation between the changes in perfusion and the absorbed radiation dose ($r=0.30$, $p=0.18$). However, a statistically significant correlation was found between local changes in RBCC and locally absorbed skin dose ($r=0.43$, $p=0.03$, Figure 2).

Film dosimetry using GafChromic EBT3 films provides a convenient method to study skin dose distribution in radiotherapy of breast cancer. To further elucidate the relation between changes in skin microcirculation and the absorbed radiation dose during breast cancer radiotherapy, future studies using a larger number of patients are needed.

Subject: Medical

Developing a calculation tool for skin dose after contamination

Robert Westland

Introduction

This project was aimed at developing a tool to unify calculation skin dose after contamination(s).

In our university and hospital there is a broad range of radioactive substances being used for research, diagnostics and production of radiopharmaceuticals. These activities are spread out over a large campus. Every location is supervised by a local Radiation Protection Officer (RPO) who is supported by and under surveillance of the central - RPO/RPE) of the radiation protection department (RPD).

Aim

When working with radioactive substances it's inevitable that radioactive contamination accidents take place. Last 10 years the RPD has experienced that RPO's are confronted with commotion during accident situations and therefore find difficulties in calculating the equivalent skin dose and reporting this in a comparable and unified manor. The RPD concluded that RPO's need guidance to make correct dose estimations.

Method

An analysis on contamination events last 10 years shows there is a similar course of the stay of radioactivity after contamination accidents. We conclude calculation of skin dose can be done automatically following this course. There are commercially systems available but these are costly and usually demand highly specific information and knowledge. Therefore I designed a simple tool which guides RPO's filling the minimal data to be able to calculate - worst case - integrated skin dose given a certain activity, on numerous radionuclides and given a period of time (taking the effects of decontamination into account).

Results

I found a way to support RPO's coping with accidents by providing a simple tool for the calculation and reporting of skin dose due to contamination accidents. The system is very easy to use, is protected for changes, is fail proof and gives unity to dose calculations with frequently used radionuclides used on our campus.

Secondly this tool can be used for risk assessments in case of estimating skin dose due to foreseen accidents in planned exposure situations.

Thirdly this system can be used to create consciousness with radiological workers to find out themselves what are typical skin doses following a contamination accident.

In a presentation I will give a schematic overview on the course of radioactive contaminations and I will give an introduction on the calculation tool. To conclude I will sum our results.

Subject: Medical

Guidelines for Radiation Protection and Dosimetry of the Eye Lens in the Netherlands

Robert Kollaard

In the past, the dose limit for occupational exposure of the eye lens to ionising radiation was rarely exceeded. Early 2018, this limit will be reduced from 150 to 20 mSv per year. This will require more attention for the protection for the eye lens. When category A workers are liable to receive a significant exposure of the lens of the eye, an adequate system for monitoring shall be set up. A committee of the NCS is preparing guidelines to support radiation protection experts in the Netherlands with the practical implementation of the upcoming legislation.

If the calculated annual eye lens dose in the prospective risk assessment is higher than 15 mSv, a worker is to be classified as a category A worker. The largest group of those workers is found in the medical field, in particular in interventional radiology and cardiology. It should be noted that some workers in nuclear medicine, veterinary practice, non-destructive testing and isotope production may be exposed to such high dose levels as well. The type of eye lens dose monitoring depends on the exposure conditions. It is expected that whole body dosemeters give a reasonable estimate of the eye lens dose for workers who are exposed to uniform photon beams. An example of this exposure situation can be found in non-destructive testing. Due to different and varying exposure conditions, such as a short distance, varying X-ray beam direction and the use of ceiling mounted shielding, the exposure situation in interventional radiology is much more complex. Several studies show that in such situations eye lens doses are not estimated adequately by whole body dosemeters, worn on the lead apron. In such conditions eye lens dosimetry should be considered when the expected eye lens dose is more than 15 mSv.

General protection principles can be used to restrain the eye lens dose such as limiting time, increasing distance and applying shielding of the source. The use of personal protective measures (typically lead glasses) should be considered as a last step in this process. Examples of other measures to reduce the radiation exposure to the eye lens are: the optimal position of the image monitor in hospitals, radiation protection education of workers, periodical reviews of radiation applications and dose data, and the medical surveillance.

The committee intends to publish the guidelines early 2018 on the NCS website (radiationdosimetry.org).

Subject: Medical

Evaluation of physical spaces of nuclear medicine services

Catarina Torres

Nuclear medicine is a medical specialty applied to diagnosis and therapy that uses unsealed radioactive sources for image formation. A nuclear medicine service should include a physical structure that provides security and facilitates in the flow processes of radioactive materials in order to avoid unnecessary exposure to the radiation of professionals and other people who transit in the service. Current work presents the evaluate the projects installation of nuclear medicine services in Southern and Northern Paraná State of Brazil. Five nuclear medicine services were analyzed, belonging to the Southern and Northern Paraná State of Brazil, regarding radioprotection (shields) requirements and the dimensions of their environments according to the standard RDC No. 50/2002 - ANVISA, and the existence of necessary dependencies required related to the standard CNEN-NE-3.05. Data were collected in surveys into nuclear medicine clinics, through analysis of architectural designs and radioprotection plans of valued services. The results show that one of the five nuclear medicine services evaluated is not according to the rules of ANVISA and that none all the services have all essential physical dependencies to the working routines of nuclear medicine. The architectural designs of nuclear medicine services need to be improved and periodically monitored in order to meet the specifications required by Brazilian laws. The other nuclear medicine services in Brazil need to be evaluated so that we can verify their quality and provide greater assurance for all who use these sites.

Subject: Medical

Reasons and basis for implementation of medical physicists certification in Ukraine

Ielyzaveta Kulich

All over the world high technologies are used and implemented in medicine. Ukraine is not an exception. Up-to-date there are 24 linear accelerators and 2 PET centers. The amount of high-tech equipment will be increasing to provide needs of more than 42 million people in the country. Such equipment needs quality assurance by certified personal.

Ukraine selected one of ten principles of “Further generations protection”, namely not to accumulate radioactive waste. On one hand, equipment with radionuclides should be replaced by the one with generating ionizing radiation sources. On the other hand, radiation protection and safety procedures, safety culture should be affectively introduced during the use of high technologies in medical activities with ionizing radiation sources. This is described in international standards stated in the IAEA Basic Safety Standards and progressively implemented in Ukraine. At the same time there are some difficulties with standards implementation. Today definition of “medical physicist” is absent in Ukrainian legislation base as well as his/her duties and functions. However, a certain part of medical personal is performing medical physicist’s functions in part. Common register of patients’s exposure dose is absent in Ukraine.

It is an evidence to implement national education system for medical physisists interconnected with formal certification schemes for the recognition of the expertise and competence. A certification scheme could either be directly under the control of the regulatory body, or operated by a non-governmental not-for-profit organization. IRPA Guidance 2016 recommends that it can be an associate society, under an approval from the regulatory body, or its activity is regulated by national legislation.

Taras Shevchenko National University of Kyiv has a successful experience of cooperation with Swedish regulatory authority in the frames of project “Quality Assurance and Quality Control in medical radiology in Ukraine” connected with education and training of medical physicists. Faculty of Radio Physics, Electronics and Computer Systems is educating magisters on specialties “medical physics”, “biomedical physics, engineering and informatics”. Training and Research Center for Radiation Safety successfully carries out refresher courses and examination on “Radiation safety for certain activities related to nuclear energy use” more then 14 years. The center has certificate ISO 9001:2008. Base on long years experience, the university together with non-governmental not-for-profit organization Ukrainian Association of Medical Physicists and Engineers looking for a possibility to introduce certification scheme for radiation protection and medical physics experts.

Subject: Medical

Occupational study of radiation protection practices in a Portuguese Interventional Cardiology Service and its clinical relation to crystalline lens opacities

Pedro Teles

Introduction: It is known that exposure to low doses of ionizing radiation, for long periods of time, can increase the risk of certain pathologies and that this could be related to stochastic effects rather than deterministic. In the case of the eye, it has long been posited that radiation can be an underlying factor in the appearance of certain types of lens opacities. In the framework of the European epidemiological study on radiation induced lens opacities among interventional cardiologists (EURALOC) project, which intended to study the relationship between radiation dose and eye opacities on a European level, a Portuguese-specific study was devised in a University Hospital.

Method: A group of interventional cardiologists (n=10) from a Portuguese Cardiology Intervention Unit was recruited. In addition to a complete ophthalmological examination including slit-lamp examination, they were submitted to Scheimpflug images. Parallel to this clinical examination, the recruited professionals answered questions from two previously designed medical and occupational questionnaires, which analyzed the current and previous radiological protection practices of both the professionals and the services where they worked, as well as medical and confounding factors.

Results: Using the EURALOC methodology a value of dose was determined for each professional. Furthermore, the occupational practices were analyzed in a radiation protection perspective. Finally, the Portuguese-specific findings were compared with the European ones. recommendations in the improvement of the practices were implemented.

Subject: Medical

Practical radiation protection during intervention radiology at animals

Siebren van Tuinen

Under the general license for radiological activities of Wageningen University & Research a lot of very different radiological applications are operational, varying from quite simple diagnostic X-ray equipment to the operation of radiological laboratories handling open radioactive sources, and from age-determination of geological earth layers to research studies with radioactive substances and X-ray equipment on food, feed and animals.

In 2017 a new research program was started during which some animals were cardiac catheterized under examination with an X-ray device.

For this new application for Wageningen University and Research the risk-analysis based on the recommendations of RIVM was introduced and performed. The calculated results were compared with experimental results.

The area monitoring dose results showed a good agreement between the calculated and experimental values: a maximal deviation of 20% was observed.

For the workers, being present in the room during the operation, good agreement between the calculated and experimental dose values was observed for the assistants and the anesthetist: the deviations in doses values for the assistants mounted up between 5 and 50%, Logically, the highest deviations were found at the lowest doses.

The medical doctor showed a factor 4 lower personal dose than expected. This could be quite easily explained by the variation in the distance of the medical doctor to the patient.

Bases on the dose evaluation and the risk analysis the medical doctor and the catheterizing assistant were classified as radiological workers type B; based on the calculations and measurements no eye lens dose meters were obligatory; however, in 2018 some experiments will be performed with eye lens dose meters on voluntary basis. The other personnel involved was classified as ‘other workers’ working with radioactivity. For these workers a special training was organised considering working with radioactivity, especially on the field of working with X-ray equipment.

The area where the procedures take place was classified as controlled area.

The evaluation of the potential risks involved during the procedure did not result in any immediate actions other than regular ALARA recommendations.

Having completed this the internal permit for starting the activities was given.

Subject: Medical

A study of scatter radiation in diagnostic X-ray rooms and radiation protection

Natasa Todorovic

The purpose of radiation shielding is to limit radiation exposures to employees and members of the public to an acceptable level. The objective of a shielding calculation is to determine the thickness of the barrier that is sufficient to reduce the air kerma in an occupied area to a value ≤P/T, the weekly shielding design goal modified by the occupancy factor for the area to be shielded. This paper presents a method for determining the thickness requirements for barriers against scatter and leaking radiation in a radiographic room. The measurements were performed by RTI Barracuda equipment and R100B detector which are very suitable for scattered radiation measurements because of the high sensitivity and the minimal energy dependence. Obtained thickness of the barriers was compared with calculated values according to NCRP report No. 147 which contains recommendation and technical information related to the design and installation of structural shielding for facilities that use X-rays for diagnostic imaging.

Subject: Medical

The “Occupational Health Service” for medical surveillance in Radiation Protection

Raffaele Pennarola

The medical surveillance of workers exposed to ionising radiation is now extended to natural radiation (radon, etc.) and furthermore, due to ever so frequent nuclear or radiological emergencies, it could and should be extended to the exposed population and to the environment. In this context the occupational health service as defined by EURATOM Directive 2013/59 (GU U.E. 17 January 2014) plays an important role, also addressing environmental issues and studying the nature and extent of evaluation research.

In fact, the Commission’s Recommendations demand an adequate level of protection for people and the environment against the detrimental effects of radiation exposure, “without unduly limiting the desirable human actions that may be associated with such exposure.” Moreover, “the Commission’s system of radiological protection aims primarily to protect human health. Its health objectives are relatively straightforward: to manage and control exposures to ionising radiation so that deterministic effects are prevented and the risks of stochastic effects are reduced to a reasonably achievable effect.”

In terms of procedures, it is necessary to complete the medical record (Personal Health Document) for every worker exposed to the ionizing radiation risk. That medical record includes information regarding preventive measures, routine and specialized health screening.

On this subject two types of harmful effect are recognized by ICRP 103. High doses will cause deterministic effects (harmful tissue reactions), often of an acute nature, which only appear if the dose exceeds a threshold value. Both high and low doses may cause stochastic effects (cancer or heritable effects), which may be observed as a statistically detectable increase in the frequencies of these effects. The occupational health service is of great importance in the prevention of deterministic effects using monitoring techniques (for instance, microcirculation capillaroscopy, thermography, etc., of the tissues exposed) and stochastic effects using epidemiology and monitoring of biological data (genetic, etc).

Periodic health monitoring or surveillance and education on occupational health hazards can be carried out with important health consequences for the radio-exposed people. In this regard, the application studies on microcirculation developed over the years by the Medical Radioprotection Service -Occupational Health Medicine at the University of Naples Federico II - are very relevant in terms of the workers’ occupational health.

Subject: Medical

Risk management of the radiation-induced cataract

Ana Dolcet Llerena

Introduction: The Council Directive 2013/59/EURATOM of 5 December 2013, following the new ICRP guidance, stablished a considerable reduction on the limit for equivalent dose for the lens of the eye in occupational exposure, from 150mSv to 20 mSv in a single year. That requires from the Radiation Protection and Prevention Units of the Hospitals a new method to evaluate the risk of cataract in exposed professionals and a new guideline to assign PPEs such as lead glasses.

Materials and Methods: GESTISA has led the so called "Crystalline Project", manufacturing a new eye lens dosimeter and starting a pilot program with 11 hospitals in Spain, in order to collect data of the accumulated doses in several medical specialties. Those specialties were:

1) Hemodynamics
2) Electrophysiology
3) Interventional neuroradiology
4) Interventional Radiology
5) Vascular Surgery
6) Cardiac Surgery
7) Traumatology
8) Gastroenterology
9) Intensive Care
10) Urology
11) Anesthesiology
12) Nuclear Medicine and PET

Each of the 11 hospitals participated in the project with different number of professionals (including doctors, nurses, medical imaging technologists and nursing assistants) during a minimum period of three months in a total of 10 months that the project has been running so far.

Results: The results for the average acquired dose per specialty are shown on the following graphic.

Conclusions: Our recommendations, on whether a certain medical specialty should wear led glasses or dosimeter, were based on the Spanish Royal Decree 783/2001 that imposes the obligation of wearing a dosimeter in Controlled Zones, that is, the areas where there exists the possibility of reaching doses of more than 3/10 of the annual occupational limit for the lens of the eye.

According to this, every professional that can reach the limit of 6mSv/year, that is, 0.5mSv/month, should wear an eye lens dosimeter. If we have a look at the results, we find that those specialties are: Hemodynamics, Interventional Radiology, Gastroenterology*.

*Gastroenterology was due to two professionals that reached a very high dose for just one month, being the rest of the doses considerably lower, we would have to wait for more data to give a definitive recommendation.

In order to recommend the use of led glasses, we looked at the maximum monthly received doses, to look if any specialty reached 1.67mSv/month (that would make 20mSv/year), and that gave us the very same result, the three specialties mentioned above.

Subject: Medical

Stakeholder involvement throughout the revision process of the Swiss radiation protection legislation and the implementation of clinical audits: experience and lessons learned

Barbara Ott

Innovations led to new challenges that triggered the revision of the Swiss radiation protection legislation. Ten ordinances were adapted according to the new international standards - namely the ICRP103 recommendation as well as the IAEA and Euratom basic safety standards. The aim of the revision was to introduce a risk-based approach covering all exposure situations and reflecting the current state of science and technology. Stakeholder involvement was crucial for the acceptance of the revision, especially in medicine with respect to new provisions regarding justification and the introduction of clinical audits.

From the beginning of the revision project conducted by the Federal Office of Public Health (FOPH), all concerned authorities as well as designated experts covering several fields were closely involved. Relevant stakeholder groups were kept informed of the progress. For example, regular meetings were organized with professional medical societies. Regardless of this effort, many comments submitted as part of the public consultation on the new legislation showed that reservations and misconceptions were remaining amongst the stakeholders. Therefore, the FOPH started another round of one-to-one meetings in order to discuss those issues. In some points, the feedback resulted in adaptions of the legislative texts, whereas other comments stemmed from misinterpretation or were just individual opinions. Finally, the new legislation could be adopted without major resistance.

The introduction of clinical audits was an important piece of the new legislation. Conducted in the form of peer-reviews, clinical audits seek to improve the quality of patient care by eliminating unjustified procedures and optimizing justified ones. After launching the clinical audits project, stakeholders from the authorities, professional societies, hospitals and patient representatives were invited for a system modelling in order to identify key determinants. An expert panel with representatives from radiology, nuclear medicine, radiation oncology, cardiology, medical physics and radiographers was then convened in order to work out the legal basis and develop an implementation concept. To prepare pilot audits and define standards, three working groups in the fields of radiology, nuclear medicine and radiation oncology were set up. Pilot audits were conducted so far in 18 institutions. Recently, an interdisciplinary “clinical audits” platform was established; its steering committee, composed of delegates from professional societies and the FOPH, is responsible to define the overall strategy.

Involving all relevant stakeholders in early stages and throughout all processes promoted acceptance of the revised radiation protection legislation and enabled an efficient implementation of clinical audits.

Subject: Medical

Influence of low doses X-ray radiation exposure on human stem cells

Daria Usupzhanova

Despite the prevalence and severity of the effects of radiation on the body, today its effects on certain aspects of human life, in particular stem cells, which are an integral and important part of the body, are not studied, the vital reserve of which directly affects the body as a whole. Objective work to study the effect of low doses of X-ray irradiation on mesenchymal stem cells (MSCs) for the evaluation of long-term effects in vitro. The results of our study showed that low doses of X-ray irradiation contribute to the formation and accumulation of lesions in stem cells and their subsequent transfer to cellular descendants, which can lead to disruption of normal vital activity of stem cells, in particular oncotransformation.

Subject: Medical

Physical aspects of angiographic procedures with CO_2: dosimetry and mechanics of a gaseous contrast medium

Pier Luca Rossi

The number of CO2 angiography procedures is rapidly increasing, due to changes in patients' population, availability of safe gas-injectors and dedicated protocols, mainly based on post-processing algorithms (such as "image stacking", "pixel motion", "mask subtraction").

Even if the physical and radiological properties of gaseous and liquid Contrast Media (CM) are completely different, nowadays the approach to angiographic procedures with CO2 and iodine does not present significant differences: why?

To optimize the CO2 angiographic procedures, in terms of image quality to dose ratio, it is mandatory to consider the mechanical and radiological aspects of the gaseous CM, with respect the iodine one, such as the haemodynamic parameters of the patient. In fact:

1. CO2 doesn't mix with blood but substitutes it, so the radiological image quality is strictly related to the bubbles-trains moving inside the vessel with bubble dimensions that depend on injection parameters, blood flow and pressure. If a radiological system does not consider these aspects, a lot of data can be lost in the images.

2. Since CO2 is a gas and moves upwards, it is often necessary to change the patient position to fill the vessels of interest, avoiding pain during injections - so reducing involuntary movements between mask and images acquisition

3. Iodine perfusion is very fast, but CO2 requires time to fill and move along the vessel, depending on the blood flow. If the X-ray emission doesn't take care of it, the dose to the patient can be higher than other procedures, only due to longer emission-time.

4. Since the linear absorption coefficients of CO2 does not have any k-edge, the choice of the HV and current should be done with different LUT (look-up-table) if compared with Iodine procedures. At this moment, all X-ray apparatus uses the same AEC (Automatic Exposure Control) for all procedures, without any considerations about the type of contrast medium.

To clarify these issues, we have observed and analysed 20 procedures with CO2 contrast medium (peripheral angiography, EVAR, electrophysiology procedures) to evaluate dosimetric aspects - to answer at the requests about the patient doses differences between CO2 and iodine, to highlight the procedural critical issues and propose ideas for the optimization, related as to image quality/dose ratio as to mechanical aspects of gaseous CM.

Subject: Medical

Effective doses estimations for barium swallow and barium meal fluoroscopic examinations performed in Russia: a hospital-based study

Aleksandr Vodovatov

Barium swallow (BS) and barium meal (BM) fluoroscopic examinations are commonly associated with relatively high patient doses as their performance is heavily influenced by the subjectivity of the operator. Therefore, it is necessary to assess the levels of exposure and the corresponding radiation risk to the patient, which can be achieved through the estimation of the effective dose. The most practical approach is to use conversion coefficients (CCs), relating effective dose to dose-area product. The aim of the current study was to estimate the effective doses and CCs for typical BS and BM protocols based on a data collection in a general practice hospital in St-Petersburg, Russia, and to evaluate the impact of different parameters of the examination on the resulting CCs.

The data was collected on two digital KRT-Electron X-ray units at two different departments in a St Petersburg university hospital. Computational models of typical BS and BM protocols were developed based on the PCXMC 2.0 software. Each examination was divided into sets of standardized fluoroscopic phases and X-ray images. For each examination, patient and unit, the following data was collected: patient positioning, projection of exposure, total fluoroscopy time, fluoroscopy speed, irradiation field size and location, average tube voltage and total DAP. Effective doses and CCs were estimated for each phase and image, both for the over-couch and under-couch exposure geometries using tissue weighting factors from ICRP Publication 60.

For full examinations, the following CCs (µSv*Gy-1*cm-2) were estimated: 2.3 and 1.7 for BS (both departments); 2.6 and 2.0 for BM (surgical department); 2.5 and 3.8 for BM (therapy department) for over-couch and under-couch exposure geometries, respectively. The significant differences in CCs observed in the two departments can be explained by differences in exposure geometries (prevalence of AP projection in surgical department; oblique projections in therapy department) and typical irradiation field size (28×28 cm in surgical department.; 15×25 cm in therapy department.).

The effective doses and CCs are mainly influenced by the structure (number of fluoroscopic phases, projections and geometry of patient exposure) and by parameters of the fluoroscopic examinations (field size and energy characteristics of the X-ray beam). That significantly complicates the use of single CCs for a selected examination, especially in the absence of common clinical protocols.

Subject: Medical

Compliance to Diagnostic Reference Levels for radiation exposure in common radiological procedures in Dutch hospitals: A nation-wide survey carried out by medical imaging students

Harmen Bijwaard

In the Netherlands Diagnostic Reference Levels (DRLs) for radiation exposure have been defined for 11 common radiological procedures. Adherence to these DRLs is an indication of good radiological practice, in which radiation protection is considered important. Average dose values for groups of patients subject to the same procedure should generally remain below the DRL.

However, a study by the Dutch National Institute for Public Health and the Environment (RIVM) showed that many hospitals did not compare their dose estimates to the DRLs according to the national procedure. In many cases Dutch hospitals did not record weights of patients which are needed for a formal comparison to the DRL. RIVM and Inholland University (InhU) of Applied Sciences drafted a plan to remedy this with support from the Ministry of Health Welfare and Sports. It involved students of the Bachelor program Medical Imaging and Radiation Oncology carrying out the formal DRL comparison procedure in the hospitals where they receive their on-the-job training. InhU involved all Dutch applied universities that have a similar bachelor program and a nation-wide project was set up in which radiography students collected dose estimates for radiological procedures in Dutch hospitals on a voluntary and anonymous basis. In this way the participating hospitals were assisted in complying to the DRL-procedure, national dose data were collected and medical imaging students gained hands-on experience with DRL-procedures, which form an important aspect of radiation protection in the radiological practice that they will be involved in after graduating. In practice, students were instructed at the universities of applied sciences and supervised by medical physicists from the participating hospitals.

After a pilot study in 2014 this study was enlarged in 2015 to involve 21 hospitals from all over the Netherlands. In 2016 and 2017 the project was continued in a different set of hospitals. In 2017 the project included a trend analysis of all data collected so far. The obtained dose measurements show very good compliance to the DRLs that may have been enhanced by the voluntary participation. The results indicate that the current DRLs that were not based on a national survey, may need to be updated, sometimes to half their current value. More importantly, this study shows that involving students in DRL comparisons is a viable and instructive approach that is likely to contribute to maintaining radiation protection standards in hospitals in the long term.

Subject: Medical

Some practical aspects on implementation of the Council Directive 2013/59/EURATOM in the medical field in Romania

Constantin Milu

The Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/43/Euratom and 2003/122/Euratom was published on 17th of January 2014 in the Official Journal of the European Union . As it is well known, the Directive is based on the ICRP Recommendations published in 2007 as Report No.103.

According to Article 106 in CHAPTER X – Final provisions, Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with Directive by 6 February 2018. This transposition process is now in a final phase in Romania too.

Many activities shall be performed during next few years, for effective and practical implementation of this Directive, particularly in the medical field.

The work starts from a general review of the problem in Romania, including:

- the identification of the real new provisions in the revised Euratom Directive, in relation with the identification of responsibilities for the different competent authorities and stakeholders involved, the detection of issues and the identification of good practices and the identification of topical issues which require further attention, action and activities.

Finally, the work suggests and recommends several important practical aspects, issues and actions; as examples:

- The need of an improved system for Education and Training of Medical Professionals in Romania on Radiation Protection, according to European Commission Guidelines, published in 2014 in Radiation Protection No.175.

- A specific guideline regarding protection of carers and comforters and registration as medical exposure.

- A complex individual radiation monitoring of medical staff from interventional radiology, taking into consideration the new equivalent dose limit for lens of the eyes in occupational exposure.

- The setting-up of a national system for prevention, registry and analysis of accidental and unintended medical exposure and the follow-up in case of their occurrence.

- A new system for education, training and recognition of Medical Physics Expert,

considering his new role in the modern imaging (EC, Radiation Protection No.174, 2014).

- New requirements of the Ministry of Health in relation to exposure of asymptomatic individuals exposed as part of an approved health screening program, on diagnostic reference levels and on the European Criteria for acceptability of medical radiological equipment (EC, Radiation Protection No.162, 2012).

The role of training centers and of professional associations is pointed-out.

Subject: Medical

Eye lens dosimetry of workers during medical interventional procedures and surgery

Fabrice Entine

The lens of the eye is one of the most radiosensitive human tissues, if exposed to ionizing radiation it can develop prematurely radiation-induced cataract. Eye lens dosimetry in interventional medical practices and surgery has been published in few clinical trials and an active debate about the causality of radiation induced cataract is still on-going. In 2007, the International Commission on Radiological Protection (ICPR) recommended a reduction in the annual dose limit for occupational exposure for the lens of the eye from 150 to 20 mSv, averaged over a period of 5 years, with the dose in a single year not exceeding 50 mSv. The compliance to this new requirement could be difficult in some workplace. The aim of this work is to assess the radiation dose to the eye lens of interventional procedures (IP) in the field of cardiology, radiology, gastroenterology and surgery in a military hospital.

This study includes 90 medical practitioners. The measured radiation exposure represented the exposure in a normal working schedule of a random worker during 3 months and this cumulative eye lens dose is extrapolated to 1 year. The eye lens doses are measured from eye dosimeter close to the right/left eye, on the temple, according to the nearest side of the radiation source. For workers wearing lead glasses the dosimeter are placed on the glasses.

The estimated annual eye lens doses ranges from a minimum of 0.4 mSv to a maximum of 3.5 mSv with an average dose of 1.3 mSv, considering that the use of lead glasses is not taken into account. The average eye lens doses are 1.2 ± 0.5 mSv for the radiological (mainly vascular catheterization, biopsy, infiltrations, embolization), 1.5 ± 0.7 mSv for cardiological (coronarography, ablations, implantation of pacemakers or defibrillators), 0.5 ± 0.3 mSv for gastroenterological (mainly retrograde cholangiopancreatectomy) and 1.3 ± 0.4 mSv for surgical (limbs fractures, vertebroplasty) procedures.

The estimated annual eye lens dose is well below the revised ICPR's limit of 20 mSv/year for interventional radiology, cardiology and surgery workers. With radiation induced cataract being explained as a possible stochastic effect, without a threshold dose, workers who regularly work in a radiological environment should remain vigilant and maintain radiation safety standards at all times. This includes adequately protective equipment, keeping distance, routine monitoring, appropriate education and for a minority the use of eye dosimeter.

Subject: Medical

Preliminary validation of the MC-GPU Monte Carlo code against PENELOPE/penEasy code system for interventional radiology and cardiology

Mercè Ginjaume

Introduction

Directive 2013/59/EURATOM establishes basic safety standards for the protection against the dangers arising from exposure to ionizing radiation. The Member States' system for radiation protection shall be based on the principles of justification, optimization and dose limitation. At this regards, the directive emphasizes the needs of justifying the benefits outweighing the risks of medical exposure. In article 60, it is specified that the equipment used for interventional radiology and cardiology are required to report the relevant parameters for assessing the patient dose. In this framework, this study presents the preliminary validation of the fast Monte Carlo code MC-GPU to determine skin dose distribution for simple interventional procedures. The work has been developed within Subtask 2.2.2 of H2020 European MEDIRAD project.

Methodologies

The novel MC-GPU code has been employed to calculate air kerma and skin dose distribution for several X-ray projections of interest in interventional radiology. MC-GPU code implements a massively multi-threaded Monte Carlo simulation algorithm for the transport of X-rays in a voxelized geometry and runs on NVIDIA GPUs, which considerably speed up the simulation with respect to the execution on a single CPU. In a first step a PMMA slab phantom was used to simulate the patient and subsequently the 34-years-old male Duke phantom from the Virtual Family was employed. Results are compared against the well-validated Monte Carlo simulation program PENELOPE/PenEasy.

Results

Results obtained from the two simulation codes show very good agreement, with differences below 0.1% for simple geometries and within uncertainty for the anthropomorphic phantom. Furthermore, both codes identified the maximum dose at the same voxel position. One of the most relevant issues of the study was the comparison of the computing times needed to complete the simulations by the two algorithms, in order to achieve standard errors <<1%. Executing time for PENELOPE on a single CPU took around 100 to 1000 times more than the same simulation implemented on MC-GPU.

Conclusions

It has been verified that MC-GPU provides good estimates of the dose when compared to the well-validated PENELOPE code for the simulated scenarios, and in very short executing time. The following steps are to simulate complex procedures with several projections and to compare results with MCNPx and measurements. Subsequently, the development of an interface with the X-ray console to obtain real-time data is planned.

Subject: Medical

Calculation of organ doses for CT examination

Fouad Maaloul

Ionising radiation needs to be precisely evaluated since CT scan is the main radiological examination today.

Biological effects caused by radiation are estimated with computational methods as it's not possible to measure the real doses delivered directly to a specific organ.

The DOSITRACE software is a Dose Archiving and Communication System (DACS) based on a new calculation method which allows a more reliable estimation of organ doses.

The aim of this study was to compare our results with the results given by the VIRTUALDOSE software using the Monte-Carlo method.

Methods

CTDIvol, current and rotation time for each acquisition were used to calculate organ doses (ICPR).

Four CT protocols (abdomen-pelvis, chest-abdomen-pelvis, chest and thorax) were used with three different CT scans. Thirty patients were selected for each protocol.

In total, CT scan exams were analysed and our results were compared with the ones obtained with the VIRTUALDOSE software.

Results

There was only a 15% difference in the estimation of organ doses between the VIRTUALDOSE and DOSITRACE software's results which is not statistically significant.

We demonstrated that DOSITRACE is a reliable software in order to calculate organ doses.

Subject: Medical

Radiation Protection Challenge: Building a new Academic Medical Centre at an existing Site

Collarette Eggels

The Erasmus Medical Centre is the largest Academic Medical Centre in the Netherlands, located in the center of the city Rotterdam. The decision to build a new hospital on the existing location was driven by the importance of the presence of an emergency department downtown Rotterdam but posed many challenges for the Radiation Protection Unit (RPU). The RPU was involved with planning, design, construction and acceptance of the new buildings but also of the temporarily relocation of departments and the demolition of existing buildings.

Optimization of radiological protection wasn't easy because there was barely information about selected radiation sources at the time the design decisions were made. In addition, the activities of demolition and construction were hindered by the fact that project management of both activities were split up and by the impossibility to stop treatment of patients for a couple of months. Therefore, departments had to be temporary relocated resulting in having to create the design for the radionuclide therapy department twice. The decommissioning of this department therefore also has to take place twice. This said and on a positive note, learning's from the first design could be considered in the redesign. An advantage that is not granted to every RPU.

In the process of (re)design, the RPU plays a dual role. On one hand the RPU gives advice with respect to the design and on the other hand it is not possible to grant internal permissions because of the lack of information regarding radiation sources. Another challenge was the change of permit. Because the Department of Radiotherapy and Radionuclide Therapy were located on the other side of the river, and the need of ongoing treatment of patients, it should be possible to start the commissioning of accelerators and relocate these departments somewhere between January 2017 and May 2018. Given that radiation sources were needed at two different locations, we had to explain to the government why there was a need for permits at both locations for each of the different radiation sources, despite fact that radiation sources would only be present, and be used, at one location at the time. Finally we were dealing with a number of external nuisance factors, such as amending legislation, fusion with other hospitals and building activities in the neighbourhood, which caused additional challenges.

Subject: Medical

Comparison of organ and effective doses for whole-body CT-examination for pediatric and adult patients estimated by different methods

Larisa Chipiga

The aim of the current study was to compare organ and effective doses of patients for whole-body CT scans calculated by different dedicated software programs with their values measured in physical phantoms.

The whole-body CT scans have a significant advantage in terms of comparison: all organs are in a primary beam of the radiation area. Organ doses were measured using thermoluminescent (TL) detectors in 1-year-old, 5-years-old and adult anthropomorphic phantoms. Three computation software programs: CT-Expo 2.3.1, VirtualDoseTMCT and NCICT (beta version 1.00) were used to calculate organ doses. A comparison between measured and calculated organ doses was performed using a Bland-Altman analysis. The effective doses were estimated according to ICRP Publication 60 and ICRP Publication 103.

An overall good agreement was observed between the investigated software and measurements results due to full irradiation of radiosensitive organs. Differences in 12 major organs were within approximately 15%. However, differences could reach up to 30% for certain organs that are located at slightly different positions in the computational models vs. physical phantoms. The effective doses estimated with the software programs agreed with the results of TLD measurements within 10% despite some differences in the organ doses. All investigated methods are suitable for estimation of effective dose for whole-body CT scans.

Subject: Medical

Evaluation of structural radiation protection by Monte Carlo methods

Lena Landwehr

In the current regulations and standards for safety for radiation protection we find general information about techniques to build an adequate structural radiation protection in radiotherapy facilities. But ducts, clearances or geometry overlaps may lead to weak spots, which are usually only noticed in the late construction phase by real dose measurements. We address this problem by observing different geometries to identify constructions, which guarantee a sufficient radiation protection.

The general-purpose Monte Carlo code MCNP was used to model the head of a clinically used linear accelerator and its surrounding radiation protection construction. The head was modelled according to publicly available literature for 6,7 MV, 10 MV and 15 MV, so not only gamma radiation, but also neutron radiation was considered. The verification was carried out with the help of depth-dose datasets.

The structural radiation protection was adjusted for the three acceleration voltages, so three different bunker models were designed analogously to specification in DIN 6748-21 and the particle distribution was observed (see Fig. 1). Following, different geometries and their radiation protection abilities were investigated. This was carried out in the primary beam and in an area with scattered radiation.

Variation of the duct diameter and its geometry showed that for ideal bent ducts the photon dose does only have small variations as a function of diameter. For neutrons, the difference between the duct types is very small. A reduction of the clearance between the radiation protection door and the floor does not have a big effect on the gamma dose behind the door for high energies. The lacking overlap between the radiation protection door and its adjoining wall is best cured by simple blocks of concrete.

With the help of MCNP different geometries were successfully modelled, so the sufficiency of different radiation protection geometries could be proven. We recommend the usage of bend ducts, so the gamma dose behind the walls is as low as possible. For neutrons, it can still be a source of leakage. Adjustments of the doors to reduce clearances show only small improvements at high costs. The usage of simple concrete blocks is efficient in both radiation protection and costs.

Subject: Medical

On the influence of strong magnetic fields to the response of thermoluminescent dosimeters

Mag. Atallah Gabriel Copty

Introduction:
Our aim is to determine whether a strong magnetic field can have influence on thermoluminescent dosimeters (TLDs) used for personal monitoring.

Two sets of experiments were performed. First to check whether already exposed dosimeters may partially lose the stored dose when exposed to a strong magnetic field, like that of a 7 Tesla magnetic resonance imager (MRI), a kind of magnetic induced fading or magnetoluminescence; second to check whether TL-phosphors accumulate dose properly while being irradiated within a magnetic field, a sort of magnetic induced attenuation of dose accumulation.

A hypothesis based on the experimental results was made concerning the magnetic influence on the kinetics of thermoluminescence.

Objectives and Methodology:
The practical purpose is to study the influence of magnetic fields from MRI Systems on TL-dosimeters of monitored radiation exposed medical personnel, dealing with radioactive patients in combination with entering in the magnetic field of an MRI.

Furthermore in the medical field of oncology new PET–MRI integrated systems are in use for diagnostic purposes as well as MRI–Linac integrated systems for therapy. Any influence of a magnetic field, on the acquired dose of a TLD, which has not been examined yet, may have medical as well as legal consequences. Magnetic field strengths ranging from 0.15 Tesla up to 7 Tesla, using MRI as well as neodymium magnets, were mainly applied on TL phosphor LiBO:Cu under irradiation with different Cs-137 sources.

Results:
The first set of experiments showed no magnetic induced fading or magnetoluminescence.

The second set of experiments showed a statistically relevant magnetic induced attenuation of dose accumulation. The peak of the effect, where about only half of the dose was accumulated, lies by 0.2 Tesla, a field strength at a typical place where staff usually assists radioactive patients in a 3 Tesla MRI.

Conclusion:
The effect we discovered, on the influence of strong magnetic fields to the response of thermoluminescent dosimeters is manifested by an attenuation of dose accumulation; this effect sheds a new light on the kinetics of thermoluminescence. Since we found out that the dose accumulation within magnetic field undergoes attenuation, one can question how to consider this effect in practice.

Any influence of a magnetic field on dose acquisition of a TLD, that underestimates the dose, may have medical as well as legal consequences.

Subject: Medical

Applications of a solid state dose profile meter in a fluoroscopic system

María Esperanza Pérez Álvarez

INTRODUCTION

Until now, computed radiography system and radiographic films are commonly accepted for field size determination. But as digital systems are here to stay, in time CR will become obsolete and radiographic film is very costly in a long term.

A new methodology for measuring field size of a X-ray machine is described using as a dose profiler the CT Dose Profiler of RTI based on solid-state technology. With Black Piranha it can be achieved sensitivity for dose rate of 40nGy/s-760mGy/s and a spatial resolution of 0,25mm. We compare our method against CR method.

METHOD

As a preliminary study, a multifunction X-ray machine was chosen. This allows us to control the dose profiler moving the table remotely, scanning the x-ray field size.

The very first time we measure it we have to characterize the speed of the table, both in its longitudinal and lateral directions. With the speed of the table and the time of measurement, we are capable to obtain the dimensions of the radiation field.

In the following measurements we could use this characterization of the speed table for our measurements.

Every time we measure it, extreme caution must be taken to ensure we are choosing the diameter of the radiation field. It requires perform one measurement where we obtain a chord of the circumference. The following measurements will be made on the bisector of this chord. Therefore we assure the dose profile is passing through the center of radiation field.

Finally, we can measure all field sizes of our multifunction X-ray machine.

RESULTS

Ocean analysis will indicate the width of each dose profile obtained from every field size as can be seen on figure1.

The method is validated by measuring the diameter of field size with a CR at the same source to detector distance.

Results of both measurements can be seen on table1.

Differences between diameter field measured with CR and measurements with dose profiler are not higher to 4mm.

CONCLUSIONS

The results of this study demonstrate our method is comparable to the CR method.

The main advantages are that outdated and more expensive methods requiring read-out after each scan can be avoided. In addition, measurements are stored with the other control data.

The main disadvantage is careful placement of the dose profiler is required and it only gives diameter information instead of the whole field.

Subject: Medical

Estimation of radiation dose for hospital staff outside the department of nuclear medicine as a result of nuclear medicine examinations and treatments

Mariska Sonneborn-Bols

Aim: Patients undergoing a diagnostic examination or treatment at the department of nuclear medicine (NM) can cause a radiation dose to hospital staff outside this department. The procedure for combinations of random hospital appointments is to plan the administration of the radioactive compound after other hospital appointments. However, this is not always possible or known beforehand as most appointments are planned separately. Over the recent years rough estimations have been made of number of combined appointments. Nonetheless, the number of NM appointments has grown substantially and there is a tendency to combine hospital visits on one day. The aim of this study was to get a better estimation of combined appointments and radiation doses this is causing for hospital staff.

Methods: During three months in 2016 all so-called random combined appointments were registered. For diagnostic examinations this was defined as administration and all subsequent appointments on the same day, whereas for therapeutic visits this was defined as all appointments in the week after administration. Standard clinical combinations of appointments, already registered in risk analyses, were excluded. The following parameters were registered:

- NM appointment: date, time and standard activity of radioactive compound

- Subsequent appointments: date, time, duration and acts during the appointment

Based on this information a theoretical calculation was made for the staff in the subsequent appointment in worst-case scenario: no excretion of the radioactive compound and one worker by type of subsequent appointment.

Results: 18% of all nuclear medicine examinations had a subsequent hospital visit the same day. No NM treatment had a combination appointment. 18F-PET examinations were most combined (177 of the total 370 combinations). The total radiation dose caused by the combination appointments was 1,2 mSv/year, but must be distributed over various departments and workers. For non-radiological workers the highest dose is 0,15 mSv/year for workers making the ECG's. For radiological workers the extra radiation dose is at most 0,11 mSv/year for workers making the CT-scans.

Conclusions: Calculated dose to non-radiological workers and extra dose to radiological workers is in worst case scenario low. Additional measurements are not necessary based on these results. The procedure to plan the administration of the radioactive compound after other hospital appointments must be pursued, but in case this is not possible it can be planned otherwise. The number of combination appointments must be monitored over the next years.

Subject: Medical

Dissemination of materials regarding exposure to ionising radiation in diagnostic and interventional radiology by using the web platform

Gabriel Stanescu

INTRODUCTION

Nuclear Training Centre (CPSDN), department within the “Horia Hulubei” National Institute of Physics and Nuclear Engineering IFIN-HH, develops training programmes on radiation protection and radiation safety in medical, industrial and research practices. The CPSDN’s web platform is a module of a complex strategy that involves a coherent integration of classical methods and online information management systems.

OBJECTIVES

The objective of this paper is to present the implementation of the Romanian version of some materials published by international bodies in the nuclear field within the dissemination module of the web platform. The aim is to increase the level of awareness of the visitors with regard to basic knowledge of radiation physics and radiation protection, maximizing the impact of information and dissemination actions carried out by CPSDN through training programmes. The results of our previous studies show a lack of knowledge about exposure levels in medical examinations with ionising radiation, even for a relatively knowledgeable audience in the field, like the visitors of the CPSDN’s web platform. Based on these results, it has been decided to achieve local versions of some materials published by international bodies (IAEA) in order to increase the attractiveness of the information and dissemination module.

RESULTS

The posters and leaflets developed by the International Atomic Energy Agency (IAEA) for dissemination of practical information on radiation protection in medical exposures were translated in Romanian, with IAEA acceptance. All these informational materials were then published within the platform in order to be disseminated among workers and the general public. Because an analysis regarding the impact of publication of materials on the platform's audience has been considered useful, a tool to monitor downloads was implemented. The recorded results indicate the clear interest of visitors for quality information on patient protection in widespread procedures with high level of radiation. To be noted the low interest on protection in pediatric interventional procedures, much rarer and less known.

CONCLUSIONS

It can be considered that the web platform's dissemination component has been enriched with topical materials in the nuclear field. By adding new features, more capabilities have been acquired to monitor and analyse the impact of the published materials.

Subject: Medical

Consequences of Maternal Exposure: Stillbirth Rate and Infant Mortality in Offspring of Radiation-Dangerous Production Staff

Sosnina Svetlana

Production Association “Mayak” is the first nuclear complex in Russia. Mayak Workers Cohort includes about 26,000 workers initially employed in 1948-1982, 25% of them are female workers.

The stillbirth rate (SR) and infant mortality (IM) in the group of female Mayak workers (FMW) offspring (n = 3234) were analyzed in comparison with the children from unirradiated mothers (n = 11741).

Groups are comparable in place of residence, birth period (1951-1973), ratio by sex and calendar year, distribution by maternal age of child birth, equal quality of medical care.

FMW were subject to protracted radiation occupational exposure in a wide range of doses. The median of individual accumulated preconceptive doses of external gamma irradiation on the whole body was 284.0 mGy, the maximum accumulated dose reached 9509.0 mGy.

Significant excess of the SR level among study group (SG) (14.8 per 10^3 and 8.1 per 10^3 in the comparison group (CG), $p<0.05$) was found. Significant predominance of the number of stillbirths among FMW with a dose of external γ-radiation before conception less than 1 Gy was noted.

Essential differences in the groups were also revealed in the level and structure of perinatal mortality (PM): 24.1 per 10^3 in SG and 17.9 per 10^3 in the CG. Certain conditions originating in the perinatal period (8.9 per 10^3 in the SG versus 5.5 for 10^3 in the CG, $p<0.05$) and intrauterine fetal death (5.6 per 10^3 and 2.2 per 10^3 accordingly, $p<0.05$) dominated in the structure of the SR and PM.

The IM rate as a whole did not differ in groups. The exception concerns postneonatal mortality, which in the SG (17.8 per 10^3) significantly exceeded those 12.9 per 10^3 in the CG. The structure of IM in the compared groups did not significantly differ. Perinatal pathology, infectious diseases and respiratory diseases were the major causes in the structure of IM. Differences in the level of congenital malformations in the groups were not found.

Conclusion: In the group of children of irradiated mothers the levels of SR, PM, postneonatal mortality were higher; certain conditions originating in the perinatal period and intrauterine fetal death were recorded more often than in CG. Despite the multifactorial nature of these conditions, the crucial role of maternal irradiation in adverse reproductive outcomes is not excluded, which requires further research.

Subject: Medical

The role of intercellular communication in endothelial cell response after ionizing radiation exposure

Valerie van Eesbeeck

BACKGROUND: Medical applications of ionizing radiation (IR) have become widely used for diagnostic as well as therapeutic purposes. Emerging evidence indicates an excess risk of late occurring cardiovascular diseases, especially atherosclerosis, after IR exposure. IR induces cellular effects which may induce endothelial cell dysfunction, an early marker for atherosclerosis. In addition, intercellular communication through channels composed of transmembrane connexin (Cx) proteins, i.e. gap junctions (GJs; direct cell-cell coupling) and hemichannels (paracrine release/uptake pathway) can modulate IR-induced responses and thereforethe atherosclerotic process. However, the role of intercellular endothelial communication, particularly the role of Cx channels, in IR-induced atherosclerosis has never been described before.

OBJECTIVE: To Investigate the role of endothelial intercellular communication in radiation-induced atherosclerosis.

METHODS: Telomerase immortalized human Coronary Artery/Microvascular Endothelial cells (TICAE/TIME) were exposed to X-rays (0.1, 0.5 and 5 Gy). Several biological endpoints were investigated: Cx gene expression, Cx protein levels, GJ and hemichannel function. In addition, production of reactive oxygen species, cell death and inflammatory responses were assessed with or without applying a hemichannel blocker (TAT-Gap19).

RESULTS: Exposure to IR induced acute and persistent upregulation of Cx43 and downregulation of Cx37 and Cx40 gene and protein levels in a dose-dependent manner. In addition, IR exposure increased GJ communication and induced hemichannel opening. Moreover, IR induced a dose-dependent increase in cell death, inflammatory responses (Il-6, MCP-1 and PECAM-1) and ROS production. These effects were significantly reduced in the presence of the Cx43 hemichannel-targeting peptide TAT-Gap19.

CONCLUSION: An increase in intercellular communication after IR exposure may alter the transfer of IR damaging signals (ROS, cell death, inflammation) between the cells, resulting in an increase in endothelial cell damage. In addition, similar alterations in Cx expression levels have been reported in the literature in endothelial cells covering atherosclerotic plaques. Therefore, these results suggest that IR may contribute to atherosclerosis progression.

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Subject: Medical

Strategies for the sustainable production of medical radioisotopes

Lars Roobol

Apart from PET isotopes like fluorine-18, almost all medical radio isotopes used in the world are produced by means of nuclear reactors. These reactors are few in number and ageing. Large scale shortages have already occurred in 2009 and 2010, due to unplanned maintenance to reactors.

These shortages have inspired many countries, most notably Canada and the United States, to start up projects leading to the production of medical radio isotopes for their own hospitals.

Since all research reactors have been built and are operated with government support (fully or partially), an economic climate has evolved in which the market price of these isotopes is well below full cost. This situation has a significant negative impact on the possibilities to develop novel and overall more cost effective production routes and isotopes.

Alternative techniques are emerging, promising to make large quantities of molybdenum-99/technetium-99m, the isotope used most in nuclear medicine, by means of various types of particle accelerators. These alternatives do not yet provide a solution for a large number of other isotopes, primarily relevant for cancer treatment.

In this article, we propose strategies for setting up the next generation of production of medical isotopes in Europe, considering the following aspects:

• resilience against disruption at individual production locations, i.e. no single point of failure in the production chain (sustainable health care);

• production with optimum cost to the environment, taking into account the installations already built and planned (environmental sustainability);

• ensuring that a broad range of isotopes is available at an acceptable price, based on a sound business case, without government subsidies (economic sustainability);

• ensuring that there are enough people available wanting to make a career in all aspects of the production chain of nuclear medicine (sustainability of knowledge);

• ability to quickly respond to the development of novel diagnostic and therapeutic modalities requiring the production of new isotopes (sustainable innovation).

Monitoring

Subject: Monitoring

Monitoring the Radioactivity of Aerosol Particles: A new Network in Switzerland

Daniel Lienhard

We established a new monitoring network measuring the particle bound radioactivity of ambient air in Switzerland. The network consists of 15 measurement sites, covering the whole of Switzerland with a focus on the areas surrounding the four nuclear power plants. At each station, a vacuum pump draws ambient air through a glass fibre filter paper with a flow rate of 18 m3/h while the particles deposit on the filter. Radiation emitted from these particles is absorbed by a high purity germanium detector located just below the filter. The energies of the absorbed gamma-rays are measured on-line between 30 and 2000 keV with a resolution of <2keV, thus permitting the identification and quantification of individual radionuclides. The spectra are automatically analysed every 5 minutes in order to calculate the concentrations of radionuclides in the air. If the permissible exposure limit of any radionuclide in ambient air is exceeded, an alarm is sent to the scientific and technical staff as well as to the National Emergency Operations Centre.

We present an overview of the technical details of the measurement device and the theoretical background of the calculations involved. In addition, we show the temporal evolution and correlation of some naturally occurring radionuclides in airborne particles.

Subject: Monitoring

Monitoring of Ambient Dose Equivalent at the Boundary of Nuclear Sites to Verify Compliance with Regulations in the Netherlands

Cristina Tanzi

A network of monitoring posts positioned at the boundary of nuclear facilities in the Netherlands measures the gamma ambient dose equivalent. The purpose of this MONET network, operated by RIVM, is to independently verify compliance with the dose limit granted in the operating permit. A combination of proportional counters and Geiger-Müller detectors (fixed as well as portable) are deployed. The measurements are analyzed in order to distinguish between changes of the gamma dose equivalent rate due to the operations of the nuclear facilities from variations of the natural background. For instance, an increase of the ambient dose equivalent due to the raining out of the radon progeny in air can, to a certain extent, be correlated with local precipitation.

The analysis of the measured dose rates relies on the determination of the variability of the measurements for each of the MONET monitors. This method allows us to estimate, for the measured ambient dose equivalent, the increased radiation dose due to normal operations of the nuclear facilities, together with a confidence limit.

Naturally-Occurring Radioactive Materials (NORM)

Subject: NORM

Natural radioactivity of building materials in Belgium: current situation and regulatory approach

Stéphane Pepin

As all other EU members states, Belgium had to implement the relevant requirements of the EU BSS regarding natural radioactivity of building material. The Belgian radiation protection authority (FANC) organized in 2016-2017 a measurement campaign of 70 building materials. These building materials were selected taken into account the indicative list of annex XIII of the EU BSS; for imported natural stones, the selection was guided by the portal monitor measurements performed by the Customs on all containers in the harbours of Belgium.

Results of this campaign as well as from previous campaigns performed by other institutions will be presented: no building material of concern could be identified. The implementation in Belgian regulations of building materials aspects of EU BSS will thus focus on regular surveys of the natural radioactivity in building materials used in Belgium rather than on systematic measurements of specific categories of building materials. For the control of imported building material, it will be striven for an increased collaboration with the Customs in order to more closely follow portal monitors data on building material containers in the harbours.

Subject: NORM

Assessing the public exposure related to the use of NORM in new types of building materials

Wouter Schroeyers

For a safe reuse of Naturally Occurring Radioactive Materials (NORMs) in construction, it is of great importance to evaluate the radiological aspects of the reuse in addition to chemical, environmental, economic aspects before the construction materials are introduced on the market. This is of particular importance for new types of construction materials, such as alkali activated materials, that allow the reuse of a large faction (wt%.) of residues. The new Euratom BSS (basic safety standards), that needs to be implemented by the EU member states by the 6th of February, sets the requirement of the radiological evaluation of building materials that incorporate specific residues from NORM related industries. In the period 2014-2017, the COST Action Tu1301 NORM4Building initiated a lot of research on the radiological evaluation of new types of construction material that are currently in the research state. In the course of the NORM4Building project a radiological database on NORM & building materials was developed. In addition, new dosimetrical tools were developed for a more realistic evaluate of the gamma dose related to the reuse of NORM in construction. These dosimetrical tools provide a more realistic radiological screening of the reuse of building materials in addition to the Activity Concentration Index (ACI) that is proposed by the EU-BSS as screening tool. In the current presentation, the contents of the NORM4Building database will be presented next to the newly developed more realistic dosimetrical tools for the evaluation of the public exposure to gamma radiation from different types of building materials. The NORM4Building database is available via www.norm4building.org and in the future via the website of the new European NORM Association (ENA).

Subject: NORM

Assessment of radiological significance of building materials and residues

Natasa Todorovic

The estimation of the radioactivity levels of materials utilized in construction sectors is crucial in the assessment of possible radiological hazards to human health. In the paper, the results of gamma spectroscopy study of 211 zircon, 425 sand, 781 lime, 348 perlite, 2692 cement, 232 calplex, 968 gypsum, 2741 granite and 21 coal fly ash samples gathered from different countries and imported in Serbia in period 2006-2016 were presented. In order to assess the radiological impact from the investigated samples, the activity concentration index IRP112 for all samples was ascertained. This research yields insight into the radioactive content in a variety of building materials of different origin. Obtained results discussed on the basis of relevant national and international legislation and guidance and compared with the corresponding results in the literature.

Subject: NORM

A practical method to comply with BSS regulations for the exposure to gamma radiation in dwellings, when taking multiple construction layers into account

Jasper Tomas

The Basic Safety Standards (BSS) (EURATOM 2014) introduce a reference level for the external exposure in dwellings to gamma radiation emitted by building materials. It states that special attention should be given to materials that may contain relatively high concentrations of natural radionuclides (listed in Annex XIII). In addition, Annex XIII introduces an activity concentration index that can be used as a screening tool to identify materials that may cause the reference level to be exceeded. A challenge arises from the BSS: The activity concentration index given in Annex XIII considers a single building material, while the reference level applies to the exposure due to all building materials in a given dwelling. Therefore, the question arises how to deal with the common situation were multiple construction materials are used in several layers.

This research addresses this topic. A practical methodology is presented that allows for the assessment of external exposure due to gamma radiation emitted by multiple building materials. The methodology can be the basis for regulation of additive NORM to building materials. It builds upon the methodologies introduced by CEN (CEN 2017) and NRG (De With 2017) and can be summarized as follows: 1) The properties of each applied layer of material, such as specific mass and radioactive content, are taken into account. 2) The regulator determines the conditions that apply to each type of material layer, i.e. its `intended use'. This includes the thickness that should be assumed for a material layer and if the layer is considered to be a `bulk material', or a `surface material'. 3) The regulator defines the maximum allowed dose received from the bulk and the surface materials.

As a result, for both bulk and surface materials a graph can be constructed that shows the maximum allowed percentage of additive NORM for each material density. Depending on the chosen dose limits the two resulting curves can be very similar, such that a single curve is sufficient for all construction materials, see Figure 1.

Examples will be shown in which practical situations are assessed. A comparison will be made between the application of the activity concentration index and the proposed methodology. Finally, an outlook will be presented on the extension of the methodology that may regulate the exposure to thoron progeny due to thoron exhalation by building materials.

Subject: NORM

Remediation of a pit for mine drainage water in Germany in terms of an artificial cover

Tobias Hein

Drainage waters from mining activities often show elevated concentrations of natural radionuclides. Pumping into a pit for storage usually includes the precipitation of radioactivity and a subsequent deposition in form of sediments. These sediments are referred to as NORM and have to be handled adequately. In the present study, a relatively small pit for coal mine drainage water with elevated levels of natural radioactivity has to be remediated. The usual way for such a remediation is the excavation of the NORM material and the subsequent landfilling. However, in the present case the radiological and geological conditions as well as complicated administrative procedure of landfilling with respect to acceptance criteria for the NORM material in Germany encouraged the development of a concept for the remediation in form of a suitable artificial cover. In the presentation, the following points are covered:

• discussion of the legal requirements according to the respective present radiological and conventional legislation,

• presentation of the radiological measurements and geotechnical investigations,

• presentation of the circumstances concerning environmental pollutants,

• illustration of the concept for the remediation in form of the artificial cover (material, dimensions, etc.) as well as

• discussion of the long term requirements for reuse of the covered area.

Additionally, an outlook with respect to (possible) changes of the legal requirements due to the upcoming modifications according to the 2013/59/EURATOM NORM will be given.

Subject: NORM

Rapid Evaluation on the Clean-up of a Titanium Dioxide Production Site

Zu-Hee Woo

Titanium dioxide pigments manufacture is one of the most significant NORM (Naturally Occurring Radioactive Material) activities in South Korea. Recently, one facility terminated its operation and completed the decommissioning including site clean-up in a short period of time. According to the Act on Protective Action Guidelines Against Radiation in the Natural Environment in 2011, national authority should verify that no residual contamination remains in the area of concern to approve site clearance. For this, the car-borne gamma ray survey using a large volume of NaI(Tl) scintillation detector and in-situ HPGe gamma ray spectromety, that is the most appropriate method to cover large areas effectively, was performed.

Based on an in-situ measurement result, the equivalent activity concentration distributions and contamination levels of U-238, Th-232, and K-40 before and after decommissioning were evaluated.

Subject: NORM

NORM: Are We Speaking the Same Language?

Gert Jonkers

Virtually all participants of this congress will know that the acronym NORM does mean Naturally Occurring Radioactive Materials. However, in the literature this acronym is ambiguously interpreted. Some authors use the acronym NORM, where they actually are referring to the (nuclide's of a) radioactive element Th or U (or daughter nuclides). In such a case the acronym NOR (Naturally Occurring Radionuclide) would be much more appropriate and unambiguous. A natural resource always does contain low – sometimes even hard to measure – concentrations of primordial (or secondary) NOR's. So, from a scientific point of view these resources always may be denoted as NORM. From a regulatory point of view, however, it is undesirable to denote materials with NOR concentration levels below regulatory concern as NORM. From chemical processing of natural resources various gaseous, liquid and/or solid process streams with low levels of redistributed NOR's may result. In relevant cases these kind of streams are also indicated by the acronym NORM (but according the Oxford dictionary material is described as 'matter from which a thing is or can be made'). Even a worse indicator will be reference to annex VI of the European Council Directive 59/2013/Euratom as "the list of NORM industries", as if it the purposes of these industries to produce NORM. This presentation will address the common semantics used in papers and presentations on NORM issues, and attempts to provide guidance for use of appropriate and unambiguous terminology with respect to NORM. It will be more an interactive, discussion type of contribution instead of a thorough scientific contribution.

Subject: NORM

How to build the national-level NORM inventory? An example developed from scratch

Boguslaw Michalik

Problem of NORM (naturally occurring radioactive materials) was recently elucidated to a certain degree by the latest European BSS (Council Directive 2013/59/Euratom) as well as IAEA ones (GSR Part 3) that both cover several NORM occurrence aspects including occupational exposure as well as its possible interaction with environment. Many countries currently are facing a problem of all NORM cases identification. Usually many premises exist and majority of cases of concern can be easily identified based on generic knowledge about NORM features. However, activities involved with NORM cover broad industrial sectors of much diversified characteristics. Exposure situations caused by NORM presence are different in terms of appearance and depends strongly on technological processes applied. Moreover, many industries of concern have not been regulated in term of radiation safety to date hence strong needs are observed to have a systematic approach to identify all NORM situations in a country level.

In this article a four-tier system of NORM identification developed from scratch is proposed. It commences by analysing natural resources available in a country. Then, active mining industry, mineral processing industry, including supply sources and transport media, and waste stream are considered as possible source of NORM. For every tier available sources of information, necessary actions for e.g. to avoid unpredicted loss caused by NORM, typical exposure situations and possible monitoring as well as mitigation methods are provided.

Subject: NORM

Establishing a national NORM inventory and determining NORM management options – Estonia's experience

Taavi Vaasma

Nation-wide studies have been carried out between 2014 and 2017 by the University of Tartu to determine and radiologically characterize potential NORM-related industrial activities in Estonia. These studies were supported by the Ministry of the Environment, which acts as the regulatory body to carry out the implementation of requirements from the Council Directive 2013/59/EURATOM into the national legislation.

The investigated industrial activities were selected based on available knowledge and international practices and experience. This led to the investigation of the following industries:

- Oil shale industry (power plants and oil production);
- Groundwater treatment plants;
- Rare metal processing industry;
- Cement production;
- Biofuel-based central heating;
- Maintenance of large combustion boilers; clinker ovens;
- Underground mines.

The studies have demonstrated that there are currently three industrial activities where NORM is produced as a by-product – rare metal production, groundwater treatment and cement industry. Although NORM from the rare metal production (chemically and radiologically hazardous material) was a previously known concern, NORM created in groundwater treatment (elevated concentrations of Ra isotopes) and cement industry (elevated concentrations of Pb-210 in clinker dust) was identified for the first time.

These new findings together with currently missing strategies and practices for the management options of NORM-materials are forcing the national authority to establish an overall policy and strategy on NORM management. First steps have been taken - a list of industrial activities have been identified where reporting on the radionuclide activity concentrations in various (by-)products can/should be incorporated to the overall environmental licensing process. Also, justified options (e.g. landfilling, repository, reuse) for the management of different NORMs are being investigated.

Problems arising from insufficient experience and lack of regulatory framework regarding NORM in Estonia can be highlighted through the experience with groundwater treatment plants where NORM was first discovered in 2013 (at Viimsi Vesi Ltd.). A lack of actions taken to start investigating suitable management options for this material caused a standstill between the authority and drinking water suppliers, resulting in illegal management of NORM (filter material), concerns over the radiation safety of workers and economic losses for the drinking water suppliers. In 2016, Viimsi Vesi Ltd. proposed to the national regulator to dispose the NORM-waste in municipal landfill. Currently this process is under way by the authority and licenses are expected to be issued within 2018.

Subject: NORM

NORM residue and NORM waste Policy and Strategies challenges and opportunities

Daniel Kidane

Naturally Occurring Radioactive Materials (NORM) are available in many natural resources. Human activities while exploiting natural resources enhance the concentration, solubility, and subsequently the exposure to these materials. Dispersion of these materials will contaminate soil, ground water and surface water. To mitigate the problems they pose it is necessary to prepare effective policy and design sound and viable strategy to manage NORM residue and NORM waste. But preparing policies and designing strategies are not enough. What matters is their implementation. For sustainable implementation of the policy there are many factors. These are economical, political stability, social acceptance and trust, availability of advanced technologies and human capital a country has. The vision, awareness and commitment of the decision maker, peace of the country, transparency, social benefit, remediation and rehabilitation of (legacy cites, current/ongoing practices and future planed practices sites), educated human capital and status of the economy of the country are crucial points for the implementation of the policy and strategy. For effective and sustainable management of the policy and strategy addressing these issues is important. This paper treats the challenges and opportunities that the factors create on the implementation of NORM residue and NORM waste policy and strategy. It also proposes the possible solutions.

Subject: NORM

Transfer of naturally occurring radionuclides to biota, exposure to man and risk perception – Case Orrefjell

Håvard Thørring

One of the largest uranium deposit in Norway, Orrefjell, is situated in the Upper Salangen area. The enhanced U levels in the bedrock are related to pegmatitic intrusions in Precambrian basement gneisses. Case Orrefjell – a cooperation between scientists from natural and social sciences, and pupils from a local high school – investigated possible adverse effects from living in an area with enhanced levels of NORM. The project had a broad scope and included studies of local geology, environmental transfer of relevant radionuclides, human exposure to radon, and the risk perception of people living in the area. The involved pupils made a considerable contribution to the outreach of the project.

The Orrefjell area is used for human recreation and as pastureland for rough grazing animals. An important part of the project was therefore to get a better overview of external exposure and levels of important radionuclides in soils and vegetation. At the sites with considerably elevated background, surface soils contained high levels of 226Ra and 210Pb/210Po. Up to 1700 Bq/kg DW of 226Ra was found in plants. In contrast, the levels of 238U were low in most surface soils and plants from these sites.

To evaluate radon exposure to people living in the Salangen area, indoor radon levels were measured. 23 % of the homes had radon levels above the recommended maximum level of 200 Bq/m3 set by the Norwegian authorities. The highest indoor radon concentration (2100 Bq/m3) was found in the upper part of the Salangen valley close to the areas with enhanced U levels. The indoor radon concentrations will be used to improve the national susceptibility map for radon. High outdoor radon concentrations were also measured in the area.

In addition to the natural science surveys, we also explored to what extent local people are aware of the uranium deposit at Orrefjell, and if it causes concern. This was accomplished through a survey of people's awareness of radioactivity and risk from radon exposure. About 200 inhabitants completed the survey. 63 % of the respondents were aware of the elevated uranium levels in Orrefjell but largely use the area equally to other areas. Moreover, the inhabitants are aware of the risks of radon exposure, and know that radon might contribute to lung cancer. Despite this, only one fifth had taken their precautions and measured their residential levels. Thus, they do not seem too worried about the potential consequences.

Subject: NORM

Discharges from NORM industries in Germany: estimate of doses to members of the public

Christian Kunze

The European Basic Safety Standards (BSS) 2013/59/Euratom have removed the previous distinction between practices and work activities. Henceforth handling and processing NORM is covered by the concept of practices. Consequently, doses incurred by members of the public resulting from discharges from NORM industries must be taken into consideration to ensure compliance with the dose limits for public exposure according to the BSS, Art. 12.

In transposing the BSS into national law, Art. 23 requires Member States, inter alia, to identify classes or types of practice involving naturally-occurring material (commonly known as NORM industries) that may lead to exposures of members of the public that cannot be disregarded from a radiation protection point of view. Discharges are part of the practice and may be subject to regulatory control.

The German Federal Office of Radiation Protection (BfS) contracted IAF-Radioökologie GmbH to implement a research project entitled “Estimation of potential public exposure due to discharges from NORM industries”. In the context of this project, dust, radon and water discharged from NORM industries were investigated.

The investigation included the 16 sectors of NORM industries listed in Annex VI of the BSS, and additional sectors that have been known in Germany for potentially being of radiological concern. In total, 26 industrial sectors have been analysed.

This paper provides an overview of the approach, methods and results of the research project that was carried out between June 2015 and December 2017. The analysis of each industrial sector and the associated discharges started from a review of the size of the sector (number and capacity of plants currently operating in Germany, and, where appropriate an outlook to future developments) and the technological processes which may cause radiologically relevant discharges. A conservative screening tool was developed and applied to select NORM industries that may safely be excluded from a more detailed analysis.

NORM industries that passed the screening stage were then analysed in detail with respect to the source term of radioactive discharges. The dispersion of radioactivity in the environment was described using advanced models such as air quality code ARTM, and all relevant pathways were considered for dose estimates.

It is important to note that the project deliberately avoided a site-specific analysis but adopted a “generic” approach, i.e., covering a wide range of situations that may typically be encountered in Germany, in terms of sources terms and environmental dispersion conditions.

Subject: NORM

Role of environmental impact assessment in regulatory decision making at NORM legacy sites in Norway

Jelena Mrdakovic Popic

The revised Pollution Control Act came into force in Norway in 2011, resulting in radioactive waste being regulated alongside other types of pollutants, thus providing a holistic, ecosystem based approach to the protection of human health and the environment. The Norwegian Radiation Protection Authority has been working on regulation of existing, legacy and potential NORM sites where radiation protection and radioactive pollution to the environment could be potential issues for consideration.

In this paper, importance of environmental impact assessment in the process of regulatory decision-making was shown on examples of two different legacy NORM mining sites.

Study sites, former iron (Fe) mining site and former niobium (Nb) mining site, are located in the Fen Central Complex, geologically well-known area rich in NORM. Six field expeditions were organized in four different seasons in order to analyze the potential seasonal variation.

The environmental impact assessment was based on measurements of:

- terrestrial gamma dose rates,
- outdoor and indoor radon (220Rn, 222Rn) levels,
- activity concentrations of radionuclides (232Th, 238U and their progeny) in environmental samples;

Assessing of radiological risk to terrestrial biota was done using the ERICA Tool, while assessing of risk to exposed humans by calculation the radiation doses in relevant exposure scenarios.

Terrestrial gamma dose rates, thoron (220Rn) and radon (222Rn) concentrations in the air were elevated, up to 16 µGy/h, 5000 Bq/m3 and 400 Bq/m3, respectively, with significant seasonal variation. Calculated annual exposure doses to humans could exceed 10 mSv. Main dose contributor was found to be terrestrial gamma radiation.

Wide ranges with heterogeneous distribution and ‘hot spots’of radionuclides (232Th, 238U and progenies) was found in waste soil and slag at both legacy NORM sites exceeding the screening level for radioactive waste material (1 Bq/g) given in Norwegian legislation. Radiation dose rates for terrestrial organism, calculated by the ERICA Tool with site-specific data, were in range 2 - 11 µGy/h, with maximal value estimated for lichen and bryophytes. Although higher than typical background dose range of terrestrial organisms, biota exposure doses do not implicate radiation risk.

Based on results of done assessments several remediation options were considered and will be presented. Issues and challenges related to assessments and regulatory decisions, but also to assignment of responsibility, risk communication, role of stakeholders and remediation plans will be additionally presented.

Subject: NORM

What is the radiological/ecological impact of NORM residues and effluents on the environment?

Hildegarde Vandenhove

Some industrial activities such as oil and gas extraction, phosphate fertilizer production, ceramic production, coal combustion in power plants or mining and ore processing for the production of metals (tin, aluminium, …), geothermal energy production, … involve the use of materials, usually regarded as non-radioactive but which contain naturally occurring radionuclides (NORM). NORM industries may be of radiological concern for the general public and the environment as a result of their discharges and wastes.

We will present a short overview of the waste production processes and the radiological content of the raw materials, residues and discharges for the NORM industries that may require regulatory control. The main sources and pathways by which technologically enhanced radioactive materials can impact on man and environment and methodologies to assess radiation doses for the dominant pathways for external and internal exposure and fauna and flora exposure will be described. For a few example cases linked with the phosphate industry, a more in depth analysis of the radiological impact to man and environment will be performed.

Human and environmental impact assessment for NORM liabilities and legacy sites requires a site specific approach. The number of dedicated studies on public exposure is rather limited, though it is clear that some exposure situations need a critical evaluation of the risk. NORM is extremely long lived and impacts cannot only be considered in the short term but must include the potential impact for future generations. Long-term impact assessment, stewardship, long-term memory and long-term efficacy of remedial options are key for a robust management of NORM legacy sites.

Subject: NORM

Options for NORM waste management in mining industry

Boguslaw Michalik

In coal mining industry significant amount of NORM residues is credited in form of sediments precipitating from radium rich formation water. The amount of such sediments reaches the level of few thousand tons per year in a singular mine. As the average activity concertation of radium isotopes in these sediments reaches few Bq/g a special treatment must be applied when they are removed from a mine dewatering system. This creates a serious challenge from radiation protection perspective. On the other hand, the technology applied in coal mining industry as well as specific features of excavation process create many opportunities for utilisation such residues, well justified from technical and economical point of view.

In this article methods of sediments treatment already applied, possible, however not applied yet and being under development are discussed. Technical problems with mixing, dilution, underground deposition or landfill are discussed in terms of technical difficulties as well as legal obstacles. The analysis resulted in conclusion that in coal mining industry spare capabilities exists to manage NORM waste in a safe way that can be used for utilisation such waste from other industries.

Subject: NORM

Lessons learned midway through the implementation of the Radium Action Plan 2015-2019 in Switzerland

Murith Christophe

Introduction

In Switzerland up to the 1960s radium was used in the luminescent paint applied to the dials and hands of watches. Given the lack of awareness at that time of the real dangers associated with radium and the weakness of the regulation regarding radiation protection, this activity led to contamination in the workshops and the dwellings in which radium was used as well as in landfill sites where radium-containing waste had been sent as a matter of course.

Methodology

The Radium Action Plan 2015-2019 has been developed to systematically eliminate those existing situations leading to an inacceptable exposure to radium of the Swiss population. Concerning workshops and dwellings in which radium was used, the plan includes 4 steps: the search for potentially contaminated sites, the measurement and assessment of each site, the remediation of those sites where the public would be exposed to a dose above 1 mSv per year and the management of the radium-containing waste resulting from the remediation. The lessons learned midway through the implementation of the action plan by the Federal Office of Public Health will be presented, based on intense diagnostic measurements and remediation campaigns.

Results and discussion

The experience acquired up to now relies on the diagnosis of approximately four hundred sites (houses and gardens) and the remediation of forty of those. The procedures and criteria used for diagnostic measurements, remediation and waste management have proven to be appropriate and effective, including with regard to the financial aspects. Stakeholder involvement was an important ingredient for the successful implementation of the action plan. This requires to actively inform the population and to develop an effective and transparent communication. Building trust between authorities and tenants or owners is essential since measurement and remediation procedures imply intrusions into the privacy. The good collaboration with the local and regional authorities was also a key success factors.

Conclusion

The principles developed by the ICRP for existing exposure situations are proved to be efficient for the practical management of the legacies associated with radium used in the watchmaking industry. The variety and complexity of the situations encountered in all areas (measurements, depollution, waste management, involvement of stakeholders) has made it possible to develop the required procedures and to educate and train the intervention teams. The experience gained could be used in other situations such as post-accident recovery.

Subject: NORM

Geo/Radio-Chemistry/Physics of the Members of the Thorium and Uranium Decay Series

Gert Jonkers

The mining of mineral resources from the Earth's crust can roughly be subdivided into the extraction of gases (natural gas), fluids (water, oil) and ores (coal, phosphate rock, metal ores). In general the extracted mineral resource will contain low concentrations of primordial (and secondary) Naturally Occurring Radionuclide's (NOR's), notably K-40, Th-232(-series) and U-238(-series). Where gas extraction only may transport radon as a secondary NOR into the human ambient environment, ores do generally contain both the primordial Th-232 and U-238 parents in full secular equilibrium with their daughters (secondary NOR's). Upon processing of the ore the primordial (and secondary) NOR's distribute over the various processing phases according to their chemical behaviour under processing conditions. This presentation will provide an example of the appearance of various NOR's during the processing of an ore. Process or waste streams, in which NOR's after processing may reappear, are generically denoted as Naturally Occurring Radioactive Material (NORM). With extraction of fluids only those primordial/secondary NOR's, that both live long enough and do dissolve under reservoir conditions in the reservoir fluids, may appear in surface treatment/process installations. Furthermore this presentation will address the underlying causes of geo/radio-chemical/physical dissolution phenomena of the distinct NOR's into the mobile phase, the transport of these NOR's to the surface and their appearance in surface treatment/processing facilities. The break-up of (full) secular equilibrium series will also strongly influence the interpretation of gamma-spectrometric analysis of NORM samples. Next to this options for cleaning objects, that are surface contaminated with NOR's and for final NORM disposal will shortly be addressed.

Subject: NORM

Survey on naturally occurring radioactive materials (NORM) in the Dutch non-nuclear industry

Emma Folkertsma

The Dutch National Institute for Public Health and the Environment (RIVM) has made an inventory of industrial sectors in the Netherlands involving naturally occurring radioactive material (NORM). This includes an overview of the types of practices possibly leading to the exposure of workers or members of the public, which cannot be disregarded from a radiation-protection point of view. This inventory is used as a basis for the identification of industrial sectors and types of practice for the new Dutch legislation, effective since February 2018, as required by the directive 2013/59/Euratom.

Moreover, RIVM has carried out a survey within these identified industrial sectors to collect detailed information on the materials containing radionuclides of natural origin (mainly primordial radionuclides).

Radionuclides of natural origin can be present in raw natural materials as well as in (semi-processed) products, residual materials and waste. Even though activity concentrations are often low, accumulation of NORM contamination could lead to activity concentrations that require measures to protect individuals against the detrimental effects related to ionizing-radiation exposure.

The survey resulted in an inventory of (practices dealing with) NORM in the Dutch, non-nuclear industries. It also provided detailed information on the types of radionuclides, including their quantities, and activity concentrations. This provided useful insight in the materials of concern for further studies.

Finally, the information gathered in this survey was used to provide insight into the expected consequences of the revised Dutch legislation resulting from the transposition of the European Basic safety standards directive (2013/59/Euratom). This includes a perspective on the expected changes in regulatory control of these practices. For this, the various materials were classified based on their level of control (license, registration, or exemption).

Survey results on the type of industries, properties of typical materials and consequences of new legislation will be presented.

Subject: NORM

Radiological assessment of non-processed waste of a niobium mine aiming the use of it as building material

Thammiris Mohamad El Hajj

Environmental radiological protection aims to ensure protection from anthropogenic sources of radiation exposure, including those naturally occurring radionuclides that might be released into the environment due to human activity. Even though these radionuclides are of primordial origin, the exposure to them cannot be neglected in an impact assessment. Radon, for example, occurs naturally in the environment and it is one of the most studied carcinogens; there are several studies that relate carcinogenicity to dose exposure through epidemiological studies with mining workers and case studies with the general population. This work assessed samples from a niobium mine in Brazil which produces massive quantities of non-processed waste (NPW) per year. Due to the concern about the environmental impact of stacking up this material in the long-term, investigations have been made to evaluate its use as concrete. Although the gravel is physically suitable to be used for this purpose, there are no regulation from the Brazilian National Commission of Nuclear Energy about commercializing this sub-product which has highly variable radiological activity because of the different lithologies present in the mine. Thus, this work, in addition to measuring radon and thoron on the naturally radioactive ore (21 boreholes), it has also conducted the analysis in concrete proof-bodies (3 samples) to analyze if the use of diluted material (i.e. the sum of gravel and cement) constitutes a hazard for human exposure. These concrete proof-bodies were made with the current stacked-up material crushed and sized. Rad7 was used to measure radon for 48 hours each sample. The average results were 1.96 ±1.62 Bq/m3g for Rn-222 and 40.50 ±37.01 Bq/m3g for Rn-220 using closed circuit. Furthermore, a performance comparison between open and closed circuit is being conducted with Rad7 and RadonMapper to establish a correct methodology for thoron measurements. In conclusion, the analysis showed great variability between samples, hence, possibilities were explored aiming the safe use as building material. First, when analyzing the long-term mining plan, whether a specific NPW batch constitutes a hazard, it could be excluded for sale and be used in the mining infrastructure. Second, boundary use conditions, e.g. foundation for roadbeds, and/or different constituents to the concrete could be also be investigated in further studies so their commercialization could be kept feasible to minimize negative environmental consequences of having the material stacked up forever.

Subject: NORM

raPHOSafe: Classification and Separation of Radium 226Ra-rich Phosphogypsum from Non-Radioactive Tailings Material

Joerg Feinhals

DMT conduct a pre-study for compiling key technical constraints for a relatively low-cost conveyor belt pilot facility for automated classification and separation of low contaminated (Ra 226-bearing) phosphogypsum (PG) tailings material. This patented radionuclide-bearing classification and separation system allows to separate non-radioactive PG material from radioactive (i.e. PG radiation above legal radiation limits for tailings), environmentally hazardous PG. This helps to minimize the amount of PG due for remediation and allows zero-waste recycling of the non-critical PG into gypsum-based construction material. The non-radioactive PG tailings material can be zero-waste recycled to gypsum-based interior dry-walling material, whereas the contaminated (Ra 226-bearing) PG material can be further processed for medical applications (as Ra 223) incl. cancer medication.

The benefit from this project is a win-win scenario in which the PG tailings stakeholders (e.g. phosphate industry, PG tailings management company, radiation agency, other government bodies) will finally be able to zero-waste recycle and remediate PG tailings worldwide, and the pharmaceutical industry obtain a highly sought-after precious resource for cancer medication treatment.

Subject: NORM

CSN's Pilot Inspection Programme as a tool for achieving sustainable compliance in NORM industries

Marta García-Talavera

For a couple of decades now, NORM processing or generating industries have been subject to regulatory radiological control in several countries. At European level, the 1996 Basic Safety Standards (BSS) Directive included some general-scope provisions on work activities involving NORM. These provisions, however, had a very uneven implementation across Member states. The new BSS – published as Directive 2013/59 – reflect a clear commitment of the Commission to consolidate the regulatory control of NORM industries, requiring they be managed in the same framework as other practices.

In Spain, regulation specific to the control of NORM industries was passed in 2011, expanding on the requirements earlier imposed in transposition of the 1996 BSS. Nevertheless, those legal mandates translated into a poor practical implementation for several diverse factors. Thus, in a parallel effort to the BSS transposition works, a strategy to foster compliance was designed and led by CSN (Spain's radiation protection authority). This strategy includes four core lines of action, one of them being a two-year Pilot Inspection Programme for NORM industries.

Two of the main aims of this Pilot Inspection Programme are: (a) to allow inspectors to learn on the ground about the obstacles preventing firms from complying with regulation, and (b) to identify synergies with on-going health & safety and environmental controls. Consequently, rather than a stringent punitive deterrence model, a flexible, educative approach was adopted, with a focus on progressing towards efficient implementation at the facility level.

The present work describes the main aspects of CSN's Pilot Inspection Programme, which was launched in 2017, and discusses its outcomes in finding sustainable compliance solutions in industries that have traditionally operated out of regulatory radiological control.

Subject: NORM

Integrated approach for workers protection in industries involving NORM

Hélène Caplin

Many industries involve naturally occurring radionuclides materials (NORM) in their processes. Due to the wide range of raw materials and that of processes, the occupational radiation exposure is very variable for the different workplaces of a plant, for the different plants of an industrial sector.

Furthermore, for many of these industries, exposure to radioactive material is not tackled as a specific issue.

As a result of the transposition of the European directive 2013/59/Euratom, the French labour code is going to be amended to foster a comprehensive approach in the field of occupational risks (fire, explosion, chemistry…). In this manner, all the hazards are considered in the Health, Safety and Environment (HSE) policy of the plant. This approach is consistent with the graded approach recommended by ICRP and IAEA.

One of the aspects of this integrated approach is that all the hazards due to Uranium are taken into account. Indeed, among the naturally occurring radionuclides, Uranium 238 (and its daughter product Uranium 234) and Uranium 235 are found in variable amounts in ores. Natural Uranium presents a chemical toxicity higher than its radiological toxicity. However, currently in France, only the radiological toxicity of Uranium is considered by the operators.

To optimize the workers protection, it may be necessary to take into account the chemical hazard arising from uranium, in addition to the radiological hazard. However the approach for chemical protection is different from that of the radiation protection (airborne concentration control versus dose assessment).

HSE policy shall encompass all the provisions against all the risks and control that there is no conflict between them:

- optimization of the workplace, taking into account the collective protection equipment and the monitoring,
- zoning plan,
- individual protection equipment.

Moreover, radon and thoron is an issue that can’t be disregarded. Generally, this aspect in industries involving NORM is considered apart from the other hazards, even the radiological hazard. The management of radon or thoron by the control of airborne concentration or by one of the occupational exposure pathways is a current open question.

Subject: NORM

Monitoring of NORM in secondary raw materials from the non-ferrous metallurgy in Belgium

Stéphane Pepin

Non-ferrous metallurgy in Belgium uses a large range of secondary raw materials, some of which may show an enhanced concentration in natural nuclides. Identifying and characterizing the raw materials which may be of concern from a radiation protection point of view is often a challenge and requires in most of the cases the development of a cost-efficient screening approach.

Non-ferrous metallurgy has been included since 2012 in the “positive list” of NORM sectors subject to notification to the radiation protection authority (FANC): an overview will be given of the different types of non-ferrous metallurgy in Belgium (production of Sn, Pb, Co, Zn, noble metals,… through both pyro- and hydrometallurgical processes), of the type of secondary raw materials involved and of their radiological characteristics. Challenges regarding radiological screening and analysis (such as detection and characterization of enhanced Pb-210 and Po-210 activity concentration) will be discussed.

From a regulatory perspective, this large range of exposure circumstances exemplifies the need of a graded-approach to the issue. This regulatory approach will also be presented.

Subject: NORM

Evaluation of radiologic hazards related to some building materials and soils at the Metropolitan Area of Curitiba (PR)

Catarina Torres

The Brazilian soil contains a great variety of igneous and metamorphic rocks, including granites, granitoids and unconsolidated sediments. As a result, rather big variety of radionuclides, such as uranium and thorium, can be found in typical building materials used in civil construction. Numerous studies performed in different countries show that the radon exposure is the main cause of lung cancer among non-smokers. Current work presents the results of radioactivity measurements of indoor environments, soil and building materials, which received special attention since they were considered as an important source of indoor exposure to 222Rn. The survey was conducted at the Metropolitan Area of Curitiba (PR) by the Laboratory of Applied Nuclear Physics of the Federal University of Technology (UTFPR) during last decade. For radon in air activity measurements, polycarbonate Track Etch Detectors CR-39, mounted in diffusion chambers protected by borosilicate glass fiber filters, were used. The calibration of CR-39 and the alpha particle tracks chemical development procedures were performed in collaboration the National Institute of Radiological Sciences (NIRS, Japan). The instant radon detector AlphaGUARD (Saphymo GmbH) was used in the measurements of the average concentrations of 222Rn and 220Rn in soil gas and building materials. The major part of indoor 222Rn concentration in studied dwellings was found to be below 100 Bq/m³. In the case of workplaces, all 222Rn measurements concentrations were below 100 Bq/m³. These values were considered within the limit of 300 Bq/m³ established by ICRP Publication 126. The 222Rn concentrations in soil ranged from 31 ± 2 kBq/m³ to 35 ± 4 kBq/m³ and the average values of 220Rn are found in a range of 41 ± 6 kBq/m³ and 25 ± 11 kBq/m³. The measurements of building materials presented the concentration values of 222Rn in a range from 52.9 ± 5.4 Bq/m3 to 2053 ± 700 Bq/m³. Therefore, the samples of some building materials, such as sand, crushed stones, bricks, Portland cement, etc., were submitted to gamma spectrometry to quantify the concentration of 226Ra, 232Th and 40K. The radiological risk of studied building materials was evaluated by calculating the radium equivalent activity (Raeq), absorbed gamma dose rate (Din), the annual effective dose (Ein), the alpha hazard index (I), the gamma hazard index (I), as well as external hazard index (Hex) and the internal hazard index (Hin). Obtained values of hazard indexes were found below the recommended limits.

Subject: NORM

Natural Radioactivity and Geothermal Heating of Greenhouses

Gert Jonkers

In the Netherlands the heating of greenhouses has been achieved by the burning of millions of cubic meters of natural gas and associated emission of kilotons of carbon dioxide. Since about a decade the application of geothermal heating of greenhouses is upcoming as a future sustainable energy source thereby both saving natural gas and eliminating carbon dioxide emissions. Geothermal heating implies the extraction of hot (60 to 102 degrees C) formation water from deep lying reservoirs from a producing well (2 to 3 km depth) leading via filter units through several heat exchangers, after which the cooled water (40 to 15 degrees C) is reinjected in an injector well laterally at least 2 km from the producing well (cf. Figure Doublet). In this sense the producer>surface facilities>injector>reservoir forms a closed circular system separated from the heat network servicing the greenhouses, in which the flowers or crop grown. However, with the hot water also dissolved Naturally Occurring Radionuclide's (NOR's) will appear inside the surface facilities, where – dependent on the exact facility design and materials used – they may be included in deposit like scales (salts) or metals. This presentation will address the geological root causes of Pb-210 ions appearing in the well fluid, its electrochemical deposition mechanism with other stable lead isotopes (Pb-204, Pb-206, Pb-207 and Pb-208). Next to this, methods that potentially reduce or even prevent the deposition of lead metal will be discussed and underpinned with experimental data.

Subject: NORM

Studies on the assessment of the radioactivity level in the Magurele area, Romania

Ana Stochioiu

The paper presents the data regarding the level of the environmental radioactivity in the Magurele town, Romania where is located the Horia Hulubei-National Institute for R&D in Physics and Nuclear Engineering, IFIN-HH. The institute carries out the following activities: i) research in the nuclear field; ii) treatment of radioactive waste; iii) production of the radioisotopes for various fields; iv) decommissioning of the VVR-S research reactor. The data were obtained by specific measurements of the environmental samples such as: soil, sediments, surface and underground water, aerosols, atmospheric deposition and precipitation, spontaneous and cultivated vegetation. These were taken from representative locations and measured using alpha/beta/gamma gross and gamma-spectrometry methods. The conditioning and measurement of the samples was done at the Laboratory for Dosimetry of Personnel and Environment, notified by CNCAN. The radioactivity concentration values for potable water range between 0.02 ÷ 0.06 Bq/L for alpha emitters and 0.30 ÷ 0.60 Bq/L for beta emitters. The values for water surface and household range between 0.25 ÷ 1.10 Bq/L for beta emitters. The values for soil samples range between 620 ÷ 850 Bq /kg for beta emitters and for gamma emitters are below the detection limit. The gamma ray results range between 550 ÷ 700 Bq/kg for K-40 and 50 ÷ 70 Bq/kg for Cs-137. Spontaneous vegetation has a Cs-137 content between 1.92÷ 2.98 Bq/ kg and K-40 between 250 Bq/kg ÷ 330 Bq/kg; all values refer to the dry mass. All these values are below the level required by the European and national regulations in force. Atmospheric radioactive emissions, liquid radioactive effluents as well as the radioactivity of the studied environmental samples determine the dose for the critical group members which is lower than the dose constraint imposed by the Regulatory Body (National Commission for Nuclear Activities Control, CNCAN) for our nuclear activities performed by our institute. The level of the radioactivity in this area is comparable to that at the national level from Romania.

Subject: NORM

Accumulation of Pb-210 on Filters of Ventilation Systems

Benedicte Hofstetter

30 Filters from the ventilation system of the accelerator building of the Paul Scherrer Institute were measured for clearance with high resolution gamma-spectrometry. Artificial radionuclide concentrations were low due to storage of the filters over several years. The dominating radionuclide found on the filters was the radon progeny Pb-210 with activity concentrations between 3.3 Bq/g and 6.6 Bq/g, using the mass of the filter material without filter frame as reference. As radioactive equilibrium between Pb-210 and Po-210 can be assumed according to the storage time prior to the measurement, these concentrations are for both Pb-210 and Po-210 near or above exemption levels.

Model calculations of radon progeny accumulation were performed with typical parameters for filters in ventilation systems, a flow rate of 1 cubic meter per second over a service life of two years and a filter material mass of 1 kg. Due to the total filtered air volume of 63 millions cubic meters, it shows that even moderate radon progeny concentrations in the air can accumulate to significant amounts of Pb-210 and Po-210 on filters of common ventilation systems.

Subject: NORM

A tool to aid in the calculation of specific clearance levels for NORM based on RP-122-part II for regulating purposes

Peter Görts

The EU basic safety standards (Council Directive (2013/59/Euratom) sets the requirements and conditions for general clearance of naturally occurring radionuclides. For general clearance a set of clearance levels is given for the natural decay series of U-238 and Th-232 and for K-40. These general levels are adopted in the implementation of the directive in Dutch legislation. For specific situations higher, specific clearance levels can be requested. A decision by the competent authority on this request is based on scenario calculations and a comparison with dose limits. These scenario calculations may be based on a subset of the scenarios described in the community guidance "Radiation Protection Series 122-Part II". By order of the Dutch authority an Excel-based calculation tool is developed and presented to the industry. The tool can be used to perform these calculations for the standard scenarios, but also for modified scenarios. This aids in both the application for specific clearance levels and the decision thereupon.

Subject: NORM

Determination of radionuclides in drinking water – implementation of EU-Directive 2013/51/EUROATOM

Myroslav Zoriy

On 22th October 2013 the European Union has published a new directive 2013/51/EURATOM for the approving of radionuclide content in drinking water. In particular, this document regulates all radiological parameters (e.g H-3, Pb-210, Po-210, Rn-222, Ra-226, Uranium isotopes) that could be presented in conventional drinking water.

In present work we evaluate the possibilities of available analytical methods such as inductively coupled plasma mass-spectrometry (ICP-MS), liquid-scintillation counting (LSC) and alpha-spectrometry in order to access the concentration/activity level of the radionuclides of interest. Due to the relatively simple matrix by drinking water a special attention was paid in order to optimize the easiness and robustness of the methods.

The results show that due to the optimization processes on sample preparation and measurement procedures a significant reducing of analysis time as well as improvement of detection capability could be achieved. For instance, using LSC HIDEX300 SL as a measurement technique a reliable determination of Rn-222 in drinking water with limit of detection down to 0.28 Bq L-1, calculated in accordance to DIN ISO 11929, was succeeded. The determination of uranium isotopes was performed using multi-collector ICP-MS. This method, in compare to the alpha-spectrometry allows the determination of uranium in drinking water within analyzing time of about 3 min after simple sample dilution.

All the results obtained were evaluated in respect to the accuracy and precision using external interlaboratory comparison exercises and were in a good agreement with the reference values. All these data will be in details presented in current poster.

Subject: NORM

Application of an artificial neural network for evaluation of activity concentration exemption limits in NORM industry

Hannah Wiedner

Naturally occurring radionuclides such as K-40 and the decay products of the primordial radionuclides Th-232, U-235 and U-238 are present in many natural resources. Naturally occurring radioactive materials (NORM) containing these radionuclides are exploited by industrial endeavours and often exceed the exemption limits of the activity concentration for radionuclides of the U and Th series, depending on the mineral composition and geological origin. Industrial activities are generating a significant portion of waste and can enhance the potential of exposure of workers and the public. Furthermore, the management and deposition of material above the exemption limit is very costly. The European Metrology Research Project MetroNORM focuses on creating traceable, accurate, and standardised measurement methods, reference materials and systems for (in-situ) application in the concerned industries. The main problem with measuring NORM lies in the variety of densities and compositions of the materials. NORM emits many gamma-rays of different energies that have to be measured and analysed by an expert. Furthermore, the sample activity often barely exceeds the background and long measuring times are required.

One alternative way to approach this problem is the use of artificial neural networks (ANNs). ANNs are mathematical software tools that emulate the way the human brain works. They are trained, tested and validated with sample datasets and capable of “learning by doing”. They can generalise the “knowledge” gained by the content of the training set and apply it to new problems. This can be viewed as a new calibration tool where no expert knowledge of gamma-ray spectrometry is needed by the end-user.

In this work an ANN was created in the frame of MetroNORM that is able to decide from the input data of a raw gamma-ray spectrum if the activity concentrations in a sample are above or below the exemption limits. To train the network, six NORM reference materials have been analysed and measured. To widen the applicability of the algorithm, a set of artificial gamma-ray spectra with varying density and activity concentration and material composition have been created by Monte Carlo simulation and used in the training, testing and validation of the ANN.

Subject: NORM

Estimation of External dose rate of the Public in Baiyun Obo Rare Earth Mining Area

Nanping Wang

A survey of environmental radiation was carried out in the area of Bayan Obo rare earth mine, the largest deposit of rare earth element (REE) in the world, by in-situ dose rate measurement and the specific activity of natural radionuclides in soil.

The measured average value of dose rate was 87.8 nGy/h with the standard deviation of 27.7 nGy/h, ranged from 53.8 nGy/h to 183.3 nGy/h excluding the sites on the rare-earth tailings dam. The dose rate on the dam was as high as 469 nGy/h. We found that the most important radioactive contamination source in Baotou is thorium-232. In the samples collected from rare-earth (RE) tailings dam in Baotou, the mean radioactivity concentration of 238U, 232Th and 40K was 14.5 Bq/kg, 1209 Bq/kg and 382 Bq/kg, respectively. But the mean of thorium content was 27.7 Bq/kg in soil samples in Guyang County.

Finally, the annual effective doses equivalent (AEDE) due to gamma radiation was calculated using the data from in-situ dose rate in Baotou District and in Bayan Obo District. The average AEDE was 0.58 ± 0.03 mSv/y in the tailings dam in Baotou District. The average AEDE for all sites was 0.11±0.03 mSv/y in Bayan Obo District and in Baotou District.

The survey results indicate the potential importance of radioactivity in RE tailings dams and that remedial measures may be required.

This research was supported by the National Natural Science Foundation of China (No. 41674111).

Subject: NORM

Dry descaling of NORM-contaminated components

Rainer Gellermann

A technology for dry descaling of NORM-contaminated tubings and other components has been developed by SAKON, a service company for surface treatment of metallic components, more than 10 years ago. This technology has been further developed in the last few years. Dry treatment techniques like grinding, sandblasting or CO2-dry ice blasting are available. The final goal of the treatment is that the metal surfaces comply with the exemption levels for NORM-contaminated components or can be declared to be free of radioactivity according to requirements of scrap recycling industry. Reaching this goal is controlled by appropriate measurements. If the results confirm the compliance with the treatment goal the cleaned components can be re-used or recycled by melting. Because the applied techniques do not use water the total amount of NORM-waste produced by the treatment is low. This waste is systematically controlled for its radioactivity. Waste with an origin outside Germany has to be returned to its producer. In special cases disposal in facilities that accept NORM-waste from abroad is possible.

Subject: NORM

A study of behavior of radon-222 and carbon dioxide (CO_2) in soil air (II)

Toshio Kataoka

Introduction: The IAEA published TRS No. 474 (Measurement and Calculation of Radon Releases from NORM Residues) in 2013. In this report, radon-222 releases from repositories of NORM residues are described in detail. Meanwhile, in view of global warming, radon-222 has been used as a tracer in the study of carbon dioxide (CO2) transport in the unsaturated soil zone. In both cases, it is assumed that radon-222 and CO2 behave separately in soil air in all unsaturated soil zone (conventional assumption). The objective of this study is to examine in detail the assumption that the flow of CO2 is accompanied by radon-222 in a region of high soil CO2 production (present assumption).

Methodology: Using formulae derived on the present assumption, concentration profiles of radon-222 in soil air (radon-222 profiles) are calculated for various values of tortuosity and depth. Flux densities of CO2 at the soil surface (CO2 fluxes) are calculated for values of the tortuosity obtained from the radon-222 profiles. Flux density of radon-222 at the soil surface (radon-222 flux) and CO2 fluxes are also calculated using a radon-222 profile based on the conventional assumption. Both radon-222 and CO2 fluxes for the present assumption are compared with those calculated on the conventional assumption and measured by another investigator.

Results: Since the above-mentioned formulae contain the terms representing the measured radon-222 flux, and since the radon-222 flux calculated on the conventional assumption is about 78 % of the measured radon-222 flux, the present assumption might be more reasonable than the conventional assumption. This corresponds to “a homogeneous bare residue” in TRS No. 474. The CO2 fluxes calculated on the present assumption are closer to that measured by the investigator than those calculated on the conventional assumption. Furthermore, it is found that, when the flow of CO2 is accompanied by all radon-222 atoms in soil air (this corresponds to “covered residues” in TRS No. 474), radon-222 flux is theoretically about 14 % more than that based on the conventional assumption.

Conclusion: From the results presented here, it is suggested that the flow of CO2 might be accompanied by radon-222 in a region of high soil CO2 production. Experimentally verified, this may contribute to making more exact estimates of the radon-222 flux due to the NORM residues and the CO2 flux by radon-222 calibrated method.

Subject: NORM

Derivation of the In-situ Radioactivity Index for Materials of Existing Building including Naturally Occurring Radioactive Materials

Mee Jang

In Korea, to protect the public from natural radioactive material, it has established the "Act on protective action guidelines against radiation in the natural environment". There is an annual effective dose limit of 1mSv for products including NORM. When we consider the external hazards, it is necessary to judge the excess possibility for the materials of existing building as well as products. In this research, we developed the in-situ radioactivity index which can compare with the in-situ measurement value of radium, thorium and potassium to judge the satisfaction of the dose constraint. We assumed the "room model" for materials of existing building as radiation irradiation scenario and calculated the specific effective dose rate using the MCNPX as Monte Carlo code. Also we evaluated the activity concentration limits considering in-situ characteristics such as room area, density and thickness of building materials. We suggested the in-situ radioactivity index considering the characteristics of residence and building materials. The results are utilized as a screening tool for a lot of materials of existing building.

Non-Ionizing Radiation (NIR)

Subject: NIR

UV-radiation protection and UV-risks in perspective: the UV-sievert

Harry Slaper

Exposure of the skin to ultraviolet radiation is the primary cause of skin cancer, and skin cancer incidences are rapidly increasing worldwide. The sun is the primary source of UV-exposure, but in addition ultraviolet radiation is used in tanning salons, for the treatment of a variety of skin diseases and in industrial and laboratory applications.

In the Netherlands skin cancer incidences increased three to fourfold in the past 25 years for all three major types of skin cancer. Ageing of the population and depletion of the ozone layer and climate change combined cannot explain the rapid increases in skin cancer incidence observed. Behavioral changes are probably the most important causal factor. Thus, there is every reason to pay more attention to the prevention of skin cancer through a clear UV-radiation protection strategy.

A lot can be learned from ionizing radiation protection in this respect. In ionizing radiation-protection, the concept of the “effective dose” has been developed to allow for the risk based comparison of health effects of exposures to different parts of the body. The effective dose (expressed in mSv/yr) allows a risk based prioritization in ionizing radiation protection, and is applied in all exposure situations, among which exposures due to existing (natural) sources (such as radon). The effective dose is presently not defined for UV-radiation exposure.

The question arises how the risk from UV-radiation can be translated into the risk framework for ionizing radiation? In this paper, we answer this question by applying the concept of radiation detriment from ICRP to the skin-cancer risk from UV-exposure observed in the Netherlands. Under the realistic assumption that the majority of skin-cancer cases is related to UV-exposure, the average lifetime UV-equivalent of the effective dose, expressed in the UV-Sievert, is calculated. Following this new concept, we find an average yearly effective UV-radiation dose for the Netherlands of 3.45 mSv. This is higher than the average effective dose of 2.6 mSv that is received yearly in the Netherlands for all ionizing radiation together.

In view of the fact that this dose is an average over the population it should be realized that large subgroups with high exposure and UV-sensitive skin are at much higher risks. A reduction in future skin cancer incidence can be achieved, but at present this issue remains a challenge.

Subject: NIR

Sub-lethal UVA and UVB radiation during early life stages alter behaviour and heart rate in the zebrafish (Danio rerio)

Terje Christensen

Environmental UV radiation in sufficient doses is potent enough to affect living organisms. For fish that breed at a shallow water depth, the embryonic stage is the most susceptible to the biologically damaging effects of UV radiation.

The aim of this project was to evaluate the potential toxic effects of early life stage (4.5 – 5.5 hpf) exposure to sub-lethal and environmentally relevant doses of broadband UVA (Control, 9.3, 18.6 min, 37.2 J/cm2) and UVB radiation (Control, 0.013, 0.026, 0.078 J/cm2) on the development and behaviour in the zebrafish (Danio rerio).

The doses used caused no significant difference in survival, deformities, or hatching between the exposed groups and non-exposed controls. The heart rate was found to be significantly reduced at 60 hpf in all groups of UVB and UVA compared to controls, except for the lowest UVA dose.

Exposure to the two highest doses of UVA led to a significant reduction in the time spent active and the total distance moved compared to controls at 100 hpf, while no effect on the swimming speed was observed. The lowest dose of UVA dose had no effect on behaviour.

Exposure to the highest dose of UVB led to an increase in the time spent active and a slower average swimming speed although these effects were not significant. Neither of these tendencies were observed at lower UVB doses.

The obtained results indicate that UV doses below the LD50 levels are able to cause changes in behaviour and physiological parameters; however, further testing is necessary to assess how this type of radiation and the effects observed might be affecting fish populations.

Subject: NIR

Residential radon and UV exposure and skin cancer mortality in Switzerland

Danielle Vienneau

Skin cancer incidence in Switzerland is among the highest in the world. In addition to exposure to UV radiation, it is postulated that during decay radon progeny can adhere to the skin and potentially cause carcinogenic effects. The objective of this epidemiological study was to investigate the effects of radon and UV exposure on skin cancer mortality.

Using the Swiss National Cohort, Cox proportional hazard regression was used to study the association between exposure to residential radon and UV and skin cancer mortality in Swiss adults. Modelled radon exposure and erythemal weighted UV dose were assigned to residential address at baseline. Models were adjusted for sex, civil status, mother tongue, education, job position, neighbourhood socio-economic position and UV exposure from outdoor occupation.

The study included 5.2 million adults and 2989 skin cancer deaths, 1900 of which indicated malignant melanoma (MM) as primary cause of death. Adjusted hazard ratios (HR) for MM were 1.16 (95% CI: 1.04-1.29) per 100 Bq/m3 radon and 1.11 (1.01-1.23) per W/m2 in UV dose, at age 60. Radon effects decreased with age. Risk of death from MM associated with residential UV exposure was higher for individuals engaged in outdoor work with UV exposure (HR 1.94 [1.17-3.23]), though not statistically significantly different compared to not working outdoors (HR 1.09 [0.99-1.21], p-value 0.09).

The variation in radon and UV exposure across Switzerland is considerable, and this study suggests both are relevant risk factors for skin cancer mortality. A better understanding of the role of the UV radiation and radon exposure is relevant to public health.

Nuclear Emergencies

Subject: Nuclear Emergencies

Accidental Release of Radioactive Material – New Procedures of Radiation Protection for Aircrafts

Thomas Steinkopff

In case of an accidental release of radioactive material in the atmosphere, aircrafts will be exposed to higher radiation when entering contaminated air space (zones).

Due to the principles of radiation protection and to international arrangements, information on the distribution of radioactive particles and the expected radiation exposure have to be provided to the responsible aviation organizations as fast as possible. It is assumed that the site of the release is known but the knowledge about the source term is poor.

To solve the problem of calculating the radiation exposure based on poor knowledge concerning the source term, a two step approach has been developed.

Within the first step, as long as information on the accident is spare, the definition of a no-fly zone within a circle of 30 km radius around the source is proposed.

Secondly, dispersion simulations with actual weather forecasts and an assumed worst case scenario based on the source term of the NPP Chernobyl and NPP Fukushima are calculated to minimize the no-fly zones due to the knowledge about the expected transport path. The results of the dispersion calculations are provided as activity concentrations. The relation between the activity concentration and the radiation exposure to the crew as well as to the passengers can be calculated based on the new developed “Operation Intervention Levels” (OILs) procedure. In spite of having also uncertainties step 2 of this strategy changes significantly the size of the no-fly zone and the measures for radiation protection.

The strategic and scientific approach for necessary measures and for the provision of information how to avoid radiation exposure and contamination is presented.

Subject: Nuclear Emergencies

Variance and sensitivity analysis of food-chain models

Gergo BATOR

Artificial radionuclides are produced by nuclear explosions and nuclear facilities, if released into the environment, may reach the human body through several transfer pathways is considered as one of the important routes through which radionuclides can enter the human body via food-chain. The sensitivity analysis of input parameters for food-chain models was performed as a function of deposition coefficient and transfer factors for the long-lived radionuclides (Sr-90, Cs-137). The input parameters were used from different databases. The influence of input parameters for short and long-term contaminations of the foodstuffs after a deposition was also investigated. Their sensitivity indices were quantified as partial rank correlation coefficient.

In our calculations, we were the most conservative approach to the realistic (best estimate) modelling conditions, which in practice meant that the calculation results declined significantly, up to several orders of magnitude. PRCCs were strongly dependent on the contamination period of foodstuffs as well as the deposition time of radionuclides.

The results of this study may be serve as a useful information for improving the reliability of predictive results and saving a major effort in the collection of relevant data by identifying the main contributor of input parameters to model results.

Subject: Nuclear Emergencies

SEED : a numerical simulation tool for the deployable expert team CReDO (Operational Dose Reconstruction Cell)

Fabrice Entine

An operational dosimetric reconstitution tool is currently being designed as part of a collaboration between the French defense radiation protection service (SPRA) and the Institute for radiation protection and nuclear safety (IRSN). Called "SEED", it aims to take advantage of a powerful mobile calculator implemented by a doctor / physicist team.

In the context of a nuclear or radiological accident involving high doses of ionizing radiations, for irradiated patients, priority goes to the diagnosis because it is essential to know how the dose is distributed among the organs in order to sort the victims according to the severity of the exposure. At present there is yet only very few field techniques that are capable of rapidly characterizing an external radiation exposure. The lack of expertise techniques in this domain contrasts with risks induced by scientific, industrial and military applications, as well as the terrorist threat which makes an irradiation event significantly probable.

The dosimetric reconstruction tool uses GATE platform (which is based on Geant4 Monte Carlo code) to provide dose maps in the area of an irradiation accident. An important feature of the simulation device is to be able to operate in highly degraded situations. As it is integrated in a militarized and hardened case, it can be freed from any link to a remote computer cluster thanks to a powerful multicore calculator.

Using a simple and intuitive graphical user interface that is currently in development, trained users will be able to quickly design the whole scene of the accident using mostly the mouse and navigate in this 3D virtual world with a first person camera. This simulation tool is also compatible to work with libraries of sources, phantoms and shielding materials that can be quickly integrated into the modeled scene of the radiation accident. Numerical filters are currently in development to target the most exposed areas to help medical teams guiding victims through appropriate medical care management solutions.

This numerical simulation tool is aimed to meet the need of on-field dosimetric triage solution for radiation-exposed victims. Scientific validation will be performed by a two steps procedure:

- a first validation phase comparing the SEED results to those of a usual Monte Carlo code (MCNP) has already begun.
- a second validation phase based on a more complex scenario, similar to one of the accidents for which IRSN has already carried out expertises, will occur in 2019.

Subject: Nuclear Emergencies

Emergency measurements of the population- a task for competent incorporation monitoring laboratories

Peter Hill

After releases of radioactive substances in the atmosphere and the environment, incorporation monitoring of parts of the population is indispensable. In the incorporation monitoring laboratory Jülich, incorporation monitoring is performed for direct measurements (whole body counter), indirect measurements with radiochemical testing methods of excretion samples and internal dose assessment.

In order to obtain quick information about a possible intake, it is necessary to use modified routine test methods in the case of emergency measurements. Depending on released radioactive substances fast testing methods such us ICP-MS, Low-Level Beta counting, LSC, Alpha spectrometry and whole-body counting can be used. There is a large range of radionuclides that can be assessed. Examples in excretion analysis (urine, faeces) are among others Am-241, Cf-252, Sr-90, Po-210 and isotopes of Th, U and Cm. The whole-body counter can count gamma-rays in the energy range of ~25-2000 keV and perform organ measurements (e.g. thyroid). Typical radionuclides measured are Mn-54, Mn-56, Cr-51, Fe-59, Co-60, Zn-65, Tc-99m, I-125, I-133 and Cs-137. Testing parameters include activity, specific activity, mass (ICP-MS) and individual body dose.

This study shows validated fast test methods and procedures in a case of an incident/ accident. The validation process includes proof of traceability to metrological standards, limits of detection and quantifications, precision and accuracy.

Subject: Nuclear Emergencies

Influence analysis of air kerma calculations, different environments, deposition scenarios and post deposition mobility of radiocontaminants on the external gamma exposure inside buildings as a part of risk assessment in radiological emergency preparedness

Yvonne Hinrichsen

One important part of the risk assessment in radiological emergency management is the determination of the external gamma exposure inside buildings. For the evaluation of this exposure pathway, three main model requirements are needed: (i) the calculation of the air kerma per photon emitted per unit source area, based on Monte Carlo calculations; (ii) the deposition distribution of contaminants on the different surfaces; and (iii) their post-deposition migration. Furthermore, these evaluations require knowledge about the respective building and its surroundings.

As a first step Monte Carlo calculations, that were performed during the late nineteen eighties, were repeated with MCNP6 by using the published building data. The two datasets were found to deviate in some cases by almost 100%, depending on the combination of source and detector region. To show the applicability of MCNP6 calculations in managing contaminated buildings in a natural environment, shielding factors were calculated alongside with the experimental determination of shielding factors at a real building structure leading to well matching results. Therefore, MCNP6 was used for the calculation of the air kerma per photon emitted per unit source area for different buildings and environmental scenarios.

To determine the total external gamma exposure as a sum of the exposures from all contributing surfaces, knowledge about the effective source strengths of the different surfaces is necessary. These factors depend on the deposition scenario (wet, dry, mixed), the activity median aerodynamic diameter (AMAD) of the deposited particles (<2 µm, 2-5 µm, 5-10 µm, 10-20 µm), the chemical characteristics of the deposited particles (ions in solution and low solubility particles) and on the characteristics of the respective surface and can therefore vary a lot.

After the deposition of the contaminants various processes lead to their migration on the different surfaces. The respective development over time depends again on the parameters that were already relevant for the deposition of the contaminants and therefore have an impact on the development of the external gamma exposure inside buildings.

In conclusion, the used models can give an impression about which kind of measures should be applied in a radiological emergency situation, and are helpful especially when measures have to be applied quickly. A more detailed knowledge about contaminants and the affected environment is leading to a higher precision of the model, but cannot replace measurements on the long time scale.

Subject: Nuclear Emergencies

Overview of Accidents in Industrial Accelerator Facilities

Helena Janzekovic

Irradiators using radioactive sources or accelerators have been used in industry for decades. In the last decade sterilization of products became an important part of many industries. A use of sources in sterilization is related to numerous safety features assuring safe operation of facilities as these sources are linked to high risks to human health in case of an accident. The required dose rates in order to make an efficient sterilization might be up to thousands of Gy/s. Due to such extremely intense radiation fields, defense in depth shall be implemented in the design of irradiation facilities and high safety culture shall be in place as described in IAEA SSG-8.

The facilities are based on a use of radioactive materials, i.e. Co-60 or Cs-137, or accelerators. Lately the irradiators with Cs-137 became obsolete due to security reasons. Radioactive sources of Category 1 from the IAEA RS-G-1.9 are largely replaced by accelerators to avoid not only security issues but also management of disused radioactive sources. In 2004 the IAEA published a database of gamma irradiation facilities. No such database for accelerator's facilities exists.

In order to understand accidents related to industrial irradiators and to identify events leading to them, available literature was analysed, e.g. IAEA, OTHEA-RELIR database and IRPA proceedings. In the literature accidents related to radioactive sources are well described including detailed analyses of accidents with fatalities, e.g. in Kjeller 1982 and Nasvizg in 1991. Less information is available when accelerators are involved although the first accident related to industrial sterilization happened in 1965 in USA where accelerator was involved resulting in amputation of worker's leg and arm. This fact can be linked to safety features installed in accelerator's safety systems enabling easier maintenance of safety in such facilities than in facilities using radioactive sources. Moreover, collimated fields used at accelerator's facilities contribute to partial exposure to bodies in case of accidents, e.g. in general amputation of limbs could be required in worse-case scenario. The analysis of around ten reported events is presented systematically identifying initial event, contributing factors and lessons learned. It focuses on physical phenomena such as dark currents, on safety systems installed and safety procedures. It might help designers, users and regulatory bodies when studying safety assessment. It can contribute to better understanding risks associated with such industrial accelerators.

Subject: Nuclear Emergencies

Organisation of the environmental monitoring: lessons learnt from Fukushima.

Mélanie Maitre

In post-accident situations, the implementation of the environmental monitoring is essential for characterising the radiological situation of the affected territories, as well as, allowing people living in such territories to understand what is at stake in their environment and so helping them to become actors of their own radiological protection. In this context, roles playing by institutional and non-institutional actors are determining factors to set up a sustainable monitoring, reach a consensus and encourage the citizen vigilance.

This paper proposes an analysis of the Japanese situation 6 years after the Fukushima accident, in order to provide feedback experiences of the environmental monitoring implemented to cope with the post-accident situation. This analysis consists in (i) identifying the environmental schemes implemented following the Fukushima accident (ii) mapping the different actors who come into play in such situations and (iii) highlighting some local experiences developed by local associations or municipalities within the affected territories.

These overall goals have been achieved by interviewing different Japanese actors involved in the practical setting up of the environmental monitoring within the Fukushima prefecture. So, feedback experiences, points of view and comments have been collected from both institutional actors (e.g. Japan Nuclear Safety authority, Health and Labour Ministry, Fukushima prefecture, etc.) and local actors (e.g. local associations, municipalities, citizens, etc.) in November 2016.

Results of this study clearly show that the environmental monitoring implemented in Japan after the Fukushima accident gathers multiple actors on both national and local levels. The 'Comprehensive Radiation Monitoring Plan' (CRMP), set up by the Japanese government since August 2011 proposes a national monitoring system concerted, coherent and embracing all environmental compartments.

However, all the results obtained under this plan are put online without harmonization. This leads to confusion on the published results, which besides are not largely consulted by the local population.

Indeed, at the local level, the mistrust towards government leads people living in the affected territory to implement their own environmental monitoring. However, these local data are heterogeneous and often redundant with the CRMP but have all the trust of their initiators.

In this context, the remaining issue consists in knowing how to go towards a better sharing between results produced by institutional and non-institutional actors. It appears that scientific experts, often involved in both sides, could play a key role in sharing these results, which represents a strong lesson learnt for the preparedness phase.

Subject: Nuclear Emergencies

Recent status and applications of KURAMA-II

Minoru Tanigaki

KURAMA-II, a carborne gamma-ray survey system characterized as its compactness, autonomous operation, acquisition of pulse height spectrum data along with GPS data, has been applied for various activities of environmental radiation monitoring in eastern Japan.

A continuous carborne survey of radiation by KURAMA-II installed on local buses continues in Fukushima prefecture as a collaboration among Fukushima prefecture, Kyoto University, and JAEA. Trials for extending the types of vehicles such as delivery vans for convenience stores are on the way.

A technique with KURAMA-II for the estimation of fertility of farm land after the decontamination activities is also under development. Mountain sand is often introduced after the removal of contaminated surface soil, and this cause a severe reduction of fertility in farm land. Since the components and ratio of elements are different between mountain sand and farm land, we expect the distinction of the components of soil by using pulse height spectrum data accumulated by walking survey using KURAMA-II.

The present status and future prospects of KURAMA-II, including the status of these trials are introduced.

Subject: Nuclear Emergencies

Evaluation of transfer coefficients of two-compartment prediction models for ambient dose equivalent rates after nuclear accidents

Sakae Kinase

Assessments of projected doses through external irradiation from contamination deposited in the environment are of scientific and practical interest. There have been several studies of two-compartment prediction models for ambient dose equivalent rates in the environment following the nuclear accidents. The long-term prediction models have been proposed as two-compartment models for projected dose assessments following the Fukushima Daiichi nuclear power plant accident. However, there are significant differences among the reported model parameters for the two-compartment prediction models. It is therefore necessary to understand the behavior of radioactive caesium as the main contributors to ambient dose equivalent rates in the environment following the nuclear accidents and to clarify the future of two-compartment prediction models for particular applications. In the present study, two-compartment prediction models were expressed by three simultaneous differential equations with transfer coefficients of radioactive caesium for the central/peripheral compartments. The two-compartment prediction models differ in the compartment where the radioactive caesium elimination takes place. The radioactive caesium was assumed to be transferred/eliminated by a first-order process. The transfer coefficients were derived from the model parameters for the two-compartment prediction models described using double exponential forms. Consequently, the model parameters for the two-compartment prediction models were hybrid transfer coefficients for the distribution and elimination processes of radioactive caesium in the environment. In the models for the local environment with dry deposition, the first-order transfer coefficient from the central compartment to the peripheral compartment was found to be larger than that from the peripheral compartment to the central compartment. The first-order transfer (elimination) coefficient from the central/peripheral compartments was very small. It was found that the transfer coefficients derived from the model parameters for the Fukushima Daiichi nuclear power plant accident were consistent with those from previous studies.

Subject: Nuclear Emergencies

Restoration of contaminated areas in Sweden following an RN accident – How to best combine long-term measures in order to protect people in urban environments from radiation while taking economic and social factors into account

Therése Geber-Bergstrand

During the fall of 2017 an interdisciplinary research project was launched with the goal of providing recommendations for decision making of the restoration of urban environments in Sweden following a radiological or nuclear (RN) accident. In the recommendations, economic and social factors (e.g. reactions of the member of the public) will be taken into consideration. The project is a collaboration between several universities in Sweden and will proceed during four years.

The project aims to provide a tool for readily comparing the costs and outcomes of different remediation actions that also include dynamic costs. In this approach, expected reactions from the public will also be taken into account and be included for the recommendations of countermeasures. How much do factors such as the egalitarian aspect in the resource allocation, sense of risk relative to the statistically calculated risk, etc. influence the public acceptance of the remediation and their willingness to return to restored areas?

During the project, several parallel investigations will take place. During 2017/2018, these include:

• Monte Carlo calculated gamma radiation shielding factors in residential buildings for cluster of houses

• Investigation of instruments and measurement methods suitable for estimating internal dose of larger populations close to a nuclear accident site

• Investigation of dynamic costs associated with detriment reduction for a variety of societal stressors; radiation exposure, heavy metal exposure and road traffic security

• Investigation of public perception/reaction to inhabiting a radiation contaminated area over long-term (a literature review applied to Swedish circumstances)

Here we will present the results and conclusions so far, together with the next steps of the project.

Subject: Nuclear Emergencies

Measuring radioactivity with drones

Siebren van Tuinen

The RIKILT in Wageningen is an integral part of the national Radiological and Medical Expertise Network (RGEN) for handling nuclear emergency situations. During such an emergency a team of experts of different expertises is formed in a specific centre in the middle of the Netherlands, from which a coordinated advice is presented to the decision makers. These experts are supplied with specific information, for example the source term of the nuclear accident, the weather forecast, and monitoring data, originating from several (semi-)automatic monitoring networks.

In this network RIKILT is responsible for the supply of information on the food chain. For this, RIKILT manages a semi-automatic monitoring network of about 50 measuring stations in the Netherlands. At this stations, operators can measure for instance milk and grass samples. The measurements are collected automatically at the RIKILT in Wageningen, where contamination plots can be generated per food or feed matrix or per radionuclide.

A crucial aspect of the decision making regarding the food and feed chain is if the samples that have been taken are representative, and that samples are taken at the maximum contamination levels. The location of the maximum contamination levels can be predicted with dispersion models, but the variations on a local scale as a result of vegetation and local weather influences can be quite large.

To be able to take samples at the maximum contamination levels RIKILT makes use of a drone with a radioactivity detector. The aims of the use of the drone are two-fold:

• During radiation incidents the measurements performed with the drones can provide information considering the amount of contamination of a certain area; besides this, hot-spots can be identified quickly and efficiently without personnel entering the potentially contaminated area

• During chemical calamities air samples can be taken, based on indicative measurements with specific sensors

Several detector types are tested for their performance on fastness of response and accuracy of the measurements, with quite different results. Also some practical tests have been performed in naturally and artificial contaminated areas.

The measurement results are directly send to the ground and plotted on geographical information, immediately providing the personnel of the emergency response organisation an advice for the countermeasures to be taken.

In the next months the different chemical and radiological sensors will be further developed and tested, aiming at an fully operational measuring system at the end of 2018.

Subject: Nuclear Emergencies

Role of Poisons Centers in response to radiological and nuclear incidents

Marianne Leenders

Objective:

The Fukushima nuclear power plant disaster and growing terrorist threat during the last decade have increased awareness for incidents involving radioactive material. Poisons Centers (PC) can play an important role in the preparation on and immediate medical response to radiological and nuclear incidents.

Methods:

In the Netherlands, the PC is officially embedded in the response network for radiological and nuclear incidents. Radiation protection experts are available 24/7 to calculate radiation dose, perform risk assessment and provide health management advice after radionuclide exposure. The tasks PCs can perform are illustrated by recent involvement in exposure assessment and incident preparedness.

Results:

In the past few years the Dutch PC was consulted about several suspected radionuclide exposure cases. Haematologists asked the PC radiation experts to assess the relationship between unexplained aplastic anaemia and chronic exposure to dust from uranium-containing minerals. Calculation of possible bone marrow dose made such a relationship unlikely. Another consultation concerned a second opinion on a pregnant patient with a pelvic tumour who had to undergo radiotherapy. Advice was asked about whether or not this would be possible without harming the unborn child.

Another role of the PC is to advise authorities and healthcare professionals on management of radiological incidents in or outside the Netherlands in which Dutch citizens may be involved. After internal contamination with radionuclides, elimination can often be enhanced by administering antidotes. However, the availability of these antidotes is limited. On PC recommendation, the Ministry of Health built a stockpile of the chelators DTPA (for e.g. plutonium, americium and other actinides) and Prussian Blue (for cesium and thallium). Thereafter healthcare professionals and policy officers were trained on the recognition, risks and medical management of radiotoxicity.

In 2017 the Ministry of Health decided to distribute iodine tablets to 1,2 million households in the Netherlands. The radiation protection experts of the PC advised in the preparation of this distribution. PC employees wrote Q&A's for health care personnel and the public, gave interviews to the press and answered 40 telephone calls about iodine pills via the 24/7 telephone service.

Conclusion:

Since 1986 the Dutch PC radiation experts have assessed individual radiological exposures, trained healthcare professionals and acted as experts in radiological and nuclear incident response teams. In this way the radiological expertise of the PC, combined with medical toxicological knowledge, showed its added value to health care personnel and the authorities.

Subject: Nuclear Emergencies

Stockpile of antidotes for radiological incidents

G.A. van Zoelen

Introduction:

The Dutch Poisons Centre (PC) has a team of 5 radiation experts who advise on the medical treatment of casualties after incidents with radioactive material and/or ionizing radiation. After internal contamination, timely administration of a specific antidote is important. The antidote will enhance radionuclide elimination from the body and consequently the radiation dose will be reduced. However, besides a stockpile for stable iodine tablets, antidotes to treat internal contamination with other radionuclides were not readily available in the Netherlands until 2011. The delivery time from an antidote producing pharmaceutical company is at least two working days.

Strategy:

The antidotes considered most useful to have available were Prussian Blue (for cesium and thallium) and DTPA (for e.g. cesium, americium, curium, californium and plutonium). These antidotes cover a wide range of radionuclides, including those most likely used in a dirty bomb (that spreads radionuclides on detonation). For DTPA, the calcium salt (Ca-DTPA) is most effective in the early phase after exposure, while the zinc salt (Zn-DTPA) is recommended for prolonged treatment. A national stockpile of these three antidotes ensures early administration when necessary.

The size of the stockpile was chosen to be minimally sufficient to treat 50 persons during the first 10 days after exposure. This amount is based on a well-known, large incident with a dismantled radioactive cesium source in Goiânia (Brazil). The Dutch PC advised the Ministry of Health to establish an antidote stockpile with Prussian Blue, Ca-DTPA and Zn-DTPA. After approval the stockpile was set up at the centrally located National Institute for Public Health and the Environment (RIVM) in Bilthoven. This institute already has a stockpile of antidotes for animal bites and stings with a 24/7 infrastructure for nationwide delivery. There is also a pharmacist available for surveillance. In case of exposure, the treating physician contacts the PC and a PC radiation expert determines whether antidotal treatment is indicated.

The maintenance costs of the radionuclide antidote stock are around 3500 euro/year, taking into account the 5 year shelf life. This is low compared to the benefit such a stockpile can provide. The stockpile was renewed in 2016.

Conclusion:

For the direct medical treatment of persons internally contaminated with radionuclides, it is advisable that every country has a stockpile and 24/7 delivery system for suitable antidotes such as Prussian Blue, Ca-DTPA and Zn-DTPA.

Subject: Nuclear Emergencies

Radiation incident preparedness of Dutch hospitals

Ronald de Groot

Objective:

The 2011 Fukushima nuclear incident and increasing terrorist threat underscore the necessity for hospitals to prepare for casualties of incidents involving radioactive material and/or ionizing radiation. This is also recognised in International Atomic Energy Agency (IAEA) Safety Standard 'Preparedness and Response for a Nuclear or Radiological Emergency ' (No. GS-R-2) that provides requirements for 'Managing the medical response'. To determine compliance with paragraph 4.78 that requires arrangements for 'initial medical treatment of contaminated or highly exposed individuals in local medical facilities', the Dutch Poisons Center (PC) assessed radiation incident preparedness of Dutch hospitals in 2015.

Methods:

An online survey on resources and knowledge concerning management of casualties of radiation incidents was sent to all 87 Dutch hospitals with a 24/7 available emergency department. Additionally, nine hospitals were visited for an in-depth interview.

Results: The response to the online survey was 67% (58/87 hospitals responded). Most hospitals indicated that they prepare for the care of casualties of radiological incidents (86%). In small hospitals (< 500 beds) this percentage is 77% and larger/academic hospitals almost all take into account radiation incidents. About two third of responding small hospitals, three quarter of larger hospitals and all academic hospitals can decontaminate casualties contaminated with radioactive material.

The decontamination capacity is 1-5 persons/hour for most hospitals (83%). The capacity increases with hospital size to a maximum of 30 persons/hour for two larger/academic hospitals. Most hospitals have indoor decontamination facilities (70%) and a minority facilities outside (e.g. decontamination tents). Of hospitals without decontamination facilities 75% have not made arrangements with other hospitals about referral of contaminated patients.

Around 70% of hospitals describe radiological incidents in an emergency response plan but most hospitals do not specifically perform exercises based on radiation incidents.

Conclusion:

We conclude that in general there is compliance with the IAEA 'initial medical treatment' requirement in Dutch hospitals. The main recommendation from this study is that hospitals that are not yet prepared, either create decontamination facilities or make arrangements for referral of contaminated victims to a hospital with facilities. Additionally, it is recommended for hospitals to make regional arrangements in advance about distribution of larger groups of casualties if their own capacity is limited. Finally, it is important to include emergency response to radiation incidents in a disaster relief plan and perform exercises.

Subject: Nuclear Emergencies

An investigation of the effectiveness of sheltering versus evacuation with a focus on geographical influences

Jonathan Sherwood

This investigation is part of an international collaboration between PHE (UK) and BfS (Germany) to study whether sheltering or evacuation is the consistently better countermeasure option for reducing exposure of the public in the event of an airborne release of radioactive material. The study compared the dose reduction potential of the two countermeasures for the scenario of an accident at a hypothetical nuclear power plant over a wide range of weather conditions, source term characteristics, evacuation routing and location options. Different modelling approaches were implemented by the two organisations and it is the assessments undertaken by PHE which are discussed here.

The method used by PHE employed the PACE (Probabilistic Accident Consequence Evaluation) tool to model atmospheric dispersion and doses. This software is capable of producing the large set of simulations needed to probabilistically assess the influence of atmospheric dispersion in a wide range of weather conditions and using these to assess subsequent doses. These results were subsequently fed into a network analysis tool to generate realistic evacuation routes based on real road networks.

It is clear from the results that a major factor in the comparative effectiveness of countermeasures is the duration of release: for longer releases, evacuation is likely to be a more attractive option in terms of dose saving. It has also been found that the performance of one countermeasure against another is dependent on the circumstances and geographical features around the release – the impact of these features (such as local road network, and proximity to coast) having been a particular focus of the PHE assessment. Significantly, it has been demonstrated that under the circumstances considered in this study neither the evacuation nor the sheltering option is consistently better than the other.

Importantly, consideration is also given to factors affecting the favourability of countermeasures other than reduction of radiological exposure. Some of the risks associated with evacuation – such as road traffic accidents, moving people with special care needs – are not quantified in this assessment but are relevant, potentially increasing the favourability of sheltering as either a stand-alone countermeasure or as a precursor to evacuation, or alternatively indicating the importance of thorough planning of the evacuation countermeasure.

Further work is planned to investigate a wider range of source term configurations and evacuation routing options, for example allowing routes and evacuation centres to be adapted in the light of more (but still uncertain) information about the plume direction.

Subject: Nuclear Emergencies

Comparison of the contribution of short-lived radioiodines to the thyroid dose for the public after the radiation accidents at the Chernobyl and Fukushima-1 nuclear power plants

Sergey Shinkarev

Purpose: The purpose of this paper is to present the results of comparison of the contribution of short-lived radioiodines to the thyroid dose for the public after the two radiation accidents at the Chernobyl and Fukushima-1 nuclear power plants.

Materials and methods: In case of a nuclear accident with release into the environment of radioactive material, including radioiodines, there are four exposure pathways contributing to thyroid dose for the public: (1) internal exposure from intake of 131I; (2) internal exposure from intake of short-lived radioiodines (132I, 133I, and 135I) and of short-lived radiotelluriums (131mTe and 132Te); (3) external exposure from radionuclides deposited on the ground; and (4) internal exposure from incorporated long-lived radionuclides such as 134Cs and 137Cs. However, for the vast majority of the members of the public, intake of 131I is the dominant pathway. So, the contribution of short-lived radioiodines to the thyroid dose is convenient to express as a fraction of the thyroid dose from 131I. This contribution takes into account the ratio between doses from inhalation and ingestion intake of 131I, the ratios between dose factors of the expected dose to the thyroid in case of inhalation and ingestion intake of iodine and tellurium isotopes, the ratios between time-integrated concentration of iodine and tellurium isotopes in the ground-level air and in foodstuffs (milk).

Results: A typical contribution of short-lived radioiodines to the thyroid dose for the public following the Chernobyl accident is within a few percent of dose to the thyroid from 131I, while following the Fukushima accident this contribution is estimated to be up to (30 – 40) % for the residents where the main fallout occurred on March 12, 2011, and within 15 % for the residents with the main fallout on March 15, 2011. For both accidents the leading role among the short-lived radioiodines in terms of dose to the thyroid for the public belongs to 133I and 132I (due to the intake of 132Te and its radioactive decay to 132I in the body).

Conclusion: Significant differences in the estimates of the typical contribution of short-lived radioiodines to the thyroid dose for the public following those two accidents can be explained by differences in the dominant pathways of intake of radioiodine for the public: (a) ingestion intake with locally produced cows' milk following the Chernobyl accident and (b) inhalation intake following the Fukushima accident.

Subject: Nuclear Emergencies

Availability and reliability of meteorological data for atmospheric dispersion models

Tamás Pázmándi

Atmospheric dispersion calculations are widely used in the nuclear industry, not only for environmental impact assessment of normal operation and safety analysis for DBC (design basis conditions) or DEC (design extension conditions), but also for decision support systems for nuclear emergency response. Appropriate information about the source term and adequate meteorological data are essential for these calculations.

Different methods and numerical models can be used for the different purposes, and also various input data are applicable for the calculations. Assuming that the source term is known, meteorological data are necessary to specify radioactivity distribution in the environment and to provide adequate dose consequences for areas affected by the emission. The most important meteorological data for activity dispersion calculations are wind speed and wind direction, precipitation, atmospheric stability and height of atmospheric boundary layers.

These meteorological data may originate from local measurements or from numerical weather prediction data. These databases have different spatial and time resolution, accuracy and also credibility of the data varies.

Data available in different databases, reliability of the data and their consequences on the results of dose calculations will be presented; advantages and disadvantages of these data will be discussed.

Subject: Nuclear Emergencies

Assessment of effective dose from various exposure pathways for people living in Korea following a hypothetical nuclear accident

Sora Kim

Following a nuclear accident, a large amount of radioactive materials are released to the environment. Released radionuclides are dispersed to the environment and resulting radioactive contaminations of environmental media (air, soil, water, or food stuff, etc). Radionuclide contaminated environmental media lead to human exposure through various pathways and consequentially affect human health. Dose assessment code system has been developed to calculate radiation dose through various exposure pathways for people living in Korea following a nuclear accident. Exposure doses are calculated using radionuclide distribution concentration data in environmental media, which are estimated by atmospheric and aquatic dispersion models, etc. Exposure pathways considered in the code system are cloudshine, groundshine, inhalation, resuspension inhalation, water ingestion, and food ingestion. The code system includes a semi-dynamic food chain model for estimating the radionuclide concentrations in agricultural and livestock products in the Korean agricultural environment and ingestion doses from the intake of radionuclide contaminated foods. The code estimates the effective dose and equivalent doses for short-term (within 7 days), intermediate-term (within 6 months), and long-term (1 to 50 years) phases. It was assumed that radioactive materials were accidentally released to the atmosphere from Hanbit Nuclear Power Plant in Korea. Assessment was performed for adult living in the regions of Korea and applied Korean-specific environmental and habit data. Dose assessment was performed on I-131 and Cs-137, which are main contributors to human exposure following the nuclear accident. From the results, we could identify which exposure pathways are significantly contributed to the effective dose for each time period after the accident. In the short-term (within 7 days), the pathways of external exposure to groundshine and internal exposure from inhalation were assessed as the main contributors to the effective doses. Otherwise, the results showed that external exposure to groundshine and ingestion of contaminated food stuff significantly contributed to the total effective dose in the long-term (1 to 50 years). The developed dose assessment code will be used as a tool to estimate exposure doses for residents in Korea for the nuclear accident.

Subject: Nuclear Emergencies

Conceptual Design of Thyroid Dose Monitoring System using Gamma-ray Spectrometers

Sho Nishino

In the situation of a severe nuclear accident, a large amount of radionuclides could be released into the environment, and cause internal exposure of residents and workers. In order to estimate thyroid equivalent dose that largely contributes to the total internal dose, individual monitoring based on the radioiodine measurement in thyroid gland should be started immediately after the accident because half-lives of radioiodines are short (8.02 days for 131I). In-vivo measurement method using thyroid dose monitor is generally used for determination of radioiodine activity in thyroid. However, the most of currently-used thyroid monitors includes large radiation shields and is not supposed to be used at evacuation centers or emergency command posts in the radiologically affected area. Consequently, early measurements for a lot of people are significantly difficult.

Here, we propose conceptual design of the portable thyroid dose monitoring system that satisfies the following requirements; (1) a few mSv in thyroid equivalent dose is measurable under a highly-dosed environment around several 10 µSv/h. (2) portable enough to install into the each evacuation center and command post in the affected area. (3) easy to measure even for small children or people who need special care. The portable thyroid monitor consists of two gamma-ray spectrometers embedded into well-type radiation shields. The distance between two detectors is variable to fit physical size of the thyroid which depends on subject's age. The radiation shield consists of lead(Pb) and partially tungsten(W), and has an aperture only for upward. The adoption of tungsten allows to downsize the monitor so as to be applicable to small child's throat. The subject sitting on a chair puts their throat on the thyroid monitor from upside, and the radioactivity in thyroid is measured based on spectral analysis of gamma-ray energy.

The performance tests of CdZnTe detector (1500 mm^3), LaBr3;Ce and SrI2;Eu scintillation detectors (1 inch^3), which are candidates of spectrometer, were performed in the photon reference field at the Facility of Radiation Standards of the Japan Atomic Energy Agency. We confirmed that detectors show high energy resolution in the room temperature, and have enough detection capability even in the high-dose-rate field, by using an appropriate radiation shield. In this presentation, we introduce the detailed design of the monitor and give discussion on applicability of each detector to the thyroid dose monitor.

Subject: Nuclear Emergencies

Public information and transparency in the event of an emergency: New Basic Safety Standards and amended Nuclear Safety Directive

Tanja Perko

The European Union has developed an advanced legally binding and enforceable framework for nuclear energy grounded on the Spent Fuel and Radioactive Waste Directive (Directive 2011/70/Euratom), a revised Safety Standards Directive (Directive 2013/59/Euratom) and the Directive 2009/71/EURATOM as amended by the Nuclear Safety Directive 2014/87/Euratom. The amended Directive 2014/87/EURATOM takes account of a review of the EU framework on nuclear safety in the light of the Fukushima accident in 2011 and the findings of the EU stress tests. This Directive had to be transposed into Member States' legislation by 14 August 2017. Additionally, the new Basic Safety Standards Directive must be transposed into Member States' national legislation and administrative measures by the 6 of February 2018.

The implementation of these two Directives provides opportunities amongst the EU Member States to review existing procedures and improve implementation measures in the area of public information and transparency requirements in the event of an emergency. Furthermore, Council Decision 87/600/Euratom on Community arrangements for the early exchange of information in the event of a radiological emergency stipulates the arrangements that apply regarding the notification and provision of information whenever a Member State decides to take measures of comprehensive nature in order to protect the general public in case of a radiological emergency.

This study assesses the current practices in public information and transparency related to radiological emergencies in 28 EU Member States under the existing legal requirements, and highlights best practices. Furthermore, the study analyses the way and the extent to which the arrangements are implemented at a practical level, taking into account the points of view of various governmental and local authorities, licensees and other stakeholders. In addition, the planned changes and potential improvements for implementation of the recently adopted Directives to be transposed by the Member States in the near future are considered.

Acknowledgement: The research has been conducted in the context of the BSS radiological emergency, public information and transparency project, which has received funding from European Commission DG Energy, under grant agreement ENER/2017/NUCL/SI2.756526.

Subject: Nuclear Emergencies

Recommendations for Child and Adult Thyroid Monitoring After Reactor Accident

David Broggio

In case of a nuclear power point accident radio-iodine is one of the most important release and of major concern since it is responsible for an increased risk of thyroid cancer, particularly for children. Iodine internal exposure can be assessed quickly and accurately thanks to in vivo monitoring, for that purpose the radio-iodine burden is measured with detectors in front of the thyroid. However, one of the gaps identified after the Fukushima accident is the lack of child specific calibration for such measurements.

The CAThyMARA (Child and Adult Thyroid Monitoring After Reactor Accident) project was funded by the Europen Commission to issue recommendations regarding large scale thyroid in vivo monitoring in case of emergency. The project gathered 42 co-workers from 13 European institutes.

The work focused on the following items.

- Review of international recommendations regarding thyroid monitoring.

- The state of emergency preparedness in Europe, especially regarding thyroid monitoring.

- The concerns of European and Japanese citizens regarding the internal contamination monitoring.

- The reliability of affordable dosimeters that could be used by citizens to carry out their own thyroid monitoring.

- Intercomparison of thyroid measurements, for that purpose child thyroid phantoms were circulated in Europe and measurements were carried out with spectrometric and non-spectrometric devices.

- Establishment of ready-to-use data to convert thyroid measurements into doses. For that purpose different age classes, the fetus case, several radio-iodine isotopes and the case of iodine prophylaxis were considered.

- A study of the parameters influencing thyroid monitoring, parameters such as the counting distance, the thyroid size and the contribution from other organs were considered. The study was carried out by Monte Carlo calculations.

The conclusions from these work items were given in separate reports and used to issue recommendations.

The main conclusion of these recommendations and the salient results of the project will be presented.

The work is presented on behalf of the CAThyMARA co-authors.

Subject: Nuclear Emergencies

Rapid procedure for actinides and Sr-90 analysis in emergency urine spot samples - Validation of the method in the GHSI-RNWG emergency intercomparison exercise

Carolina Hernandez Gonzalez

After a radiological or nuclear incident it is necessary to give an early response in order to rapidly and accurately identify and quantify internal contamination in the exposed population using in vivo and in vitro bioassays.

In case of in vitro laboratories, routine methods for actinides and Strontium-90 quantification in urine samples require radiochemical separation processes and long counting time to achieve very low minimum detectable activity (MDA) values. However, the total turnaround time of 1 or 2 weeks make these methods inadequate to be used in an emergency scenario.

In this work a rapid radiochemical separation method applied to emergency urine spot samples is presented. It is based on a minimal sample treatment using commercial extraction columns (TEVA, TRU and Sr-Resin) and vacuum box technology which reduces significantly the processing time up to 4-5 hours. It allows the sequential quantification of Sr-90 using Liquid Scintillation Counting (LSC) and Pu, Am, Cm, U and Th isotopes using Alpha Spectrometry (AS), initiating the activity measurements the same day samples are received in the laboratory. Counting times of 2 hours (LSC) and 48 hours (AS) were used.

The accuracy of the method had been previously tested in EURADOS and BfS intercomparisons, obtaining excellent results [1-3]. However, none of these exercises simulated a real emergency scenario because radionuclides were known and the deadline to submit the results was 2 months.

In 2016 the Global Health Security Initiative (GHSI) / Radio-Nuclear Threats Working Group (RNWG), in collaboration with WHO and IAEA organised an emergency intercomparison where both activities and radionuclides involved were unknown and adequate to an emergency scenario, and participants were required to submit the results within 72 hours following the reception of the sample [4].

CIEMAT Bioelimination Laboratory successfully participated in this exercise. Samples were spiked with Sr-90, Ru-106, Cs-137 and Pu-239, but gamma emitters could not be analysed using this methodology.

The excellent results for Pu-239 and Sr-90 with bias of -0,07 and -0,11 respectively, and the compliance with the required reporting schedule, revealed that CIEMAT Laboratory has technical capacity to support effective response to a nuclear emergency.

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Subject: Nuclear Emergencies

NERIS roadmap for further research development on preparedness for nuclear and radiological emergency response and recovery

Thierry Schneider

Following the Chernobyl accident, European research programmes have been set up to further investigate and improve nuclear emergency and recovery preparedness and management. Created in 2010, the aim of the NERIS platform is to foster the cooperation in this field. Currently, 57 organisations from 28 different countries are members of the European platform with 26 supporting organisations, members of the legal association. The main objectives of the platform are to: improve the effectiveness and coherency of current approaches to preparedness, identify further development needs, improve know-how and technical expertise, and establish a forum for dialogue and methodological development.

The aim of this paper is to present the first roadmap adopted by the NERIS taking into account the last developments and the preliminary lessons learned following the management of the Fukushima accident.

The management of the consequences of the Fukushima accident highlighted the importance of providing a good transparency of the decision-making processes at the local, regional and national levels. It also pointed out the key role of the access to environmental monitoring. Despite the developments achieved after the Chernobyl accident in improving the assessment and management of the consequences of the accident and identifying countermeasure strategies, significant uncertainties still exist. These uncertainties have to be addressed in order to improve the assessment and management of the different phases of the accident. The extensive exchange of information through the social media just after the Fukushima accident has created a new situation, implying that experts in radiation protection should reconsider the process of information dissemination. The Fukushima accident has also clearly reinforced the role of stakeholders in both emergency and recovery situations and the need to further consider societal, ethical and economic aspects in emergency and recovery management. It also emphasizes the usefulness of reinforcing Education & Training for various actors.

Three main challenges have been identified for the NERIS roadmap: 1) Challenges in radiological impact assessment during all phases of nuclear and radiological events; 2) Challenges in countermeasures and countermeasure strategies in emergency & recovery, decision support and disaster informatics; 3) Challenges in setting-up a trans-disciplinary and inclusive framework for preparedness for emergency response and recovery.

Subject: Nuclear Emergencies

Advanced training of first responders at Forschungszentrum Jülich - Cross-border co-operation

Hardi Krumbach

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The Forschungszentrum Jülich (FZJ) is geographically located in the west of Germany in the border region between Germany, the Netherlands and Belgium. It has a specialized Division for Safety and Radiation Protection (S) and, as part of it, a radiological emergency response team with professional experience and knowledge. That's why Forschungszentrum Jülich is a valued partner in the training of fire brigades in radiation protection. But radioactive clouds, international traffic and terrorists don't stop at borders. Therefore, cross-country cooperation in the border region is important. Common scenarios for rescue forces like an accident at a nuclear power plant near the border, a heavy traffic accident on a cross-border road or a terrorist attack with a "dirty bomb", have to be considered

This paper describes examples of cross-border cooperation in the advanced training of first responders from Brandweer Zuid Limburg (Netherland) and the Region of Aachen (Städteregion Aachen, Germany).

The focus of such a practice-oriented training is on different exercise scenarios under realistic conditions. Exercises such as the search and best practice in finding lost radioactive products or a traffic accident involving radioactive material are examples of training with sealed radioactive sources. Alongside these exercises lectures further support the know-how-transfer by Forschungszentrum Jülich in the fields of emergency response, measuring techniques, dosimetry, etc. to the participants of the training.

The paper will also comment on the differences in the respective country-specific fire department service regulations applied at radiological emergencies in the Netherlands and Germany.

Together with additional partners an international cross-border-project involving three countries has been proposed, which includes the education of students and young scientists beside the training of first responders and evaluating possibilities of support of professional non-police response forces such as an information course with FZJ experts, e-learning courses for radiation protection experts or teacher training. The planned contributions of Forschungszentrum Jülich in the development of different training modules in radiation protection will be outlined.

Subject: Nuclear Emergencies

Improvement of thyroid uptake measurement with a set of 3D printed thyroid phantoms

Tiffany Beaumont

3D printing is an emerging technology that has been recently used for medical applications. In this context and to take advantage of the know-how acquired in 3D modelling of anthropometric phantoms, it is now possible to design more sophisticated physical phantoms dedicated to internal dosimetry applications.

In case of accidental nuclear release, thyroid in vivo measurements are used for monitoring the exposed population. Currently, these measurements are calibrated with an adult phantom which induces non negligible measurement uncertainties for children. In order to improve the radio-iodine uptake measurement for children a set of realistic thyroid phantoms corresponding to different ages has been designed with a 3D modelling software and manufactured with a 3D printer. A preliminary study of the transmission property of the printing material has shown that it can be considered as nearly equivalent to adipose tissue.

The counting efficiencies were determined for each phantom using a germanium detector (HPGe) and a sodium iodine detector (NaI). Systematic experiments were carried out, varying the measurement distance and the lateral and vertical positioning of the phantoms. The phantoms were filled with 133Ba solution (131I substitute) to carry out the measurements.

The main conclusions of these experiments are as follows:

- at contact the counting efficiency difference between the adult and 5-years old phantom is 41% (NaI) and 25% (HPGe);

- the efficiency decreases as an almost inverse square law of the distance, for all ages;

- counting efficiency varies linearly with the thyroid volume, whatever the counting distance;

- lateral and vertical displacements induce negligible uncertainties on counting efficiency, as compared with the phantom-detector distance.

The thyroid phantoms have also been used in a nuclear medicine department to improve the calibration of thyroid uptake measurements, as requested for the treatment of benign thyroid diseases. A 7% difference in counting efficiency was observed between the smallest and the largest thyroid volumes. Furthermore it was shown that using an iodine pill in the routine calibration phantom provides a counting efficiency corresponding to a 12 cm3 thyroid volume, which is roughly half of the average thyroid volume of patients treated in this department.

Age-specific thyroid phantoms were patented (FR1650855) and enabled the calibration of the emergency (NaI) and routine (HPGe) detection systems of IRSN. Other devices useful for improvement of pulmonary in vivo measurement are under development. Depending on the success of patenting application these devices will be presented.

Subject: Nuclear Emergencies

Development of a dynamic food chain model for assessment of the radiological impact from radioactive releases to the aquatic environment

Govert de With

For the uptake and fate of radioactive content in the aquatic environment and marine organisms, a software tool with a dynamic food chain model POSEIDON is developed in the early 2000´s. This tool is recently extended to accommodate for more advanced aquatic ecosystems. The tool together with its new functionality is validated using available data from the Fukushima accident and has now been integrated in the European decision support system JRODOS.

Traditionally activity concentrations in marine organisms are estimated using a steady-state biological concentration factor (BCF) approach based on computed activity concentrations in water. A more suitable approach, particularly for modelling the effects from accidental releases, is the use of a dynamic time dependent food chain model. Such model computes the uptake and accumulation of radioactive content in the marine organisms using a generalisation of the predator prey relationships found in the aquatic environment. This includes a food web of the most dominant marine organisms such as: phytoplankton, zooplankton, mollusc, crustacean and non-piscivorous and piscivorous fishes. In addition, the POSEIDON tool is recently extended with a benthic food web which addresses the uptake of radioactivity from the sediment layer to the marine organisms found at the interface of the sediment and aquatic layer. These typically include, deposit feeding invertebrates, demersal fish and bottom predators. The importance of such model extension results from deposition and accumulation in the sediment. Consequently, these organisms are at risk from much higher uptake of radioactivity, leading to a higher radiation dose to the organisms itself as well as potential fish consumers. In addition the uptake in benthic fish leads to a transfer of activity to the pelagic food chain located in the upper part of the water column.

The presented work will focus on i. the newly developed food chain model, ii. its application to both Baltic Sea and the Fukushima accident and iii. validation of the computed activity concentrations in water, sediment and fish against experimental data. Furthermore, estimated radiation dose for marine organisms and the implications from fish consumption will also be reported.

Subject: Nuclear Emergencies

Probabilistic assessment of the effect of sheltering and evacuation on the radiological dose for the population – a generic approach

Thomas Hamburger

As part of an international collaboration BfS (Germany) and PHE (UK) investigated the effectiveness of the countermeasures sheltering versus evacuation during a hypothetical accident in a nuclear power plant. The two organizations used different probabilistic modelling approaches for the assessment to retrieve independent results. The method used by BfS and respective outcomes are discussed here.

The RODOS (Real time On-line DecisiOn Support) system was used to calculate the effective dose in the first days after an accident in a nuclear power plant based on several pre-defined source terms and real weather data. Six different source terms were used for the simulations to investigate the impact of varying source strengths and release durations. 365 model runs were performed per release scenario to cover most possible meteorological conditions and transport patterns throughout one year.

The total effective dose for the emergency measures sheltering and evacuation were assessed at each point within a 20 km radius from the release site. Generic evacuation routes lead to four reception centers located North, South, East, and West of the release site at a distance of 30 km. The population was evenly distributed within the 20 km zone. The total effective dose was either evaluated for the population located at one point or the whole population located within one of the 13 emergency sectors. Only points or sectors were considered where the estimated effective dose for 7 days for children exceeded 100 mSv in at least one location, i.e. where evacuation would be recommended in Germany.

The effectiveness of sheltering versus evacuation was analyzed for each individual sample and the collective within the emergency sectors. The result largely depends on the selected source term, duration of the release, distance to the release site, and if individual samples are considered for a countermeasure or the whole collective within the affected sectors. For example, the probabilistic analysis showed that evacuation has a larger benefit for long releases and samples close to the release site and vice versa for sheltering.

However, the pure radiological benefit of one countermeasure over the other has to be set into the context of other factors that have to be considered by decision-makers, such as disruption, societal impact, economic cost and other hazards.

Further work on investigating the impact of different meteorological scenarios, evacuation settings and plume location during evacuation is planned.

Subject: Nuclear Emergencies

Presentation of evolutions of the CERES platform used to evaluate the consequences on population of pollutants releases

Marguerite Monfort

The Radiological and Chemical Impact Laboratory (LIRC) of the French Atomic Energy Commission (CEA) is in charge of the development of modelling tools to evaluate the consequences on human health of releases of radionuclides or toxic chemicals in the environment, for emergency planning and for safety evaluation. In this context, the laboratory has developed the CERES platform (Code d'Evaluations Rapides Environnementales et Sanitaires), in order that all impact calculations relative to CEA installations will be done using the same tools and methods.

It is used to evaluate the consequences on human health of releases of isotopes in the environment, either for emergency planning or for safety evaluation. Various types of emissions can be simulated: atmospheric accidental emission, atmospheric emission during normal operation or emission in liquid media under normal operation.

This application is used for emergency situations planning and for the realization of assessment calculations within a regulatory framework, for example in the safety documents relative to nuclear installations. It helps to evaluate either the consequences of accidental situations supposed to occur on installations or the impact of routine releases from single installations or nuclear sites on their near environment.

Two capacities exist, one devoted to radiological impact evaluations, the other one devoted to toxic chemical impact. Recent radiological evolutions mainly concern the implementation of isotopes and the evaluation of atmospheric dispersion and consequences of routine releases of short duration (i.e less than 1 year). A new method for the evaluation of impact of radon release has also been implemented. The impact of mud from water treatment station is also taken into account. For toxic releases, a work is in progress to simulate transfer in food chain and consequence of release of organic substances. An important work is also necessary to keep the database of substance characteristics up to date, mainly according toxicity reference values for chronic releases.

This platform is validated through inter comparison exercises between codes. Results obtained for atmospheric releases have been compared to results obtained with assessment codes (C3X) developed by the French IRSN.

Nevertheless we must keep in mind that all these platforms are only helps to evaluate the safety of installations. Results are sensitive to input data, especially releases in the environment, even if tests are implemented to limit input errors..

New dispersion models are being implemented to manage accidental releases, taking into account buildings effects.

Subject: Nuclear Emergencies

WHO guideline on iodine thyroid blocking for radiation emergencies

Zhanat Carr

A new WHO guideline was published in 2017. It recommends the provision of stable iodine to persons of 0 to 18 if at risk of being exposed to radioiodine, as an urgent protective action just before or during a radiological or nuclear emergency.

Inhalation of air or the consumption of food and drinking water contaminated with radioactive iodine during a nuclear accident will lead to internal radiation exposure due to the uptake of radioactive iodine by the thyroid, thus increasing the risk of thyroid cancer for younger people. Iodine thyroid blocking should be provided within the frame of a justified and optimized protection strategy.

The new guideline can be used by emergency planners, policy–makers, public health specialists and clinicians to strengthen public health preparedness for radiation emergencies, as required by the International Health Regulations and in line with international safety standards (i.e. GSR Part 7). A novel approach for developing a recommendation for an urgent protective action, using evaluation of the evidence base quality and strength was applied for developing these guidelines. The challenges of applying the graded evidence base approach to interventions in the field of environmental emergencies are described in the presentation.

The guideline focuses on the public health aspects of planning and implementation of iodine thyroid blocking in an emergency, such as dosage and timing of administration, adverse effects of stable iodine, its packaging, storage, and distribution. It supersedes 1999 WHO Guidelines for iodine prophylaxis following nuclear accidents. The guideline can be downloaded from: https://goo.gl/uvAGYS .

In order to enable the implementation of the new guideline, in 2017 WHO has conducted a survey on national policies on iodine thyroid blocking. The results of the survey are briefly presented.

Subject: Nuclear Emergencies

Cytogenetic biodosimetry small network and its advantage for radiation emergencies in occupational field

Nataliya Maznyk

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Cytogenetic biodosimetry has been for decades an important part of radiation accident countermeasures, particularly in occupational fields. As radiation accidents are quite rare, for radiation protection institutes with limited opportunity to keep running cytogenetic biodosimetry laboratory with highly trained staff for emergency preparedness and response, international cooperation and networking became an excellent choice.

We have established a small network bringing together the expertise from radiation protection and cytogenetic biodisimetry fields. We have conducted four inter-comparison studies in order to determine the best ways of communication, sample collection, sample processing, image and microscopy analysis, data distribution and data protection.

The studies comprised in both in vitro experiments and in vivo pilot investigations with occupational exposure samples. In vitro studies where clinically significant doses were used demonstrated the moderate variability of cytogenetic data obtained by different network participants. The factors to be considered for scoring harmonization were determined. In vivo studies in the low dose range provided information about the peculiarities of dose estimation depending on the number of images analyzed. It was shown that image analysis required from 3 to 5 times less than microscopy analysis for high- and low-dose whole body radiation exposure scenarios. Improving software parameters used for different samples complexity can further lessen the time for cytogenetic analysis.

We can conclude that creating small networks in biodosimetry field is of great advantage for radiation protection institutions and authorities with mandatory tasks in emergency preparedness and response. Considering our experience some requirements, including implementation of image analysis, study designs and further needs for network development will be discussed.

Keywords: biodosimetry, cytogenetics, network, occupational exposure, accidents.

Subject: Nuclear Emergencies

A site specific accidental aquatic transport model for radioactive release to the Danube at the Paks NPP

Tamás Pázmándi

Introduction

To determine the environmental radiation burden of a possible liquid radioactive emission, radionuclide transport in the Danube have to be taken into consideration, therefore, modelling the migration of radioactive material after an accidental release is crucial. Objective of this project was to create a dynamic transport model that gives more accurate results than the currently used and accepted conservative models.

After an accidental release, realistic parameters describing the local geological and hydrological properties of the river and the habit of the population are required to get parameter dependent dose conversions factors [Sv/Bq] for different age groups and exposure pathways.

Objectives and Methodology

In the study the primary focus was on the section of the Danube under Paks Nuclear Power Plant (in Hungary). Although the general equations for the hydrological part of the transport can be found in the literature, these equations are not detailed enough to be used for an accidental release. Therefore, local site specific geological and hydrological parameters of the Danube are needed. These parameters include the local shape of the river's cross-section, the stream stage dependent flow rate, flow velocity and also the local sediment data. With these data, the conversions of the general equations to site specific ones were made and the structure of the transport model was set.

For realistic dose values, other site specific data (habit data) is required. To obtain these, field studies have been made with the people living near the NPP of Paks.

Results

Influence of several parameters on the activity concentration and thereby on dose results was evaluated. One of the most important parameters is the river stream stage, since it has a huge influence on other hydrological parameters, and has a significant daily change. Therefore, in an accidental release mean values of the stream stage are not precise enough to use for calculating activity concentrations.

Analyses where carried out with the newly developed site specific equations for isotope I-131 based on a hypothetical aquatic release of 109 Bq activity. The release was taken as an instantaneous emission from a shore side point source for different stream stages.

Subject: Nuclear Emergencies

Development of Radiation Shielded Vehicle and on-board monitoring system in the Service of Emergency Responders

János Petrányi

In modern times there are drones and robots available in case of a nuclear emergency to reduce human exposure, but human present is still unavoidable. There is a need to transport persons into contaminated areas or rescue them from the hot zone. This need cannot be met with a traditional vehicle, because during transportation the amount of suffered dose can limit the time available for the actual task in the hot zone or the return journey. To fulfill both nuclear security and nuclear safety purposes, a new vehicle was created in 2014. The first Radiation-Shielded Emergency Vehicle RSV-Komondor can play a major role in case of a nuclear emergency. In this presentation I will focus on the radiation protection aspect of the vehicle and introduce the method how the onboard system calculate the dose for every person carried by the vehicle, how to support the commander with vital online information regarding dose rate levels, radiation exposition, remaining mission time, etc. The intelligent system supports the driver with instructions to avoid higher contamination, this way the suffered dose can be significantly reduced. We found a way to determine the radiation dose rate, which is not affected by the shielding effect of the vehicle. The presented methods will give an idea how to use such a system and highlight the benefits available for the user. The onboard radiation monitoring system contains multiple intelligent detectors inside and outside of the vehicle. The detectors have wide measuring range to serve as sensitive environmental radiation measuring equipment or a high dose level meter as well. I will demonstrate the concept how the system was designed to prevent airborne radioactive particles entering into the cockpit, and how the vehicle is able to enter into highly contaminated areas. I will explain how the vehicle should be able to transfer contaminated passengers, without effecting on the driver and the commander. We conducted tests to see the capabilities of the vehicle. Not just the off-road capability but the shielding and monitoring capability was checked. The presentation will not cover the security potentials of the vehicle, however it is essential to know that it can be used for this area as well. The first system is on service since 2015 and I will share some information about the gained experience.

Occupational

Subject: Occupational

Retrospective dose reconstruction for an incident with a concealed radium needle

Daniela Ekendahl

In August 2017, a historical radium (226Ra) needle was found in a building in Prague. The needle was concealed in a wall under a window frame. Maximum ambient dose equivalent rate values measured in close proximity to the window frame reached up to 2 mSv/h. The place was situated in a corridor where people normally did not stay for a long time. However, an interesting question arose: how long has the needle been there? Because of the remarkable history of the building, our speculation was that the needle could have been concealed during World War II, most likely in 1941. In order to verify this assumption, we removed one adjacent brick nearest to the place of the finding. The brick was used for retrospective dosimetry based on optically stimulated luminescence (OSL) of quartz extracted from the brick. In addition, we carried out a dose reconstruction in our laboratory. We simulated the radiation exposure conditions using the needle and a brick containing thermoluminescence detectors (TLD). In this way, we got dose rate values for a few chosen positions inside of the brick. We compared the TLD results with the OSL results of quartz from corresponding segments of the brick. A good agreement between the results suggests that the assumption of 76 years' exposure is very likely correct.

Subject: Occupational

Monte Carlo simulations for individual dosimetry of workers in disposal facilities for SNF

Frank Becker

A proper and safe management of spent nuclear fuel (SNF) discharged from commercial nuclear power plants is a subject of societal concern. Certain working procedures in the storage / disposal facilities might lead to an enhanced level of radiation exposure for workers. Hence, a realistic estimation of the personal dose during individual working scenarios is desired.

In this work a methodology for Monte Carlo simulations for the determination of the radiation exposure of workers involved in emplacement of casks with SNF in generic deep geological disposal facilities was developed. As a result of the investigations it was shown that neutron radiation dominates the radiation field and in turn determines the dosimetry. The contribution of backscattered neutrons also plays an important role.

To verify the simulations, experiments with cask-type components were carried out at the TU Dresden neutron generator (neutron energy 2.5 MeV) located at the Helmholtz Zentrum Dresden Rossendorf. Overall, a good agreement between experiments and related simulations confirms that the developed approaches are adequate for investigating scenarios in the field of spent nuclear fuel disposal.

Based on these results, comparative studies were performed that analysed emplacement scenarios of an approximately equal amount of SNF into clay-stone and rock salt. For the same work steps / waste quantities, the dose rate in claystone is higher than in rock salt. As the dose depends on the work steps, it was shown, by means of an example, that a 50% higher dose can be expected in claystone compared to rock salt.

Subject: Occupational

Intercomparison on Internal Dose Assessment (ICIDOSE 2017): preliminary results

Tamás Pázmándi

Retrospective internal dose assessment is a process that, beginning with the collection of individual bioassay data, requires the adoption of numerous hypotheses: e.g. on pathway and time pattern of intake, material specific parameters as lung solubility and particle size distribution of the inhaled aerosol, gut absorption factor for ingestion pathway.

Previously the IDEAS Guidelines were developed to promote agreement in the applied methodologies; they are based on the three pillars: harmonization, accuracy and proportionality.

To promote the harmonization of the IDEAS Guidelines for the methodology of internal dose assessment with those reported in ISO 27048 standard, a recent document, developed under a Service Contract issued by European Commission during 2014 to 2016, and soon to be published in the Radiation Protection document series of the EC, will provide “Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides“, so called: “TECHREC Recommendations”.

To check the practical applicability of the TECHREC Recommendations an internal dose intercomparison exercise was promoted in mid-2017, within the Working Group 7 “Internal dosimetry” of EURADOS, European platform for research in the field of the dosimetry of ionizing radiation.

Four case studies, having different degree of complexity, have been proposed to 84 potential participants:

A first case with inhalation of 60Co aerosol, to be evaluated both with ICRP78/119 and new OIR ICRP 130/134 models and mathematical tools;

The second case is related to routine monitoring for 125I by using 6 thyroid repeated measurements on a female subject;

A further case is based on a confirmatory monitoring programme for U isotopes in an exposed worker, which prompted the establishment of special monitoring, and for which the dose has to be evaluated without knowing the grade of enrichment (natural or otherwise) of the aerosol being inhaled;

The final case is relative to an accidental inhalation of 241Am aerosol followed by decorporation therapy using Diethylenetriamine Pentaacetic Acid (DTPA).

In the present contribution the preliminary results of the intercomparison exercise (performed during autumn-winter 2017) are presented.

For each case the description of the overall results has been performed using both conventional statistics and “robust statistics”. Comparison with the outcomes of similar intercomparison exercises in 2000 and 2006 is also reported.

Practical application of the TECHREC Recommendations is finally judged on the basis of the closeness of overall assessed results throughout all cases and on the outcome of a special workshop to be held in autumn 2018.

Subject: Occupational

Setup and validation of two new personal dosimetry systems at the Belgian Nuclear Research Centre SCK•CEN: Landauer InLight and Mirion Instadose+

Olivier Van Hoey

The Dosimetry Laboratory at the Belgian Nuclear Research Centre SCK•CEN has been providing personal dosimetry for more than 50 years. About 10.000 radiation workers are currently wearing an SCK•CEN dosimeter. Since the mid-80s the Dutch TNO dosimetry system based on thermoluminescent detectors has been used. This system is now gradually being replaced because the reader mechanics are failing more and more often and new TNO readers are no longer being produced.

Two new systems were recently introduced: the Landauer InLight system based on optically stimulated luminescent detectors and the Mirion Instadose+ system based on direct ion storage. While InLight is a conventional system, Instadose+ is very innovative. The Instadose+ dosimeters can be read at predefined intervals or by pushing its button without requiring an external reader. The dose data are transferred wirelessly to our server by Bluetooth and a network communicator. This gives several advantages with respect to conventional systems: dosimeters do not need to be sent to us every month, readings can be performed anytime and dosimeters can be assigned to a different user anytime. On the other hand, the novel character of the system made it more challenging to setup the system and to guarantee its quality.

The new systems were introduced following the European Commission's RP160 recommendations for individual monitoring. Firstly, the technical performance was assessed by testing the most important characteristics like dose response, reproducibility, energy response, angular response, sensitivity to environmental parameters (light, temperature, humidity), signal fading and reader stability. This type testing program according to the IEC62387 standard allowed to define the scope of the systems. Secondly, the algorithm for calculating the dose in terms of Hp(10) and Hp(0.07) was defined. Based on this algorithm and the results from the type test also the uncertainty budget and the detection limit of the systems were assessed. Finally, the systems were setup in practice by properly organizing the lab, developing dedicated software and defining clear work instructions. The software and work instructions also include multiple quality control mechanisms to guarantee traceability of the measured doses in terms of Hp(10) and Hp(0.07), follow up the stability of the system and avoid errors in accordance with the ISO17025 standard.

Both systems are now accredited according to ISO17025 by the Belgian accreditation body BELAC. Currently our clients are gradually being switched to the system of their preference.

Subject: Occupational

Radionuclide-contaminated wound analysis using a Timepix detector

Peter Rubovic

Timepix is a modern radiation detector that belongs to a family of hybrid semiconductor pixel detectors. Its sensitive part can be made either from Si, CdTe, or GaAs with thickness ranging from 100 µm up to 2 mm. The 14.08 mm wide square detector is divided into 65536 pixels with 55 µm pitch. Every interacting particle can be visualized and identified using morphological analysis of the shape of its track inside the sensor. Moreover, the energy deposited in each pixel can be determined, so the total energy deposited by specific particle in the sensor can be resolved. An indisputable advantage of such configuration is the possibility to set detection threshold for each pixel independently. This makes the detector practically noiseless, even with the energy threshold set to ~5 keV. Heavy ionizing particles (e.g. alphas, protons), beta and low energy gamma radiation can be detected thanks to the fact that this detector has no window. Neutrons can be detected after adding suitable convertors as well. In our presentation, we will show results of pilot experiments which focus on radionuclide-contaminated wounds analysis. In the experiments, we employed the Timepix detector with 300 µm thick Si sensor and several common radionuclides (e.g. 241Am, 239Pu, 137Cs, 60Co, 90Sr/90Y). A simple experimental setup consisting of the Timepix detector and a PC enables us to determine spatial localization of a radionuclide, its identification, and in some cases even to estimate its depth in tissue.

Subject: Occupational

Radiation Protection Aspects of the upgrade of the CERN PS Booster in the framework of the LHC Injectors Upgrade (LIU) project

Robert Froeschl

The LHC Injectors Upgrade (LIU) project has been initiated to improve the performances of the existing injector complex at CERN to match the future requirements of the HL-LHC (High Luminosity LHC). In this frame work, the CERN PS Booster (PSB) is presently undergoing an ambitious consolidation and upgrade program. This upgrade comprises a new injection charge-exchange injection system for H- ions at a kinetic energy of 160 MeV from CERN's new Linac4 using Carbon foils, the replacement of the main radio-frequency systems and an energy upgrade of the PSB rings from 1.4 GeV to 2 GeV which includes also the upgrade of the beam extraction system.

This contribution presents the radiation protection aspects of the upgrade and consolidation of the PSB in the course of the LIU project. The focus will be the implementation of the ALARA process, as it has been adopted at CERN, in this project during the various project phases, including already the design phase for critical components as well as the installation, operation and dismantling phases.

Several upgrades and consolidation works have already been performed. The main beam dump of the PSB has been exchanged in 2013 during the Long Shut-down 1 (LS1) and an extensive de-cabling campaign has been carried out in the technical stop of the accelerator complex at the beginning of 2017 to make space of the installation of new cables needed for the upgrades. The radiological assessment of the design of the main beam dump is presented, including its impact on the final design. In addition, the ALARA process will be discussed for these two major accomplished interventions, presenting also the optimization measures and their approval.

Several upgrades are planned to be performed in the Long Shut-down 2 (LS2) that will take place in the years 2019 and 2020. The new charge-exchange injection system and a new beam scraping system will be installed to be able to cope with the beams delivered by Linac4. Dedicated radiation protection assessments of the interventions that will take place during operation of the equipment have been carried out for both upgrades. FLUKA Monte Carlo simulations to predict the residual ambient dose equivalent rates have been used together with detailed work procedures of the interventions to estimate the collective and individual doses for the personnel for these interventions. These estimates have significantly influenced the finally adopted designs.

Subject: Occupational

Improved handling and readout of household salt (NaCl) for optically stimulated luminescence (OSL) dosimetry for rapid, accurate and cost-effective prospective dosimetry applications

Lovisa Waldner

Household salt (NaCl), read-out by optically stimulated luminescence (OSL), has proven to be highly sensitive to ionising radiation. This has led to applications in retrospective dosimetry where household salt has been used to reconstruct doses to unintentionally exposed individuals. However, there are several problematic issues related to individual retrospective dose assessments using NaCl e.g. the signal is depleted if the salt is exposed to light and the conversion from absorbed dose in salt to human absorbed dose is not straightforward. In order to still make use of the good dosimetric properties of NaCl it has previously been suggested to use NaCl for prospective dosimetry. Here we present significant improvements for various prospective dosimetry applications with NaCl readout by OSL: a completely new approach for handling the salt together with a newly developed readout protocol, the dosimetric properties such as minimum detectable dose, reproducibility, may be greatly improved.

Using the new method of handling the salt and the improved readout protocol, the minimum detectable dose (MDD = 3×SD) and the minimum measurable dose (MMD = 10×SD) were calculated as 11 and 37 µGy respectively for one of the household salts (rock salt) and 18 and 60 µGy respectively for the other household salt (ocean salt). The signal reproducibility is within 2% when calculating absorbed doses using only one calibration dose of a Sr-90/Y-90 calibration source, administered after the readout of the “unknown” signal. When relating the unknown signal to the signal from a single calibration dose, it is possible to determine absorbed doses within 6% of the theoretical value. However, sensitisation caused by irradiation of the salt must be considered in order to achieve precise absorbed dose estimates within 6%. For high absorbed doses (> 300 mGy), it is necessary to either extend the readout with more calibration doses in order to adjust for possible sensitivity changes of salt or to use a calibration curve for dose estimations, thus eliminating the need of any calibration dose.

Subject: Occupational

Management Gurus on Radiation Protection

J. van den Eijnde

Background

In radiation protection, management issues are much less discussed than technical issues. The cause is probably that management is often seen as a soft skill, for which solid useful theories are not available and which can best be learned on the job.

This however is not the case. There are some very useful theories, of Noble prize winners, that can be used in understanding and implementing organisational structures, radiation protection culture and safety regulations. To facilitate the discussion in the radiation protection community on management issues, some of these theories will be discussed, with an emphasis on practical radiation protection issues.

Methods

The focus in this article will be on the following theories. The 'McKinsey 7-S Model'; 'Structure in Fives' (H. Mintzberg); 'Cultures and Organizations' (G. Hofstede); 'Thinking, Fast and Slow' (D. Kahneman).

Results

In the 'McKinsey 7-S model' an organisation is described with the terms Shared values, Strategy, Style, Structure, Staff, Systems and Skills. Using this description will facilitate the discussion on changing radiation protection culture as started with the IRPA 2014 'Guiding principles for establishing a radiation protection culture'.

'Structure in fives' will give more insight in the origin of the choice in the Directive 2013/59/Euratom for both an rpo and an rpe, and in some problems the implementation of these obligations might raise. It is discussed if the 'generative culture status', as defined as the most desirable culture status in the IRPA 2014 report, is feasible for a radiation protection culture.

'Cultures and Organizations' will facilitate the discussion on differences in structure and culture between countries; f.i. the emphasis on leadership that is proven to be correct in Anglosaxon countries might not be valid in other countries.

The recent book 'Thinking, Fast and Slow' can be used to explain the relevancy of the legally prescribed risk analysis.

Conclusion

By using some concepts of accepted management theories the discussion on radiation protection management will be facilitated. Institutions that educate rpo's and rpe's should integrate the learning of managerial insights and tools in their curriculum.

Subject: Occupational

Suitability of a new generation Direct Ion Storage (DIS) dosemeters for use in an approved individual monitoring service

Tom Grimbergen

Like the majority of the approved Individual Monitoring Services in Europe, the NRG Individual Monitoring Service presently uses thermoluminescent dosemeters (TLD) to monitor radiation exposure of radiation workers. Since the beginning of this century some Individual Monitoring Services in Europe use dosemeters based on Direct Ion Storage (DIS) as legally approved dosemeters (1). The newest generation Direct Ion Storage (DIS) dosemeters have the advantage that the detector signals can be transferred for evaluation to the dosimetry service periodically using bluetooth and internet communication, such that there is no need for sending the dosemeter to the dosimetry service for readout. Also, the user can initiate intermediate dose readings, which means that the user can get information on a possible exposure incident almost instantaneously.

Two types of Direct Ion Storage (DIS) dosemeters (InstadoseTM+ and InstadoseTM2) provided by Mirion Technologies were investigated for their suitability to be used as an alternative for the TLD dosemeters at the NRG Individual Monitoring Service. Extensive tests taken from IEC 62387 (2) were performed such as those for energy and angular response, coefficient of variation and non-linearity, buildup and fading, and influence of ambient temperature. From the results it can be concluded that the DIS dosemeters tested are able to fulfil the most important IEC 62387 criteria and show performance similar to that of TLD.

Procedures for quality assurance were set up, such as a “dummy customer” and procedures to test long term stability. Apart from the radiation performance requirements, the DIS dosimetry system should fulfil additional requirements such as requirements for protection of personal data. Therefore an IT-system was set-up which ensures appropriate data security levels. Based on the results of the investigations the authors conclude that the DIS dosemeters tested can be a suitable alternative for TLD. A request for approval of this new generation DIS dosemeters in the approved Individual Monitoring Services of NRG will be submitted to the Dutch authorities early 2018.

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Subject: Occupational

The IRPA efforts in enhancing awareness in the implementation of eye lens monitoring and protection of workers

Marie Claire Cantone

ICRP in its statement on tissue reactions, April 2011, after reviewing epidemiological evidence on tissue reactions, recommended a reduction in the eye lens dose limit for occupational exposure in planned exposure situations from 150 to 20 mSv/y. This recommendation has been incorporated into the new IAEA BSS and in the current Euratom BSS. The European Member States are required to implement the new BSS by February 2018 and accordingly, for monitoring and surveillance, workers with lens exposure likely to exceed 15 mSv/y will be classified as category A workers.

In 2012, with the enactment of a dedicated task group, IRPA started a process to survey the initial views of the Associate Societies (AS) worldwide and to provide a medium for discussion on the implications of implementation of the new limits for the lens of the eye in occupational exposure (1,2,3). IRPA launched a second phase in 2015 with a task group given over to review progress with the implementation of the recommendations from the early phase, to collate the practitioner experience in the field (4). The IRPA Guidance on implementation of eye monitoring and eye protection of workers (5) was published in 2017 to provide practical recommendations about when and how eye lens dose should be monitored, as well as guidance on use of protective devices depending on the exposure levels.

IRPA has agreed to continue to monitor and to ensure that the findings and issues highlighted through the task groups continue to be an integral part of the ongoing international discussion, as well as including any future updates on implementation of the revised lens dose limit. A third phase is to be launched in 2018 to contribute to the creation of a positive approach and awareness of development in radiological protection in the working place by focusing on the practical aspects of dosimetry and dose registration. This phase will also consider doses to the eye lenses of patients undergoing procedures in which these may be high. The trend in the AS views and the exchange of experiences at international level among the AS, from the initial phase of IRPA survey on the lens of the eye, will be presented and discussed.

Subject: Occupational

Eye lens dosemeters intercomparison exercise organized by EURADOS

Isabelle Clairand

In the context of the revision of the European Basic Safety Standards Directive 2013/59/EURATOM, stating a new eye lens dose limit for occupational exposure equal to 20 mSv per year, EURADOS organized an intercomparison dedicated to eye lens dosemeters, including tests with photon and beta radiations. The main objective was first to complete the previous intercomparison of this type organized in 2014 by EURADOS only for photon fields and to update the overview of the different dosimetric systems currently available in Europe for eye lens dose monitoring. The eye lens dosemeters provided by the 22 participants coming from 12 different countries, were all composed of thermoluminescent detectors, of various types and designs. The dosemeters were irradiated with several photon and beta fields defined in relevant standards. Participants were asked to report the doses in terms of Hp(3) using their routine protocol. The results provided by each participant were compared to the reference delivered doses. All the results were anonymously analysed.

Results are globally satisfactory for photon qualities since 90% of the results are in accordance to the ISO 14146 standard requirements. For a minority of participants, some discrepancies between the results and reference doses were observed in the case of the irradiation setups characterized by large angles and/or low energies. These results are very similar to those observed in the case of the previous eye lens dosemeter IC organized by EURADOS, where 90% of the results were in accordance to the standard.

Results for betas are less satisfactory and illustrate the difficulties in measuring beta radiation. The main observed problem was an over-estimate of Hp(3) for low beta energy. The intercomparison demonstrates that dosemeters designed for Hp(0.07) are not suitable to monitor the dose to the eye lens in case of betas because the filter placed in front of the detector is too thin. Dosemeters designed for Hp(0.07) are suitable for monitoring the eye lens dose only in pure photon radiation workplaces but not in workplaces with significant contributions of beta radiation. Only dosemeters well designed for Hp(3), i.e. optimized for both photon and beta fields simultaneously, are able to perform properly eye lens dose monitoring at all workplaces

Subject: Occupational

EURADOS Action on Harmonisation of Individual Monitoring: Intercomparisons, Surveys, Training and Networking Activities

Codrut Cherestes

In the field of radiation protection, activities are often carried out by small numbers of highly-specialised staff. One such activity is the individual monitoring of worker doses from ionising radiation, an activity that helps employers to fulfil their health and safety obligations to their employees. Across Europe there is significant variation between Individual Monitoring Services (IMS) in terms of their required staffing levels, their access to technical support and their contexts within parent organisations. In larger IMSs, staff often work full-time on operation of the service, and the higher throughputs mean that experience builds relatively quickly; whilst staff of the smaller IMSs are likely to have other responsibilities that occupy their time and restrict the building of such experience. There are also differences in the dialogue that takes place between IMSs in the same country. Thus, the opportunities for personal development can be limited.

EURADOS is a network of more than seventy institutions from across Europe, involved in research and other radiation dosimetry activities. EURADOS operates through a number of Working Groups. In 1996, a task group was set up with the aim of promoting harmonisation of individual monitoring in Europe. Since then it has pursued a number of activities that have successfully met that aim, but that have incidentally provided opportunities for training and networking. These opportunities have helped to ensure that best practice is rapidly shared amongst the staff of IMSs.

Harmonisation activities continue to include: regular self-sustaining IMS intercomparisons and the associated participants' meetings; training courses based on the technical recommendations produced by EURADOS for the European Commission; surveys, to establish perceptions and needs; "learning network" events at the EURADOS annual meetings; and the operation of an online discussion group.

This paper describes these learning activities and future plans in detail, as well as providing information obtained from feedback.

Subject: Occupational

Regulatory oversight of safety culture in the nuclear industry

Yvonne Dubbers

Introduction

The safety culture concept was first formally applied to the nuclear power industry by the International Atomic Energy Agency's (IAEA's) International Nuclear Safety Advisory Group. The term was used to explain how the lack of knowledge about risk and safety and failure to act appropriately contributed to the Chernobyl accident.

Framework for strong safety culture

The IAEA defines a strong safety culture as "the assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance." The IAEA has developed an international framework for strong safety culture consisting of five overarching safety culture characteristics:

• Safety is a clearly recognized value;

• Leadership for safety is clear;

• Accountability for safety is clear;

• Safety is integrated into all activities;

• Safety is learning driven.

Each one of these 'safety culture characteristics' has attributes that have been identified as essential for achieving a strong safety culture (see appendix 2). These attributes can be used by organizations as a reference when assessing and improving safety culture.

Regulatory oversight of safety culture

The ANVS embraces the IAEA's approach which is based on Edgar Schein's iceberg metaphor. According to Schein, any organizational culture should be studied at three levels (figure 1) which go from the very visible (conscious) to the tacit and invisible (unconscious) ones. By interpreting what people say, the behavior of leaders and staff, and other visible aspects (e.g. safety performance data, policies, standards of housekeeping and material condition, how incidents are investigated and how findings are addressed) strengths and blind spots within a particular culture can be identified.

One of the (oversight) methods is the independent assessment, aiming to further develop and strengthen the organization's culture. A number of tools (interviews, questionnaires, focus groups, document reviews and observations) are used to systematically collect a wide variety of organizational data. This multidimensional data is analysed and consolidated into an "image" of the organization's culture.

Another method is KOMFORT which supports recording organisational and human

factors (artefacts) during on-site inspections. The continuous collection of information in the personnel-organisational area serves the long-term monitoring and helps to understand, improve and/or detect negative developments in this area at an early stage, similar to an early-warning system.

Subject: Occupational

Clearance levels for surface-contaminated objects leaving a nuclear facility: preliminary results

Federica Russo

In 2013, an Integrated Regulatory Review Service (IRSS) mission was conducted by the International Atomic Energy Agency (IAEA), with the objective to perform a review of the Belgian nuclear- and radiation-safety regulatory framework. One of the conclusions was the identification of a need for clearance levels for surface-contaminated objects, in addition to the already existing generic clearance levels. In 2016, Bel V and the Dutch National Institute for Public Health and the Environment (RIVM) launched a joint pilot project aimed at evaluating the applicability of the SUDOQU (Surface Dose Quantification) methodology for deriving nuclide-specific surface-clearance criteria for objects released from nuclear facilities.

SUDOQU is a methodology that allows dose calculations for exposure to surface-contaminated objects, developed by RIVM in the aftermath of the Fukushima nuclear accident to provide surface-contamination criteria for imported consumer goods. The innovative feature of this methodology is the assumption of time-dependent surface- and airborne-contamination levels, described through a mass balance incorporating several removal and deposition processes. This makes SUDOQU particularly promising for the derivation of surface-clearance levels, as it allows for a more realistic dose assessment for public exposure scenarios, where the exposed person is likely to use a same contaminated object for which the activity progressively decreases as a result of its use.

As a first step, the project focused on the development of public exposure scenarios for the reuse of a typical office item, e.g. a bookcase or a desk, released from the controlled area of a nuclear facility. Deterministic calculations were performed to assess the annual effective dose, considering several radionuclides and different values of the model's relevant input parameters. The results disclose an intricate interplay among the involved mechanisms, in which a certain assumption might emphasise the contribution of one exposure pathway at the expense of another, thus generating a delicate balance between opposite effects: the final outcome is specific for the considered nuclide and exposure scenario. The results were benchmarked against those of alternative surface-contamination models, and proved to be in good agreement.

The preliminary results of this pilot project demonstrate the versatility of the SUDOQU methodology, as well as its suitability for dose assessments related to clearance of objects from a nuclear facility. The project will thus be extended to more generic study cases, for the development of nuclide-specific surface-clearance levels.

Subject: Occupational

Improving personal dosimetry of medical staff wearing radioprotective garments: design of a new whole-body dosimeter using Monte Carlo simulations

Clarita Saldarriaga Vargas

Medical staff working in interventional radiology and cardiology are exposed to scattered ionizing radiation coming from the patient. Radiation protection garments (RPG) like a lead apron and a thyroid collar are therefore worn by this population, together with (a) personal dosimeter(s) for monitoring the effective dose. Accurate personal dosimetry when wearing RPG is not straightforward, mainly because such garments protect the body partially and are made of high-Z materials. These features make the exposure of the body highly inhomogeneous and affect the reading of conventional Hp(10) dosimeters [1]. Although several single and double dosimetry methodologies have been proposed to estimate the effective dose when wearing RPG (E_RPG), many studies have shown that these methods can result in unacceptable underestimations or strong overestimations depending on the exposure conditions [1, 2]. This study aimed at designing a personal whole-body dosimeter capable of estimating E_RPG directly, without the intermediate step of Hp(10).

The dosimeter was designed by means of Monte Carlo calculations, taking as a reference the energy and angular dependence of the effective dose E_RPG calculated using an ICRP110 reference male phantom equipped with a 0.5mm-thick lead apron and thyroid collar [1]. Photon irradiations of the dosimeter and the ICRP phantom were simulated in MCNPX_2.7.0, using monoenergetic beams and X-ray spectra of selected N, W, and RQR qualities with energies up to 120 keV.

A realistic dosimeter model based on two Ag-doped phosphate glass radiophotoluminescent detectors with high- and low-Z filtration is presented. The dosimeter “reading” dose is obtained from a linear combination of the dose to these detectors. An extensive number of simulations were performed to optimise the material, thickness, shape and position of all filters. Simulation results indicate that current dosimeter model can estimate E_RPG with an error of ±25% for most monoenergetic beams and ±15% for X-ray spectra. Although its dose response can still be improved and has to be validated experimentally, these in silico results show the potential of such dosimeter to improve personal dosimetry of this occupationally-exposed population, by reducing the uncertainty in the estimation of the effective dose and offering a more practical solution than current methods.

References:

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Subject: Occupational

Results of the EURADOS intercomparison IC2016 on whole body photon dosemeters

Tom Grimbergen

EURADOS the European Radiation Dosimetry Group performed international intercomparisons for whole body dosemeters for individual monitoring services (IMS) already for more than 20 years. Since 2008 these whole body intercomparisons were performed on a regular two yearly basis. In the recent whole body dosemeter intercomparison IC2016, in total 86 monitoring services from 36 countries with 103 dosimetry systems participated. More than 2200 dosemeters were irradiated by two selected accredited irradiating laboratories. As dose quantity the personal dose equivalent Hp(10) and Hp(0.07) was used.

The irradiation plan consisted of ten irradiation setups with four different photon radiation qualities (S-Cs, S-Co, N-40, N-150), one additional beta radiation quality (Sr-90) and tree different angles of radiation incidence (0°, 45° and 60°). The applied doses covered a wide range from 1 mSv to 500 mSv. Selected aspects of dose linearity, energy and angular response even under mixed irradiation conditions (S-Cs together with Sr-90) of all systems were tested and analysed.

The paper describes the individual results for the personal dose equivalent quantities Hp(10) and if submitted for Hp(0.07) of all participating systems and compares these results with the “trumpet curve” performance criteria according to ISO 14146 (2000). In addition these recent results were compared with previous intercomparison data too.

Subject: Occupational

New software to integrate uncertainty in the optimisation of monitoring for internal contamination

Estelle Davesne

In case of risk of occupational intakes of radionuclides, the potential internal contamination of workers must be monitored. This monitoring is carried out by measuring the activity retained in the body or present in excreta. The results of these measurements can be interpreted in terms of committed effective dose using biokinetic and dosimetric models adapted to exposure circumstances.

However, the measurement variability and the incomplete knowledge of exposure conditions introduce uncertainty in the dose assessment. Statistical methods were developed to evaluate this uncertainty as a criterion to optimize individual monitoring programs. The objective it to guarantee compliance with dose limits or dose constraints within a defined level of confidence and using reasonable operational means. These statistical methods were implemented in OPSCI software developed in collaboration between IRSN and AREVA.

This software allows, by integrating uncertainty:

- estimating the minimum dose detectable by a routine monitoring program from available information on physico-chemical forms of the handled material, on the level of activity at the workplace, and on the detection limits of the techniques available to measure incorporated radionuclides;
- assessing the committed effective dose following an intake incident, along with its associated uncertainty, from measured retained and/or excreted activities;
- helping the person in charge to choose the monitoring program best adapted to the potential or ascertain exposure conditions.

The developed methods will be explained and applied to real cases in order to demonstrate their practical interest.

Subject: Occupational

Personal neutron monitoring at the Paul Scherrer Institute

Eduardo Yukihara

The Paul Scherrer Institute (PSI) carries out personal neutron monitoring services since 1998 using polyallyl-diglycol polycarbonate (PADC) track-etch detectors. Starting in 2010 this has been done using the commercial system from Track Analysis Systems Ltd. (UK). The design of the dosemeter used at PSI has been optimised for workplaces around high-energy accelerators, where the neutron energy spectra are dominated by fast neutrons. In addition to the dosimetry of the workers at PSI, the service is also offered to other research institutions in Europe, such as CERN (Switzerland) and DESY (Germany), and via the partner dosimetry services MPA-NRW (Germany), and Seibersdorf Laboratories (Austria). The overall performance of the PSI neutron dosimetry system in routine is determined by PADC material properties, etching conditions, read-out analysis methods, etc. In 2017 a total of ~35’000 PADC were processed with a portion of 30% of PADC used for quality assurance procedures. In this contribution, we will provide an overview of the neutron dosimetry service at PSI, including results of quality assurance tests, e.g. PADC material acceptance tests, as well as the results from the latest intercomparisons and investigations on material properties.

Subject: Occupational

Uncertainty estimation of thyroid activity measurements and its consequences in dose assessment

Anna Pantya

For the great majority of incorporated radionuclides the internal dose is estimated in two steps. In the first step the actual activity present in the body is determined by direct or indirect monitoring methods. By direct measurements activity in the whole or part of the human body can be determined (in vivo), while by the indirect methods the radioactivity of physical and biological (in vitro) samples are assessed. In the second step the intake value and the associated committed dose can be estimated on the basis of measured data considering necessary assumptions on exposure conditions (time and route of intake, chemical form etc.).

In the in-vivo measurement the low activity of the human body, the non-standard geometry and the limited measurement times considerably increase the measurement uncertainty in comparison to that of environmental or biological in-vitro samples. The adequate thyroid measurement results are influenced by various parameters e.g. the shape of thyroid, position of the thyroid inside the human body, the detector distance from the body surface, the distribution of the activity within the organ and the position of the detector during calibration with a thyroid phantom. All these factors affect the accuracy of dose estimation as well. The results of uncertainty assessments were included in dose estimation calculations with MONDAL 3 and IMBA codes. The influence of the uncertainties of assumptions such as the date and route of intake, the physical and chemical form were also investigated in terms of the accuracy of the final internal dose assessment.

The measured results are supplemented with Monte Carlo simulations, in order to extend the study by applying wider range of variable parameters. The main steps and results of the research will be presented in the presentation.

Subject: Occupational

Effective doses from the Norwegian diet

Mari Komperød

Ingestion doses between and within countries are expected to vary significantly due to differences in dietary habits and geographical variations in radionuclide concentrations. This work presents the most comprehensive assessment to date of the effective radiation dose from the Norwegian diet, from natural as well as anthropogenic radionuclides. Ingestion doses to the Norwegian public are calculated using national dietary statistics and, when available, data from Norway or other Nordic or Northern European countries were used to estimate typical levels of radionuclides in the diet.

The age-weighted average effective dose received by the Norwegian population from the diet is estimated at 0.41 mSv y-1 from naturally occurring radionuclides and 0.010 mSv y-1 from anthropogenic radionuclides. This is approximately 50% higher than the estimated world average provided by UNSCEAR. The estimated radiation doses received by children and infants are somewhat higher than for adults (0.45 and 0.60 mSv/y, respectively). Aside from the constant dose from 40K, 210Po is the radionuclide that provides the largest dose contribution from the diet, followed by 222Rn, 228Ra and 210Pb. Naturally occurring radionuclides in seafood is the largest single contributor to the total ingestion dose, averaging 0.088 mSv y-1, mainly due to 210Po in fish and shellfish. Since seafood 210Po concentrations vary considerably between marine species and is such an important part of the exposure estimate, it is important to use data for the species consumed in the respective country or region when performing dose estimates.

Ingestion doses were also assessed for selected population groups with elevated exposure. Individuals with a very high intake of contaminated wild foods, such as reindeer or game, may receive a significant contribution to the total annual exposure from anthropogenic radionuclides originating from the Chernobyl accident. In Norway, this is particularly the case for Sami reindeer herders, who consume much more reindeer meat than the average population. Persons with elevated 222Rn concentrations in their drinking water supply are also estimated to be among those receiving the highest ingestion doses in Norway.

Subject: Occupational

Personal and Environmental Monitoring at the Paul Scherrer Institute using a Radiophotoluminescence Dosimetry System

Frank Assenmacher

In 2015 the Paul Scherrer Institute (PSI, Switzerland) introduced Ag-doped phosphate radiophotoluminescence (RPL) glass detectors (Chiyoda Technol, Japan) in its individual and environmental dosimetry service. Currently 2500 people, mainly PSI staff and from public institutions, are monitored on a regular basis with RPL personal dosemeters. In this contribution, we describe our collected experience using this technique: (1) results from national and international intercomparisons in external and environmental dosimetry, often including unusual radiation qualities and high exposure dose levels; (2) environmental dosimetry using RPL in the area around PSI; (3) results from quality assurance procedures giving a long-term overview on the stability and accuracy of the RPL dosimetry system; and (4) examinations of the practical measurement uncertainty due to increasing accumulation of background dose from natural radiation background.

Subject: Occupational

Characterization of scattered radiation field in interventional radiology theatres

Marie Marie Nowak

This study validates the feasibility to use a hybrid pixel detector for X-ray dosimetry in clinical applications. The use of a real-time energy-resolving detector allows for the generation of radiation maps in operating theatres providing a new tool for the radiation protection of patients and medical staff. The detector used in the measurements was the Timepix3 hybrid pixel detector, developed at CERN within the framework of the Medipix3 collaboration. This detector uses Time over Threshold to measure X-ray energy, it uses CMOS technology and has square pixels of 55 µm side in a matrix of 256 x 256 pixels. The Timepix3 chip detects the charge generated by each incoming photon in a pixel and sends out the hit pixel coordinates, the charge amplitude and the arrival time. This information can be used off-line to reconstruct the spectrum of the incoming photons. It provides a new device concept for radiation field characterisation, easier-to-use and more compact than conventional X-ray spectrometers used in radiation protection.

The chip was calibrated following a standard procedure with radioactive sources and fluorescent materials, for which a dedicated Python code was developed in order to obtain a specific calibration curve for each one of the 65’536 pixels. First measurements were carried out in irradiation conditions relevant for diagnostic applications, using a reference Beam qualities recommended by the International Electrotechnical Commission for medical applications (RQR series). This allowed us to characterise the energy spectrum of the radiation field in clinical applications and to demonstrate that the calibrated detector could be used for dosimetry measurements. Both the primary beam and the scattered radiation field have been measured. We found the minimum detectable energy around 4 keV, and the energy resolution for Am-241 (59.5 keV) is 25%. In a second step, measurements were performed in theatres for several interventions in radiology departments in two different hospitals, allowing intercomparison: Christchurch Hospital (New Zealand) and University Hospital of Lausanne (Switzerland).

These measurements were used to characterise the radiation field and produce maps with an energy spectrum for relevant points in the room. From this information it is possible to calculate dose in various tissues avoiding dosimeter-specific calibration factors. The spectral information is particularly valuable to improve eye lens dose assessments and it can be used to optimise radiation protection gear.

Subject: Occupational

Dose Rate Estimations and Potential Exposure Situations for Incorporation of Tritium from Gaseous Tritium Light Sources (GTLS)

Matthias Rizzi

Gaseous Tritium Light Sources (GTLS) are usually small pin-sized objects used as illumination in a variety of consumer goods like watches, key-markers or gun sights. Following The 2007 Recommendations of the International Commission on Radiological Protection exposure situations due to inhalation or ingestion of tritium from such radioactive sources have to be seen as planned exposure situations for the general public. Since the annual dose limit for the public is 1mSv, an exposure from an accidental release of tritium must be lower.

In the present paper different exposure situations are described. Based on earlier experimental studies the effective dose for each exposure is calculated. It is shown that the effective dose from tritium exposure may very well exceed the annual value of 1mSv for inhalation as well as ingestion under certain circumstances. The results are discussed against the background if dose rate from such exposure situations is justified, especially with respect to their intended use. Furthermore an outline for effective measures for optimization is given.

Subject: Occupational

Processing methods of the measured results with passive dosimeter used in occupational exposure and dose assessment accuracy

Felicia Mihai

The occupational exposure protection of the personnel which used radioactive sources has to be made among others with personal passive dosimeters. The measurement accuracy of the personal dosimeters depends of a lot of factors from detector features, technical processing, and human factors till methods of information processing recorded by the dosimeter system.

Considering the detector features depend of the manufacturer the other factors depend of dosimetry services.

In this work is presented the dose assessment accuracy as a result of processing by different mathematic equations of the measured data with film personal monitoring dosimeter. In this way, the film dosimeters where exposed to different dose values from 0.1 mSv ÷ 1.0 Sv to Cs 137 standard source.

The mathematical equations used in the fitting of the dosimeter response were of sigmoidal, exponential and linear type. For each optical density versus dose dosimeter response obtained on the film under dosimeter badge metallic filter the fitting process by mathematical equation was performed. The choice of the mathematical equation for fitting the data is determined by the residual size. The mathematical equations studied in this paper allow a good assessment of the radiation doses but there is no mathematical equation that fully fits the measuring range (0.1-1000) mSv.

The most relevant results were obtained on the film under Pb 0.40 mm, Plastic filters and Cu 1.00 mm filter especially. So, refer to Cu 1.00 mm obtained data, the dose assessment uncertainties were 6.4 % by fitting data with the exponential equation on the 0.1 ÷ 50.0 mSv dose range and considering for uncertainty calculation dose from 0.5 mSv to 50.0 mSv; 4.7% by fitting data with the linear equation on the 20.0 ÷ 700.0 mSv dose range and considering uncertainty on 30.0 ÷ 700.0 mSv; 6.3% by fitting data with the sigmoidal equation on the 0.1 ÷ 500.0 mSv dose range and considering uncertainty on 0.3 ÷ 70.0 mSv; 6.2% with sigmoidal equation on the 70.0 ÷ 1000.0 mSv dose range and considering uncertainty on 70.0 ÷ 1000.0 mSv. To assess the low doses the linear fitting on tightly dose range was necessary. The dose assessment uncertainties was 5.0 % by linear fitting of the 0.1 ÷ 1.0 mSv and considering uncertainty calculate on 0.1 and 1.0 mSv inclusively.

Subject: Occupational

Induced activation studies for the LHC upgrade to High Luminosity LHC

Cristina Adorisio

The Large Hadron Collider (LHC) will be upgraded in 2019/2020 to increase its luminosity (rate of collisions) by a factor of five beyond its design value and the integrated luminosity by a factor ten, in order to maintain scientific progress and exploit its full capacity. The novel machine configuration, called High Luminosity LHC (HL-LHC), will increase consequently the level of activation of its components.

The evaluation of the radiological impact of the HL-LHC operation in the Long Straight Sections of the Insertion Region 1 (ATLAS) and Insertion Region 5 (CMS) is presented. Using the Monte Carlo code FLUKA, ambient dose equivalent rate estimations have been performed on the basis of two announced operating scenarios and using the latest available machine layout.

The HL-LHC project requires new technical infrastructure with caverns and 300 m long tunnels along the Insertion Regions 1 and 5. The new underground service galleries will be accessible during the operation of the accelerator machine. The radiological risk assessment for the Civil Engineering work foreseen to start excavating the new galleries in the next LHC Long Shutdown and the radiological impact of the machine operation will be shown.

Subject: Occupational

Evaluation of FNTD and PADC neutron dosimeters in yearly intercomparisons

Alberto Stabilini

The Paul Scherrer Institut (PSI) offers a neutron dosimetry service based on polyallyl diglycol carbonate (PADC) detectors (TASTRAK, Track Analysis Systems Ltd.) to several institutions working in the high energy physics (Fiechtner and Wernli, 1999). Since 2016 PSI has been collaborating with Landauer Inc. to compare the innovative fluorescence nuclear track detector (FNTD) (Akselrod et al., 2014) with the PADC detector system. In 2016 and 2017 we participated in the neutron dosimeter intercomparisons organized by the Physikalisch-Technische Bundesanstalt (PTB, Germany) with both of these systems. This work provides an overview of these intercomparison results.

For the 2017 intercomparison, 28 PADC detectors and 28 FNTD detectors were sent to PTB. There irradiations were performed, for both PADCs and FNTDs, according to the reference irradiation conditions shown in Table 1 (some detectors were also left unirradiated). PADC were evaluated at PSI: the detectors were chemically etched in a 6.25 M NaOH solution for 2 h 50 min at 85 °C and analyzed by the TASLIMAGE Neutron Dosimetry system. FNTD were evaluated at Landauer Inc. using a commercial FNTD reader FXR700N based on confocal laser scanning microscopy.

Results show general agreement between the two detector types and the reference values. The maximum deviation from the reference was a factor 1.6 for PADCs and a factor 1.8 for FNTDs. Both PADC and FNTD dosimeters can distinguish between sources used for irradiation, relying on the track density ratio behind converters for fast and slow neutrons. In particular, in FNTDs evaluation, a source dependent calibration factor is derived according to the track densities ratio. Referring to the intercomparison in 2016 (Yukihara et al., 2017), there was an improvement regarding unirradiated FNTD, which showed no appreciable doses. Although there was a wrong irradiation source assignment for 5 detectors when the doses were <0.8 mSv, the results were still within the tolerance limits recommended by the German Commission for Radiation Protection (Strahlenschutzkommission, SSK). The wrong irradiation source assignment is due to the low track counts, for which statistics is too poor to offer an unequivocal track densities ratio. Results are presented in Figure 1, including a re-evaluation applying the correct calibration coefficients (open points): PADC detectors showed overall less variability than FNTDs among the same irradiation group, with a ~20% systematic overestimation. FNTDs, even if showing more variability in the same irradiation set, provided mean results closer to the reference.

Subject: Occupational

The Dose Rate Protection System at SwissFEL

Elisa Musto

The new Swiss Free Electron Laser (SwissFEL) at Paul Scherrer Institute (PSI) is currently being commissioned.

The SwissFEL primary electron beam is foreseen to reach an energy of 7 GeV with a pulsed-time structure in the range of a few ps.

This poster describes the Dose Rate Protection System (DRPS), a safety system whose aim is to ensure that the Swiss radiation protection regulations are respected, and the first measurements performed to validate it.

The DRPS design had to face some challenges from a radiation protection point of view. The accelerating facility is, in fact, located in a national recreational area, partly accessible by general public. Moreover, since the shielding of the facility is designed to cope with full beam loss only for a few s, the DRPS has to react before dose legal limits are violated.

The DRPS monitoring units are placed inside the SwissFEL tunnel along the whole electron beam transport range and readout by a data acquisition system (DAEQ). The requirements, which the monitoring units had to fulfill, were based on simulations performed with the Monte Carlo transport code FLUKA. These simulations showed that in case of full beam loss a significant contribution to the dose outside the tunnel shielding arises from neutrons, and that the spectral neutron distribution is almost independent on the primary beam energy. Extended range neutron dose rate monitors suitable for measurements in pulsed neutron fields were selected and opportunely customized to cope with the SwissFEL environment, where an intense photon background is also expected.

The DRPS calibration makes use of a classification of the SwissFEL facility in terms of comparable shielding configurations called Shielding Classes (SC): the dose attenuation due to the different SC has been derived from Monte Carlo simulations and analytical methods. For same loss point different SC may connect the tunnel to different areas outside of it. These areas may be subject to different regulations in terms of dose guidance values. The most stringent scenario in terms of shielding and guidance value pairs is used by the DAQE to calculate alarm thresholds taking into account the detector configuration. These thresholds are automatically adapted if any detector parameter changes. If an alarm threshold is reached, a signal is sent to stop beam operation.

The DRPS is currently operative. Its commissioning involved measurement campaigns, performed in November and December 2017: the outcome validates the calibration assumptions within systematic uncertainties.

Subject: Occupational

Radiation Protection Assessment of the Emission of a D-T Neutron Generator: Simulations with MCNP Code and Experimental Measurements in Different Operating Conditions

Gian Marco Contessa

Practical guidelines are provided for the safe use of a portable d-t Thermo Scientific MP-320 neutron generator producing pulsed 14.1 MeV neutron beams.

The neutron generator's emission was tested experimentally and reproduced by MCNPX Monte Carlo code. Simulations were particularly accurate, even generator's internal components were reproduced on the basis of ad-hoc collected X-ray radiographic images.

Measurement campaigns were conducted under different standard experimental conditions using an LB 6411 neutron detector properly calibrated at three different energies, comparing simulated and experimental data. In order to estimate the dose to the operator vs. the operating conditions and the energy spectrum, the most appropriate value of the conversion factor between neutron fluence and ambient dose equivalent has been identified, taking into account both direct and scattered components.

The results of the simulations show that, in real situations, when there is no information about the neutron spectrum at the point where the dose has to be evaluated, it is possible - and in any case conservative - to convert the measured value of the count rate by means of the conversion factor corresponding to 14 MeV energy. Safety distances are also evaluated for workers and population in normal working conditions both in an "open field" scenario and inside a real bunker.

The outcome has a general value and can be useful if this type of generator has to be used when more accurate evaluations, e.g. by Monte Carlo simulation, are not available, also enabling a more accurate design of experimental activities in different setups. The increasingly widespread use of this type of device for industrial and medical applications makes the results of this work of interest in different situations, especially as a support for the definition of appropriate radiation protection procedures and, in general, for risk analysis.

Subject: Occupational

Occupational doses for aircraft maintenance workers due to thoriated magnesium alloys

Andreas Schirmer

Thorium was used for several decades as a component in lightweight magnesium alloys in order to improve the creep-resistance. Also for large components as diffusers, compressor housings and gear boxes of aircraft engines Mg-alloys with a Th-content up to 4 % were used. The elevated cost and the higher tendency of corrosion as compared to other Mg-alloys were accepted in these applications. Presently the use of Th-Mg-Alloys concerns components in military aircraft. Hence the present or retrospective assessment of occupational doses concerns air force personnel and employees in military aircraft repair. Here the results of dose-rate measurements on a wide variety of aircraft engines used in the German Federal Armed Forces (Bundeswehr) are presented. The spatial characteristic of the radiation field is presented since it determines the calculation of both, effective dose and organ dose due to external exposure. Further, the role of the corrosion of long term stocked components to provoke incorporation is addressed.

Subject: Occupational

Dosimeters for monitoring of eye lens exposure at nuclear power plants

Marko Fülöp

Reduction of the annual dose limit from 150 to 20 mSv significantly increases the importance of the accuracy of eye lens monitoring. Recently there have been proposed several models of eye lens exposure monitors for photon and beta fields placed at various positions on a head.

During the operation of NPP, workers are required to check the equipment on a day-to-day basis in areas with mixed neutron and gamma fields.

However there are only a few publications that deal with eye exposure monitoring in neutron fields.

This work is focused on proposal and comparison of two models of personal eye lens monitors suitable for neutron and gamma ray fields present in NPP.

The proposed models of personal monitors are based on detection of albedo neutrons and photons by pairs of TL dosimeters (TLD 600 and TLD 700). Both monitoring systems are fastened on a frame of safety glasses. The first monitoring system is located in the middle of the forehead above a root of nose and the second one consists of two dosimeters fastened above zygomatic arches at eye corners in contact with skin.

The properties of neutron eye lens monitoring systems, such as angular and energy dependencies, were evaluated using MCNPX simulation of the Zubal head voxel phantom in which analytical models of eyes and lenses were inserted. Kerma factors and corresponding quality factors were used to calculate equivalent doses of neutron lens monitors. The real neutron energy spectrum in NPP was measured using a Bonner spectrometer.

Calibrations of the eye lens monitoring systems in units of operational quantity Hp(3) for neutrons were performed using the water cylindrical phantom with 20 cm diameter and 20 cm height and unmoderated Pu-Be neutron source.

Results of measurements show that the radiation fields within the workspace in NPP are inhomogeneous with soft neutron energy spectrum. Proposed neutron monitors of eye lens are energy dependent and therefore they require correction factors for actual neutron energy spectrum present on a workplace.

Gratitude: This post arose for the EURADOS

Subject: Occupational

Execution of the EURADOS 2017 intercomparison for whole body neutron dosimetry

Sabine Mayer

The European Radiation Dosimetry Group (EURADOS) has carried out a number of different intercomparison exercises in the past that qualify as proficiency tests for different dosimetry systems and radiation types. In 2017, the second EURADOS intercomparison for neutron dosemeters (IC2017n) has taken place. The first intercomparison (IC2012n) highlighted the difficulties some personal dosemeters have in terms of accuracy, especially for moderated fields and energies near their fast neutron threshold. It also demonstrated the reliance of many dosimetry systems on pre-information about the neutron field. 31 systems were entered in IC2012n.

This second intercomparison concerns the performance of neutron dosemeters intended to measure neutron personal dose equivalent, Hp(10), as provided by individual monitoring services. The neutron dosemeters must be the ones used routinely in individual monitoring of occupationally exposed workers. No systems under development were allowed in the intercomparison. 33 systems were entered into the intercomparison. All were passive systems with most being etched track systems, and the remainder mainly albedo thermoluminescence dosemeters (TLD).

The irradiations, which included exposures to neutrons and mixed fields of neutrons and photons as commonly encountered in workplaces, have been performed in accredited irradiation facilities in terms of personal dose equivalent, Hp(10). The range of energies used in the intercomparison extended from thermal to several MeV, with different dose values and angles used. Most irradiations have been performed in neutron fields with no additional photon component, over and above that resulting from the neutron-producing process, e.g., photons from a radionuclide neutron source. However, for some fields, an additional photon component had been included.

In general, intercomparison exercises need to be undertaken regularly to demonstrate that standards are upheld and that any new dosemeters meet the required standards. This contribution reports on the execution of the EURADOS IC2017n and gives a preliminary analysis of the results.

Subject: Occupational

Application of traditional type test standards to non-traditional dosimetry - Using IEC 62387-2012 to type test the Mirion Instadose products

Michelle Baca

Summary of type test standard

IEC 62387-2012 is a standard that rigorously tests dosimetry systems; successful testing typically indicates a robust system. It provides guidance and criteria for testing personal dose equivalent and environmental monitoring.

Capabilities of instadose2

The instadose2 is a semi-passive dosimeter; it communicates dose information via low-energy Bluetooth at scheduled intervals or when activated by the user. Each dosimeter has two direct-ion storage (DIS) detectors, operating similarly to ion chambers and providing independent Hp(10) and Hp(0.07) measurements. Each detector has two elements contained in a chamber, a high sensitivity element (DeepLow or ShallowLow, DL or SL) and a low sensitivity element (DeepHigh or ShallowHigh, DH or SH). The DIS has been commercially available since the mid-1990s but only recently has been designed for use as a service dosimeter rather than a wholesale dosimetry system.

Challenges of interpretation

The IEC type test standard was written for traditional dosimetry services; one that consists of separate readers and dosimeters; a service that expects the routine return of devices for processing; and a service that can periodically perform physical inspections of the dosimeters after return and prior to re-issue.

As the instadose2 is both a reader and a dosimeter, interpretation and application of the standard quickly becomes challenging; it is imperative to test the devices adequately, ideally while minimizing overlap of dosimeter and reader tests and capitalizing on the unique capabilities of the dosimeter.

The instadose2 is not a device that is returned once shipped to the client. Monitoring of health and ensuring quality in this service model is not anticipated nor expressly tested in the type test standard.

Summary of results

The type tests were conducted per the standard, or, when necessary, with the intent of the standard in mind while adjusting for the unique service model of the instadose2. All tests were performed in 2016 – 2017, at the Mirion Irvine facility, SCK·CEN in Mol, Belgium, and PNNL in Richland, Washington. The instadose2 meets the requirements of IEC 62387-2012.

Conclusions

As dosimetry technology advances, the methods to test the performance of dosimetry needs to advance alongside. Any deviations from those standards should be evaluated and justified. As these standards are revised, service providers and manufacturers should be part of the discussion. Tests should be representative of field conditions but also give room for innovation.

Subject: Occupational

EURADOS intercomparisons for photon and beta personal dosemeters: a review of results and conclusions

Tom Grimbergen

In response to growing demand from Individual Monitoring Services (IMS) for independent performance tests for dosimetry systems, the European Radiation Dosimetry Group (EURADOS) has been organizing dosimetry intercomparisons for many years. Most of these fit into the programme of self-financing intercomparisons for dosemeters routinely used by IMS. This programme is being coordinated by EURADOS working group 2 (WG2) and started in 2008. Up to now this programme has included five intercomparisons for whole-body dosemeters and two for extremity dosemeters in photon and beta fields, and two intercomparisons for whole body dosemeters in neutron fields. The intercomparisons programme is fully described in reference [1].

The intercomparisons for whole body dosemeters have been carried out regularly every two years (IC2008, IC2010, IC2012, IC2014 and IC2016) and those for extremity dosemeter were performed in 2009 and 2015 (IC2009ext and IC2015ext). They were open to all participants and the costs were totally covered by the participation fee. Both the number of participating services and the number of participating countries has increased steadily. Detailed information about these intercomparisons can be found in references [2-7].

For each intercomparison, the irradiation plan is defined so that participants can obtain information of their dosimetric systems on characteristics such as linearity, reproducibility, energy and angular dependence, and response to mixed irradiations. Irradiation laboratories are selected on the basis of their accreditation, previous experience in similar tasks and price. Irradiations are performed in terms of personal dose equivalent, Hp(10) and Hp(0.07).

From IC2014 on, an on-line platform for supporting the entire registration process, communication and data exchange was implemented. The platform is easy to use and secure; it allows the participants to monitor the status of their dosimetry systems in real-time and to download all relevant information and documents.

The results were in all cases analysed according to the performance criteria established in the standard ISO 14146 [8], commonly known as the ‘trumpet curve’.

The participation in intercomparisons gives IMS the opportunity to show compliance with their own quality management system, compare results with other participants and develop plans for improving their dosimetry systems.

This work summarizes organizational aspects, technical details and the results of the different intercomparisons of dosemeters in photon and beta fields and highlights some conclusions about the trends observed over time and the general performance of IMS of external radiation.

Subject: Occupational

The myOSL series of portable and stationary dosimetry equipment based on BeO-OSL

Daniel Richter

BeO is an excellent dosimetric material with near tissue equivalency and best exploited by optically stimulated luminescence (OSL). The dose range and sensitivity make it a first choice for personal and medical dosimetry. Efficient application in OSL dosimetry requires instrumentation capable of reading as well as fast zeroing. We here present two new BeO-OSL-readers designed for rapid mass measurement in personal dosimetry and for single element use.

myOSLdosimeters, consisting of 2-BeO-elements (Hp(0.07) and Hp(10)), can be read with the myOSLraser equipment. Here reading as well as zeroing is achieved in a single unit within seconds for a standard dose in personal dosimetry. This allows a fast throughput and is cost effective because no separate zeroing device is required. For irradiation purposes, e.g. local calibrations, the separate myOSLirradiator is equipped with a Sr-90/Y-90 source (37 MBq). Individual dosimeters are automatically identified by a bar-code within either system and managed for automated measurement, zeroing, irradiation, etc. The measurement of large numbers of dosimeters, e.g. in dosimetric services, is achieved with the myOSLautomatic attachment. This automated feeding system for 200 of the myOSLdosimeters can be mounted on any myOSLraser or myOSLirradiator.

The myOSLdosimeters as well as the myOSLraser comply with IEC-62387. The system provides excellent reproducibility of the dosimetric material (0.66% sd for 136 repeats of a 1mSv dose). Such performance is achieved by state of the art stabilization of luminescence stimulation and detection. The myOSLdosimeters exhibit an excellent linear dose response, a large dose range applicability and high sensitivity.

Flexibility is provided by the single BeO-element OSL-reader/eraser myOSLchip. Due to its low weight it is truly portable and can be even battery operated. The myOSLchip dosimeters fit into standard phantoms. Mechanical transport is achieved manually, and the user therefore has full control of measurement and bleaching. Individual dosimeter calibration is here possible as well. The number of dosimeters and measurement data managed by the device itself is restricted only in portable mode, but full use of the myOSLdosimetry software can be made in non-portable operation and connection to a PC.

This myOSLdosimetry software allows full scale data management for any devices of the myOSL series, including individual dosimeter calibration and device calibration. Dosimeters exceeding single or total accumulated threshold doses are automatically flagged and automated reporting functions are included.

Physics, Chemistry & Biology

Subject: Physics, Chemistry & Biology

Accounting for ingrowth of radioactive progeny in dose assessments

Teun van Dillen

In radiological dose assessments it is common practice to directly include the dose contributions from radioactive progeny in the dose evaluation of the parent nuclides. This convenient approach is generally implemented by modifying the dose conversion coefficients of the parent nuclides. We studied the current method adopted by the Euratom Article 31 Group of Experts (Radiation Protection 122, part 1) and by the International Atomic Energy Agency (IAEA, Safety Reports Series No. 44) who studied the annual effective dose in the context of exemption and clearance. This method was originally developed for long-lived radionuclides, but applied to all nuclides. We concluded that this method is not applicable to parent nuclides and related progeny both with half-lives < 1 year, then possibly underestimating the annual effective dose.

Therefore, we have developed an alternative, practical technique to conservatively include the dose contribution of daughter nuclides into that of the parent nuclide. Similarly to the existing method, our technique considers a net dose conversion coefficient (DCC) constructed of the sum of the parent-DCC and a weighted daughter-DCC. In the existing method, the weights were based on the maximum activity (concentration) of the daughter nuclides within a time span of 100 years. The method that we will present considers the maximum of the number of decays of the progeny over any one-year interval within a one-century time frame. As an example, the weighting factor of I-131 as daughter of its parent Te-131 increases by a factor of 500 with respect to the existing method, from 0.002 to 1.0.

Subject: Physics, Chemistry & Biology

Development and benchmark of a microdosimetric model able to predict the efficiency of luminescent detectors exposed to charged particles: implications for space and hadron therapy dosimetry

Olivier van Hoey

The increasing utilization of lithium fluoride based thermoluminescent detectors in radiation environments as space and hadron therapy beams requires an accurate knowledge of their efficiency for measuring a wide range of charged particles and energies. The experimental determination of the relative efficiency of luminescent detectors through irradiations in calibrated heavy charged particle accelerators is time consuming and very expensive. Furthermore, due to technical limitations it is often not possible to irradiate the detectors with energies above 1 GeV/u or with less common isotopes. In addition, the efficiency determination for very low energies is biased with big uncertainties of all parameters (i.e. LET, range, absorbed dose). However, a complete characterization of the efficiency of these detectors is needed, especially for space applications where particles with a really broad energy spectrum and exotic isotopes are present.

Using the Monte Carlo code PHITS, a microdosimetric model has been developed to predict the relative efficiency of luminescent detectors for measuring different radiation qualities. This is done by relating the simulated dose probability distribution of the specific energy in nanometric targets with an experimentally determined response function. The model has been tested for LiF:Mg,Ti (MTS) and LiF:Mg,Cu,P (MCP) thermoluminescent detectors exposed to charged particles from 1H to 132Xe in the energy range 3 MeV/u to 1000 MeV/u. The obtained results have been compared with experimental data present in literature showing a very good agreement. The implications of the use of this model for space and hadron therapy dosimetry applications will be discussed with a particular focus on a recently developed method for assessing the change of the relative biological effectiveness (RBE) within the spread-out Bragg peak (SOBP) of a proton therapy treatment by using luminescent detectors.

Subject: Physics, Chemistry & Biology

Implementing the calculation of doses to biota in PC-CREAM 08®

Tracey Anderson

PC CREAM 08® was developed by Public Health England as an update to the original PC CREAM, which was developed under contract to the European Commission and implements the EU methodology for routine releases. The tool is a suite of models and data intended to be used to assess the radiological impact of continuous and constant releases of radioactive effluents to atmosphere, rivers and marine waters arising as a result of normal operations. Until now, PC CREAM 08® only assessed radiological impact to humans; work is currently under way to implement the calculation of dose rates to the Reference Animals and Plants (RAPs) defined by ICRP. In order to achieve this, the user identifies the area of interest (the target area) and PC CREAM 08® calculates the mean activity concentration in the media in which the RAPs live, e.g. air, on the soil surface, underground, etc. Activity concentration ratios (CRs), taken from ICRP Publication 114, are used to estimate the RAPs' internal activity concentration and dose conversion factors (DCFs), taken from ICRP Publication 108, are used to calculate the internal and external dose rates to the RAPs. Consideration is given to the amount of time that RAPs spend in different media, for example Duck and Frog spend some time above ground and some time on or in freshwater and Rat spends some time above ground and some time underground in a burrow. This poster presents dose rates per unit discharge to a variety of RAPs calculated using this methodology and compares the results with output from other tools, such as ERICA, that calculate doses and dose rates to non-human biota. Differences and similarities are discussed.

Subject: Physics, Chemistry & Biology

Relative biological effectiveness in a proton spread-out Bragg peak formed by pencil beam scanning mode

Anna Michaelidesova

Worldwide implementation of proton therapy to clinical practice requires detailed knowledge of biological response of normal and tumor tissues to proton irradiation. In proton therapy, a generic value of Relative Biological Effectiveness in the whole range of the Spread-Out Bragg Peak is used. The Relative Biological Effectiveness value was established to be 1.1 according to in vitro and in vivo experiments using cell cultures and mice during proton therapy early days. However, many studies have shown that the Relative Biological Effectiveness value is not constant in the whole range of the Spread-Out Bragg Peak. Mainly, at the distal edge of the Bragg peak, values of Relative Biological Effectiveness are increasing due to the higher Linear Energy Transfer of the low energy protons.

Normal human neonatal dermal fibroblasts were grown in tissue flasks and irradiated using the Pencil Beam Scanning mode in various positions of the Spread-Out Bragg Peak. The whole irradiation volume of 10x16x8 cm3 was composed by 13 layers, ie. 13 different proton energies. The longitudinal spread of the beam, and thus the homogeneous dose region was 8 cm. Cells were irradiated in four irradiation positions: entrance, proximal, middle and distal. Cell survival and micronuclei assay were then followed. Cell samples were irradiated by a 60-Co source for comparison. Monte Carlo simulations to estimate the Linear Energy Transfer values at the irradiation positions were performed using a general purpose Monte Carlo particle transport code PHITS.

The Relative Biological Effectiveness values found from the cell survival of human normal neonatal fibroblasts irradiated by protons in the Pencil Beam Scanning mode were found to be significantly higher that the recommended by the International Commission on Radiation Units and Measurements value for clinics 1.1. In the distal position of the Spread-Out Bragg Peak, the Relative Biological Effectiveness values were found to be 2.05 ± 0.44, 1.85 ± 0.42, 1.53 ± 0.38 for survival levels 90, 50 and 10%, respectively. The proportion of binuclear cells containing micronuclei as well as the micronuclei frequencies display an increasing tendency towards distal end of the Spread-Out Bragg Peak, which corresponds to the increasing complexity of damage to chromosomal DNA.

Subject: Physics, Chemistry & Biology

Radiation resistance in the cyanobacterium arthrospira

Anu Yadav

The multicellular cyanobacterium Arthrospira has been studied for many years because of its excellent nutritive value as a food- and feedstock and its many applications in biomedical sciences. The MIC group at SCK•CEN studies Arthrospira sp. PCC 8005 as a principal organism and edible endproduct of the MELiSSA bioreactor, a life support system developed by the European Space Agency. Our aim is to elucidate the genetic and biochemical pathways involved in the resistance of strain PCC 8005 to acute high doses of gamma radiation, i.e, upto 5,000 Gy, and the fundamental principles of cellular radiation resistance. To study the effect of ionizing radiation (IR) on the growth and morphology of Arthrospira and to check whether resistance to extreme high IR doses is a general trait in Arthrospira, different strains of Arthrospira were exposed to increasing doses of Co60 gamma radiation. They were analysed for culture-based growth recovery, morphological changes, and cellular and molecular effects. For the latter we used TEM microscopy and LC-MS/ESI-TOF metabolic profiling. We also studied these strains for IR-induced changes in the intracellular content of proteins, pigments, carbohydrates, and fatty acids. We found that resistance to IR in Arthrospira strains is not just confined to the strain PCC 8005 but this feature was also present in all other Arthrospira strains investigated, albeit that some strains seemed to be more resistant to IR than others, i.e. the lethal dose varied in the range of 2,000 – 5,000 Gy. We also observed during continuous cultivation of strain Arthrospira sp. PCC 8005 under controlled conditions that slight variations in growth conditions can have a profound effect on its trichome morphology, with a permanent change from the original spiral form to a straight morphotype. In concordance, we noted differences between these morphotypes in the amount of light harvesting antenna, the cellular content of hydrophilic and lipophilic proteins and fatty acid composition, although the FTIR analyses suggest that organic chemical compositions of those morphotypes are analogous. Interestingly, the new straight trichome morphotype was found to be more resistant to IR than the original spiral morphotype. To further understand this complex response, we performed an in-depth analysis using mass spectrometry and are designing experiments to follow changes in gene expression using RNAseq. In a later stage, a resequencing project is planned to elucidate the genetic changes between the spiral and straight morphotypes.

Subject: Physics, Chemistry & Biology

The use of ionizing radiation in experimental animals, a sustainable combination

Andre Zandvoort

Working with radioactivity and working with experimental animals have at least one thing in common; the need to justify the use. Similar to the justification for using radioactivity, the use of experimental animals always has to be justified. In medical research however, experimental animals provide an essential tool for gaining knowledge of disease origin and progression. In combination with radioactivity the possibilities are even broader. For example, human tumorcells can be transplanted in a mousemodel to follow the development of the tumorcells in combination with intervention strategies. In the past, tumor development was followed by transplanting a larger number of animals and sacrifice animals at different time point. Nowadays, the development and biological behavior of the tumor can be followed in detail by imaging techniques. This reduces the number of animals used with substantial numbers.

In this contribution, we will give an overview of the different possibilities for using ionizing radiation in experimental animals. Animals can be imaged with PET scans based on injected radioactive tracers. Using PET scans, biological processes in, for example, the brain or heart can be studied. Also, tumor development and susceptibility of the tumor for intervention strategies can be followed longitudinal. Other animal imaging possibilities in Groningen are SPECT and CT scans.

Also irradiation of animals with X-rays or protons is possible. Effects of irradiation of tumors in combination with strategies to prevent irradiation damage can be studied in mice and rats. Irradiation of tumors with protons is nowadays a hot topic because of the reduction of aversive side effects on the healthy tissue surrounding the tumor. Animal models provide a useful tool to investigate the effects of proton irradiation on tissues in the pre-clinical stage. In Groningen, the Center for Advance Radiation Technology (KVI-CART) has the facilities for irradiating animals with protons. The protons are generated by the 200 MeV cyclotron. Animals are positioned under anesthesia at the end of the beam and by collimate the beam, specific regions can be irradiated.

By using imaging techniques animals don’t have to be sacrificed at different time point but can be followed longitudinal. This justifies the use of radioactivity and, as an appurtenant benefit, reducing the number of animals needed, resulting in sustainable use of radioactivity as well as experimental animals. In addition, experimental animals prove to be a useful tool for pre-clinical research for clinical irradiation strategies.

Subject: Physics, Chemistry & Biology

Ecological effects of ionizing radiation in a freshwater microcosm

Tanya Hevrøy

Ecosystem response to gamma radiation exposure depends on the different species sensitivities and the multitude of direct and indirect pathways by which individual organisms can be affected, including the potential for complex interactions across multiple trophic levels. In this study multi-species microcosms were used to investigate effects of ionizing radiation in a model freshwater ecosystem, including endpoints at both structural and functional levels and as well as ecological interactions. Microcosms were exposed for 22 days to a gradient of gamma radiation with four dose rates in the range from 0.72 to 19 mGy/h. Results showed significant dose related effects on photosynthetic parameters for all macrophyte species. No significant effects of radiation were observed for the consumers in the microcosms, however trends indicate the potential for longer-term effects. We also witnessed a different response of Daphnia magna and Lemna minor compared to previous single-species studies, illustrating the importance of multispecies studies, which aim to encompass systems more realistic to natural ecosystems. Microcosms have allowed us to isolate specific relationships between interacting species and test the effects of ionizing radiation on them, both directly and indirectly. In addition, the ecological pathways and processes measured was central to understanding the results we witnessed. This approach to radioecology has been strongly promoted in recent decades, and to our knowledge, this is the first microcosm study performed at environmentally-relevant dose rates.

Subject: Physics, Chemistry & Biology

Development of the new radiation monitoring system using DNA molecules as a radiation sensor

Kikuo Shimizu

A biological dosimeter that directly reflects cellular responses to ionizing radiation in living organisms would be useful for protecting human health against exposure. We are developing a novel dosimetric system using DNA molecules as a radiation sensor. DNA molecules are irradiated and the resulting DNA damage is quantified by a real-time polymerase chain reaction (quantitative PCR, qPCR).

We investigated the DNA lesions caused by gamma or carbon ion particle irradiation and revealed that the extent of DNA amplification is negatively correlated with the magnitude of linear energy transfer (LET) of exposure to radiation. While ionizing radiation elicits not only DNA strand breaks but 8-hydroxy-2'-deoxyguanosine (8-OHdG) production, the levels of 8-OHdG produced by high- and low-LET gamma irradiation were similar, demonstrating that 8-OHdG production was not affected by the magnitude of LET.

Subject: Physics, Chemistry & Biology

Ionizing Radiation Promotes Epithelial to Mesenchymal Transition in Human Lung Cancer Cells through MMP12 up-regulation

Hae-June Lee

Lung cancer is responsible for the largest number of cancer-related deaths worldwide. Approximately 60% of patients with non-small cell lung cancer receive radiotherapy. Recent studies have indicated that epithelial-mesenchymal transition (EMT) is associated with malignancy in various types of cancer, and activation of EMT signalling in cancer cells is widely considered to contribute to metastasis, recurrence, or therapeutic resistance. It is well-believed that EMT is also triggered by extracellular stimuli such as hypoxia and radiation [1]. And it is widely accepted that EMT plays a key role in the radio-resistance phenomenon and has been broadly explored in several types of tumors such as gliomas and lung cancer [2,3]. We observed that significant upregulation of MMP12 in A549 cells and their culture medium when EMT phenotype increased by radiation. We postulated that over-expression of MMP12 may induce mesenchymal-epithelial transition in A459 cells and accelerate IR-induced increase of cell migration. We confirmed MMP12 overexpression in A459 cells or human recombinant MMP12 treatment to culture medium increased invasion and migration capacity. Correspondingly, silencing of MMP12 in A549 cells significantly inhibited invasion and migration capacity as well as restoration of EMT phenotype. Taken together, these results indicated that MMP12 plays a critical role in tumour microenvironment during radiotherapy and suggest that MMP12 could be a potential target to overcome radio-resistance for cancer treatment.

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Subject: Physics, Chemistry & Biology

Baicalein attenuates radiation enteropathy by regulating pro-inflammatory cytokine IL-33

Hyosun Jang

The gastrointestinal tract is a radiation-sensitive organ, and is occurred a clinical problem, called acute radiation enteritis, which involves diarrhea, inflammation, edema, sepsis by radiotherapy for cancer treatment or accidental radiation exposure.

Baicalein is a major flavonoid compound isolated from Scutellariae radix, an important herb used in traditional medicine. Its safety has been clinically proven, and it possesses anti-allergic, antioxidant, and anti-inflammatory properties.

Here, we investigated that whether baicalein improved acute radiation enteropathy by downregulating IL-33.

Whole abdomen of male C57BL/6 mice was single irradiated with total dose of 13.5 Gy (2 Gy/min). The irradiated mice (IR) were treated with baicalein (10 mg/kg, intraperitoneal injection) for 6 days. To evaluate intestinal barrier function, bacterial translocation, FITC-Dextran assay, and claudin 3 expression were analysed using the mesenteric lymphnode and intestinal tissue. Also, Histological analysis and intestinal organoid formation assay was performed in the ileum of baicalein-treated IR mice. The gene levels of inflammatory cytokines and chemokines were evaluated in the tissue using Real-Time RT-PCR.

IR group showed histological damage such as shortening villi length and impaired intestinal crypt. However, balcalein-treated IR mice were attenuated histological damage and improved crypt counts in the intestine. And positive cells of ki-67, a proliferative marker upregulated in the baicalein-treated IR group. Intestinal barrier function and tight junctional molecule attenuated in the bacalein treated group. We also identified the anti-inflammatory effects of bacalein thorough decrease infiltration of inflammatory cells and expression of inflammatory cytokines and chemokines in the baicalein-treated group. Especially, baicalein inhibited levels of IL-33, which is increased IR group in early time.

In conclusion, baicalein improves the effect of anti-inflammation and damaged intestinal barrier function by reducing IL-33 in radiation enteropathy. Baicalein may provide a new therapeutic agent to manage radiation enteropathy.

Subject: Physics, Chemistry & Biology

Contribution of macro and micro-dosimetry in alphatherapy

Nadia Benabdallah

In nuclear medicine, the injected activity needs to be personalized for each patient. For alpha-particle emitting radiopharmaceuticals, a personalized dosimetry is challenging because of the short range of alpha particles. The aim of this work was to develop tools to optimize patient-specific dosimetry in alphatherapy. To that aim, the study focuses on 223RaCl2 (Xofigo®) used for the treatment of patients with castration-resistant prostate cancer metastasized to bones.

First, quantitative imaging must be performed to characterize the macroscopic biodistribution of the radiopharmaceutical in the patient body. As SPECT imaging gives a better quantification than planar imaging, the possibility of quantitative SPECT imaging of 223Ra was investigated for the first time. Several phantoms studies were performed in order to determine the best SPECT imaging protocol, according to the MIRD Pamphlet No. 23.

Then, as bone marrow is an organ at risk for these treatments, the dose to this region is needed. Current dose models do not account for energy or bone-site dependence as shown by alpha-particle absorbed fractions given in ICRP Publication 30. Using the most realistic voxelized model of the skeleton for adult male that describes the bones at a microscopic scale and MCNP6 Monte Carlo code, the S-values to the two radiosensitive tissues, endosteum and red bone marrow, have been calculated for several source tissues such as the trabecular bone, the yellow marrow or the cortical bone. Furthermore, as the marrow cellularity is dependent of the age, the evolution of alpha absorbed fraction to the red bone marrow with the marrow cellularity was studied.

Finally, the short range of alpha-particles relative to the typical scale of human organ dimensions can lead to a highly non-uniform irradiation of the target volume. The microdistribution of 223Ra was investigated in skeletally mature mice and metastasis models, using autoradiography.

Quantification accuracies of approximately 4% for a 5.6mL sphere containing 20kBq/mL can be expected. This protocol has been implemented in a new clinical trial for treatment of patients with bone metastases in renal cell carcinoma. Differences, up to 50% when considering the trabecular bone surface as source and red bone marrow as target, were observed between our model and the ICRP Publication 30. The autoradiography images will be used to correlate absorbed dose to therapeutic response.

This study investigates different aspects of the 223Ra dosimetry and offers tools to optimize dosimetry for other alpha emitters.

Subject: Physics, Chemistry & Biology

Tell me what populations eat, I will tell you how much they have been exposed

Sophie Vecchiola

Realism of exposure scenario used for the evaluation of health impact due to radiological exposition and more precisely the ingestion dose has become an emerging thematic. A way to improve realism of exposure scenario is to enhance the knowledge of local population's dietary habits. To illustrate the major issues of this thematic, first results of ingestion dose calculation performed conducted for this study show a significant impact on the ingestion dose (an order of magnitude) as well as the total effective dose (by a factor about 2).

This assessment of ingestion doses is currently performed by mathematic models which need to collate food stuffs into fixed category as for example leafy vegetables, root vegetable and so on. The amount that is consumed in each category is associated by autarky data. These reflect the proportion of food locally produced that is consumed. Furthermore, dose assessment is performed for several age categories. Periodically, national surveys are mostly carried out for health-related purpose (nutrition, chemistry …) and data provided do not necessarily fit our needs. For this reason, they must be treated before being implemented into mathematic models. The French TSO mainly use data provided by 1991 INSEE national survey in the absence of local data. These data are relatively old and may no longer be representative of current dietary behaviours. A review of available data show that the consummation of processed food significantly increases and that autarky is treated in inhomogeneous ways.

Furthermore, data provided by surveys may not be directly comparable due to the different methods used for their achievement. A part of study was dedicated to the development of a method for choosing the "best" appropriate data to answer the question asked. Indeed, character of the need depends on:

- the detail's level of the evaluation (screening, support of decision for emergency situation …)

- the exposition situation identified (normal running, emergency, post-accident evaluation…)

- the disparate of consumption (rural vs urban populations, inside a same kind of population…).

To conclude, the analyse of information collected gathered from our review and the appreciation of the sensitivity of the dose led us to put more realism into our evaluation and improve a better mastering of those one.

Subject: Physics, Chemistry & Biology

Assessing the microbiological diversity in the cooling waters of a nuclear research reactor

Valérie Van Eesbeeck

The BR2 nuclear research reactor comprises different watery environments: the primary cooling circuit consists of a closed loop containing water that cools down the fuel rods in the reactor core. An open basin surrounds the reactor vessel, whereas spent nuclear fuel is stored in the contiguous spent nuclear fuel pool (SNFP) in order to cool down before being safely disposed. Remarkably, despite the low-nutrient environment combined with the highly radioactive character of the water and the presence of dissolved radionuclides, microbial growth is not fully prevented. Indeed, several microbes appear to be able to survive and thrive in such conditions. Microorganisms identified in those environments thus provide a unique opportunity to acquire new insights into survival strategies and radiation-resistance mechanisms. In addition, the study of those organisms could lead to the discovery op suitable candidates to be used in the bioremediation of contaminated effluents.

The objective of this work is to explore the bacterial communities present in the described environments of the BR2 nuclear research reactor. In parallel, this research also focuses on following up these communities over time during and outside reactor operation to monitor the long-term effect of ionizing radiation. Finally, this project also aims at a phenotypical characterization of the prevailing species.

For the characterization and the follow-up of the bacterial communities, a 16S rRNA amplicon sequencing approach was adopted. Results from a long-term follow-up experiment highlighted a clear shift in the bacterial community profile during and outside reactor operation, both for the basin and the primary water. This could be due to the change in physico-chemical parameters that these waters undergo when transitioning from one state to the other.

With regard to the phenotypical characterization, strains were isolated from the basin and the SNFP and subsequently subjected to ionizing radiation in a gamma irradiation facility to test their radiation resistance. This experiment showed that all 12 tested strains tolerated a dose of 300 Gy, but only 8% of the strains was able to cope with a dose of 2100 Gy, indicating large variability in radiation resistance between different strains, and as such not necessarily a high radiation tolerance to survive in the basin and the SNFP.

Subject: Physics, Chemistry & Biology

Reanalysis of the epidemiological data of the Hanford site considering the dose rate

Michiya Sasaki

The International Commission on Radiological Protection has calculated the nominal risk coefficient for cancer deaths due to radiation exposure for workers and members of the public using data of survivors of the Hiroshima Nagasaki A-bombs, together with the dose and dose-rate effectiveness factor. On the other hand, radiation workers are usually exposed to low-dose-rate radiation in their daily jobs, and numerous epidemiological studies have also been conducted at nuclear facilities in many countries. In the United States, Gilbert et al. have estimated the excess relative risk of cancer mortality using a dataset of approximately 33,000 radiation workers at the Hanford site, obtained by monitoring workers employed for at least six months from 1945 to 1986. Cardis et al. also used this dataset for a pooled analysis study of cancer mortality in three countries in 1995, and the dataset was also used for analysis in the recent INWORKS study by Richardson et al. In these epidemiological analyses, although, the cumulative dose was the primary index used to estimate the excess relative risk due to radiation exposure throughout, the 'dose rate' can also be an important factor because many animal and biological studies suggest the existence of a dose-rate effect. Thus, in this study, the excess relative risk of cancer was reanalysed in terms of the dose rate using the data set of radiation workers at the Hanford site, which is available through the website of the Comprehensive Epidemiologic Data Resource. This new approach will be beneficial for combining the epidemiological results with the biological mechanism of radiation exposure.

Radon / Thoron

Subject: Radon / Thoron

Cost-effectiveness analysis of policies to reduce lung cancer risk from indoor radon in Italian dwellings

Francesco Bochicchio

Cost-effectiveness analysis (CEA) is a useful tool to evaluate policies aimed to reduce lung cancer risk attributable to radon exposure in dwellings and workplaces. The CEAs described in this work are based on a model in which: i) the effectiveness of different policies is evaluated in terms of QALY (Quality Adjusted Life Years) gained by the involved population and ii) the considered costs are those necessary for radon concentration measurements, for radon remediation measures, along with the health treatments costs. For the existing dwellings, policies - both mandatory and recommendatory - aimed to reduce radon concentration for dwellings with radon level higher than a fixed reference level (RL) have been taken into account. Moreover, a mixed policy – i.e. obligations for dwellings with radon concentrations higher than a fixed RL, and recommendations for those ones with radon level lower than RL – has been also considered in order to apply the optimization principle required by the 2013/59/Euratom directive. The main results of the CEAs are: 1) the policies based on obligations only are generally more effective (and more cost-effective), in terms of QALYs gained, than the policies based on recommendations only; 2) the mixed policy resulted more effective (about +30% of QALY gained) – and only slightly less cost-effective (–5% Euro/QALY gained) – than the policy in which obligations were addressed only to dwellings with radon level higher than RL. For policies addressed to dwellings in new buildings, similar analyses have been also carried out. In this case has been considered as preventive measures those including both basic and full preventive measures, i.e. those including the use of systems to facilitate the later installation of active preventive measures (e.g., electric fans) for those dwellings that still have high radon concentrations after the building construction.

Subject: Radon / Thoron

New Radon sources for low-level calibrations

Florian Mertes

The PTB (Physikalisch-Technische Bundesanstalt, National Metrology Institute, Germany) is involved in the EMPIR (European Metrology Programme for Innovation and Research) project MetroRADON, in which measurement methods and standardization of radon activity concentrations in air are optimized. This is vital in assuring the European basic safety standards concerning radon and radon progeny exposure, which is estimated to cause 3 % - 14 % of all lung cancers today. Constant activity concentrations are needed to calibrate and design new methods for radon-activity concentration measurement devices for low-level radon activity concentration determinations. Unlike radon-gas standards, constantly emanating reference sources produce constant atmospheres of radon activity concentration. With these atmospheres, improved counting statistics even at low activity concentrations can be achieved, where conventional methods using radon-gas standards would fail simply because of its decay.

For the described task, the PTB has developed new concepts for the production and characterization of primary Rn-222-emanating Ra-226-sources, based on thin-film deposition techniques for Ra-226. The sources are specifically designed to produce and maintain constant radon activity concentrations in the range of a few 100 Bq/m³. Source stability in terms of emanating power is continuously verified by gamma-spectrometry utilizing portable room temperature solid-state scintillation detectors. Radium activity of the sources is determined by defined solid angle alpha-spectrometry, which results in a primary activity standard for Ra-226. Through comparative measurements with enclosed sources of the same geometry, the emanation coefficients are obtained by gamma-spectrometry, requiring no detection efficiencies or nuclear data. The resulting uncertainty in Rn-222 activity concentration is below 5 % for k = 1.

The development process and first measurement results will be presented.

Subject: Radon / Thoron

Determination of activity size distribution of radon progeny based on ambient aerosols size distributions

Katarzyna Wołoszczuk

Central Laboratory for Radiological Protection (CLOR) in cooperation with Central Mining Institute (GIG) performed simultaneously measurements of activity size distribution of radon progeny and ambient aerosols using different types of aerosols. Measurements were performed in a radon chamber with a volume of 17 m3, where radon was generated by a radium-226 open source, and ambient aerosols by an oil candle, vax candle, and incense sticks. Such measurements were also made in an aerosol depleted atmosphere after cleaning the chamber air by means of a high-efficiency pump and filters. The activity size distribution of radon progeny was determined using Radon Progeny Particle Size Spectrometer (RPPSS) in the range of 0.6 nm to 2494 nm, based on activity measurements for 8 stages composed of impaction plates or diffusion screens, and semiconductors alpha detectors. The measurements of the ambient airborne particle size distribution were performed in the range from a few nanometres to about 20 micrometres using Aerodynamic Particle Sizer (APS) spectrometer and the Scanning Mobility Particle Sizer Spectrometer (SMPS). Then the activity size distributions and related dose conversion factors (DCF) for the occupational hazard and for the general population were estimated using the results corresponding both to the SMPS and APS spectrometers, and to RPPS spectrometer.

Subject: Radon / Thoron

An Introduction to the MetroRadon Project - Metrology for Radon Monitoring

Hannah Wiedner

This paper is an introduction to the ongoing MetroRadon project - a 3 year Joint Research Project in which 17 European metrology and research institutes aim to provide metrology for radon monitoring. The purpose of this project is to develop reliable techniques and methodologies to enable SI traceable radon activity concentration measurements and calibrations at low radon concentrations and will help to establish a basic European metrological infrastructure for radon measurements, enabling sound monitoring of radon and radon protection in Europe. The need for this project is mostly motivated by the requirements of the implementation of the European Council Directive 2013/59/EURATOM (EU-BSS), aiming to reduce the risk of lung cancer for European citizens due to high radon concentrations in indoor air. Another goal of the project is to enable uptake and exploitation of its results and experiences by all stakeholders concerned with radon, from regulators and policy makers, professionals in designing, performing, evaluating and interpreting radon surveys, radon instrument manufacturers to the construction industry and scientific community.

The methods developed in the project will assist EU member states in the establishment of their national radon action plan, which is required under the EU-BSS. The novel development of a European unified index of geogenic Rn hazards, which can be defined flexibly independent of the data available, will provide a consistent picture of susceptibility to geogenic Rn across Europe. The definition of this Radon Hazard Index (RHI) will be an important tool for the harmonised implementation and performance of national radon action plans of EU member states according to the EU-BSS requirements.

Novel calibration methods and traceability validation at low radon activity concentrations will be devised, and new and stable radioactive reference sources developed to enable these calibrations and achieve sufficiently low uncertainties.

For the first time, the distortion of the radon measurement results due to the presence of thoron will be considered and corrected at low radon activity concentrations. Traceability to a primary thoron standard will be ensured and refined, enabling the thoron influence to be reliably investigated.

Guidelines and recommendations on the new calibration and measurement procedures will be published. Traceability of European radon calibration facilities using the new procedures and novel reference sources will be evaluated and the project partners will ensure that the results of this project will be taken up by end users, standards organisations, regulators and international bodies and associations.

Subject: Radon / Thoron

Designing and construction of a new radon calibration facility in Romania

Aurelian Luca

The implementation of the European Union Council Directive no. 2013/59/EURATOM in 2018, requires facilities to assure reliable and accurate calibration of the instruments measuring the radon concentration in air, in all the EU countries.

In the frame of the Romanian national research project "Realisation of a radon chamber – Calibration stand for the equipment used in the measurement of radon and daughter products concentration in air" (CARSTEAM), a radon chamber was designed, constructed and installed at IFIN-HH, in the Radionuclide Metrology Laboratory (LMR), with the participation of the scientific partners from ICSI Rm. Valcea and the University of Bucharest. The chamber was designed in order to obtain a System for Test Atmospheres with Radon, according to the standard IEC 61577-4 (Radiation Protection Instrumentation – Radon and radon decay product measuring instruments). The radon chamber is a metallic tight precinct, with walls made of stainless steel (4 mm thick), cylindrical shaped, with a door; the inner volume is 1 m3. In order to control the main environmental parameters during the calibration procedures (temperature, humidity and pressure), using climatization equipment, the radon chamber is placed inside an external chamber with thin double steel walls containing polyurethane foam in between (thermal insulator of 150 mm thick), see the annexed pdf file. Two alternative inputs for radon gas were foreseen: one - from an originally designed transport container with a vial containing a certified activity of radon (standard source), and another one – from a small pipe transporting a continuous radon flux emanated from a 226Ra source (Pylon). Temperature, pressure and humidity sensors are mounted inside the radon chamber and transmit the recorded data on a computer. Two fans are used to homogenize the radon inside the chamber. Electrical power supply is available for the radon measurement instruments to be calibrated in the chamber; the data signal is transferred to the same computer through air tight serial connectors type RS232. Input/output pipes with electrovalves can introduce pressurized air of high purity (99.99%), respectively evacuate the mixture of air with radon and its daughters in the building special ventilation system. Automated functioning of the radon chamber is under implementation; the new calibration procedures will be integrated in the LMR quality management system, ISO 17025:2005 compliant. International traceability and its validation for the calibrations performed with this new facility will be obtained by participating in the EMPIR MetroRADON European research project (2017-2020).

Subject: Radon / Thoron

Robust measurement of the thoron exhalation rate from building materials

Govert de With

Thoron exposure from building materials has been a topic of considerable research; nevertheless, measurement of thoron exhalation from building materials is still subject of continued investigation. While international harmonized standards for radon from building materials such as e.g. ISO-11665-9 (ISO, 2016) already exist, measurement protocols for determining the thoron exhalation rate from building materials are at present still based on internal procedures developed by the laboratories itself. For this reason an inter-laboratory comparison on the thoron exhalation rate from various mainstream building materials is performed with five participating laboratories. The laboratories use different testing principals, such as different detection techniques, sample size and measurement time. The results demonstrate considerable variation in the measurement readings and variations in test procedures by the various labs. The findings highlight three areas for improvement of measurement robustness. These are: i. traceable thoron standards for detector calibration, ii. robust protocols for measurement and sample treatment and iii. implications of material characteristics and its effect on thoron exhalation. The paper will present the findings from the inter-laboratory comparison and will critically review the test procedures used by the laboratories.

Challenges found in calibration procedures and traceability to either primary or secondary standards are identified and discussed. Furthermore, thoron exhalation is primarily a surface phenomenon due to its short half-life. As a result sensitivity to climatic conditions, material characteristics, as well as material curing and aging can have an impact on the thoron exhalation and must therefore be adequately addressed in the test protocol. Experimental data is provided to demonstrate the impact of such phenomena on the thoron exhalation and the implications for robust testing are discussed. The outcome of this review is completed with a set of recommendations for future development of a harmonized standard.

Subject: Radon / Thoron

Supplementary cementitious materials and additives – effective measures to hinder radon in concrete

Magnus Döse

The second largest cause of lung cancer is related to radon (222Rn) and its progenies in our environment. Building materials, such as concrete, contribute to the production of radon gas through the natural decay of 238U from its constituents.

The Swedish Cement and Concrete Research Institute (RISE CBI) have examined the use of liquid additives and supplementary cementitious materials (SCM´s) and their effect on reducing the radon exhalation rate at a relative humidity of 75 %. Ten different concrete recipes were cast. The diffusion coefficients of each concrete recipe were also examined. In this study the SCM´s consisted of different fly ashes, micro silica and slag. All recipes contained identical aggregates and the water binder ratio (w/b) was set to 0.55. The efficiency factor (k) was set to 1 for all SCM´s.

Chauhan & Kumar have presented the potentials of reducing the radon gas exhalation rates from concrete by using by-products, such as rice husk and silica. Also Yu et al. and Taylor-Lange et al. have shown the possible effects of reducing the exhalation rate of radon gas by using alternative puzzolanic binders, such as fly ash or metakaolin.

The principle of measuring the radon exhalation rate was performed using a closed system according to ISO-11665-7. The measurements where performed with an ATMOS 33 ionizing pulsation chamber. The principle used for calculation of the diffusion coefficients have earlier been described by Kovler, Sahoo and Chauen & Kumar. In brief, a 50 mm thick slab of concrete are mounted between two symmetrical small volume chambers. Measurements of the radon growth in the receiver chamber are made when equilibrium between uranium and its progenies are established in the source chamber.

The results (Figure 1) indicate a reduction of the exhalation rate from radon gas measurements for some concrete recipes by 25-35 %. In one case a reduction of approximately 60 % was achieved using SCM. The radon diffusion coefficient's varied between 1.3 × 10-8 and 6.5 × 10-9. A reduced bulk diffusion coefficient of approximately 50 % could be shown compared to the reference concrete.

Conclusively, the effect of using a liquid additive or a supplementary cementitious material may have a strong impact on the radon gas exhalation rate from building materials. Using SCM´s instead of cement also yields a positive imprint to the environmental goal of reducing carbon dioxide in the atmosphere.

Subject: Radon / Thoron

Establishing Ireland's current population weighted national average radon concentration using a new survey protocol.

Alison Dowdall

In 2002, a National Radon Survey (NRS) in Ireland established that the population weighted national average indoor radon concentration was 91 Bq m-3. This figure was a key determinant in then deriving that approximately 13% of all lung cancer cases in Ireland can be linked to radon gas. This equates to nearly 250 lung cancer cases each year. Since then, demographic changes in Ireland are likely to have impacted on the population weighted national average and therefore the number of radon related lung cancer cases.

In 2014, the Irish Government adopted the National Radon Control Strategy (NRCS) for Ireland. The aim of the NRCS is to minimise the exposure to radon gas for people in Ireland and to reduce to the greatest extent practicable the incidence of radon related lung cancers. A knowledge gap identified in the NRCS was to update the population weighted average for Ireland. The updated national average may be used as a baseline metric to assess the effectiveness of the NRCS over time.

Recognizing that it is not feasible to repeat the 11,319 measurements carried out for the 2002 NRS due to time and resource constraints, a stratified random sampling protocol was designed that is representative of where the population live and that would produce a result that can be compared with the 2002 NRS. However, the existence of that comprehensive survey allowed for a new protocol to be developed, involving measurements carried out in unbiased randomly selected volunteer homes. This paper describes that survey protocol and its implementation.

The results of the 2016 survey showed that the current population weighted national average indoor radon concentration in Ireland is 98 Bq m-3. The modest increase can be attributed to a range of factors but is mainly due to changes in the Irish population since 2002. This updated population weighted average should feed into future work to update the number of radon related lung cancers in Ireland.

Subject: Radon / Thoron

Outdoor risk from thoron and progeny in a NORM area with old mines.

Hallvard Haanes

The radioactive gases radon (222Rn) and thoron (220Rn), and especially their short-lived decay products, are big contributors to dose received by the public from natural sources of radiation. These doses may however be even higher in areas with elevated levels of naturally occurring radionuclides. Moreover, dose rates are in general high in caves and mines due to build-up of these gases and may be extreme where caves and mines penetrate bedrock with elevated levels of natural radioactivity. The health risk to uranium miners has thus been well documented. Moreover, it has recently been shown that in such areas, the amounts of these gases released through natural cave or mine ventilation can be large and impact outdoor dose rates. One area where this may be an issue is the volcanic Fen carbonatite complex (Norway) where bedrock levels of thorium (Th-232) are high and the ground is perforated by old abandoned iron mines. It consists of a forested hill with tracks, multiple mine entrances and tailing deposits, and lies adjacent to rural houses and close to a small village. The area is used by locals for recreational activities and there is ongoing roadwork. Thoron exhales from the ground and tailings deposits, and air with extreme levels ventilates from the old abandoned iron mines. We have therefore assessed the amounts that ventilates from the mines with different weathers through the year, as well as variation in activity concentrations and dose rates locally within this area, as well as outdoors in the nearby village to assess dispersal from the area.

Subject: Radon / Thoron

Method's limitation of ^{222}Rn in water measurements

Jovana Nikolov

Radon originates from the radioactive decay of naturally occurring uranium and radium deposits. Radon is picked up by groundwater passing through rocks and soil containing such radioactive substances; it enters water supplies when this water is pumped up into a well. Radon is released into waters as a result of natural processes like decay of its parent nuclide 226Ra and predominantly dissolution from the surrounding geological environment (rocks, soils). 226Ra and its decay product 222Rn in water contribute to human exposure in two ways: ingestion (drinking water) and inhalation (while drinking water and using thermal waters in health purposes).Water intended for drinking purposes has to be analysed for its radon content according to the new EURATOM Drinking Water Directive 2013. Monitoring of 222Rn in drinking water sources is a part of routine measuring analysis carried out by many environmental laboratories. There are different methods for 222Rn in water measurements developed (RAD7, Alpha-guard, LSC etc.). Liquid Scintillation Counting (LSC) method is very often preferred method for measuring of 222Rn in water. The main advantage of this method is that it allows multiple sample automatic analysis and the measurements show very low detection limits. In any case, most of the used methods suffer from the influence of 226Ra presented in water on real estimation of 222Rn activity concentration in water. In most 222Rn in water measurement methods there are also problems in calibration of instruments, especially in LSC method. The only way to prepare a calibration source is to use 226Ra in water for calibration by relying on secular radioactive equilibrium which is achieved between 226Ra and 222Rn in about one month. This paper presents advances and limitation of few methods for 222Rn in water measurement (RAD7, LSC and gamma spectroscopy).

Subject: Radon / Thoron

The Relationship between Social Deprivation and Domestic Radon Levels: a Study in the East Midlands, UK

Antony Denman

The natural radioactive gas, radon, is present in the built environment, and at high levels is associated with an increased risk of lung cancer. This risk is significantly further enhanced when occupants also smoke. Studies investigating a number of environmental pollutants suggest that the more-deprived populations are exposed to higher levels of many pollutants, with direct adverse impact on the health of these populations.

In contrast, however, two recent studies have suggested that increased social deprivation in the UK is associated with lower environmental radon exposure. The UK government now publishes the Index of Multiple Deprivation (IMD), a measure of average overall deprivation, as well as indices of subsets such as health, education status, income and living environment. This paper considers this suggestion by reviewing social deprivation and radon levels in 94 231 postcode sectors - small areas of around 7500 people - in both urban and rural settings, in the East Midlands of England, using the IMD for 2015. The area includes a number of major towns, among them Leicester, Bedford, Northampton, Wellingborough, Kettering and Rugby, together with many villages in rural areas.

There is an apparent trend to greater overall deprivation in low radon areas, in contrast to many other environmental pollutants. The trend only has a weak correlation. This study identifies two factors that show some correlation with this trend. Firstly, urban areas have lower average deprivation than rural areas. Secondly, since urban areas tend to contain higher proportions of multi-storey apartment blocks than rural areas, the lower radon exposure experienced by residents of the higher floors reduces the overall average residential radon exposure in the locality. In addition, a significant contributor to urban radon exposure is the location of most major urban centres in the UK on intrinsically low-radon geologies.

Subject: Radon / Thoron

Radon levels in the higher natural radioactive region of a city in China

Qifan Wu

Outdoor radon-222 is mostly produced by radium-226 in soil, which belongs to the uranium-238 decay chain, while indoor radon-222 is from both soil and building materials. The higher radium or uranium concentration is in soil or building materials, the higher radon level, as well as higher gamma radiation level it will be. The research area locates in the higher natural radioactive region of a city in southwestern China. Radon concentrations had been measured by solid-state nuclear track detectors or CR-39 for one year. The radon detectors were placed in three months each period, four periods for one year. External radiation levels were detected by X-gamma dose-rate meter.

Outdoor external radiation level in this city was 123.1±42.5nGy/h, higher than country average value of 65 nGy/h [1]. The average annual radon concentration was 73.3±35.8 Bq/m3 for indoor and 37.7 ± 12.6 Bq/m3 for outdoor, higher than country average value of 44Bq/m3 for indoor and 13.4±7.2 Bq/m3 for outdoor [2, 3]. There were 192 indoor radon measurement points. About 14.5% of them exceeded 100 Bq/m3 of indoor radon level for new buildings of national standard [4].

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Subject: Radon / Thoron

Passive radon detectors in the field - Intercomparisons: experiences and perspectives

Mauro Magnoni

In the last decades radon exposure has become more and more important among all other “traditional” radioprotection issues, as the evidence of its severe health effects was clearly confirmed by several epidemiological studies. For that reason, more strict regulations were recently demanded by many international bodies, in particular ICRP and WHO. In EU the recent Basic Safety Standard (Euratom Directive 59/2013) clearly regulated the protection against radon exposures to radon both in workplaces and in dwellings. In this context, a cheap, effective and reliable radon measurement method also at low radon concentrations is needed. Nowadays, radon detectors based on the passive detection of the alpha radiation emitted by 222Rn and its short lived radon daughters (218Po, 214Pb, 214Bi, 214Po) can be considered as the standard procedure for the assessment of long term radon exposure in radon monitoring campaigns. It is therefore obvious the need of implementing reliable calibration procedures for all the laboratories involved in radon measurements. Therefore, in these years a number of intercomparison exercises were organized by national institutes, such as PHE (UK) and BfS (Germany). All these exercise were performed in “radon chambers”, where radon concentration, temperature, pressure, humidity were strictly controlled. However the extremely controlled conditions typical of radon chambers were too distant from the real condition encountered in the real houses and workplaces where dosemeters are usually exposed. For that reason the idea of a “radon in-field intercomparison” began to appear, in spite of greater difficulty, a useful tool to investigate the behaviour of passive detection systems in real conditions. Therefore, a working group, leaded by AIRP, the Italian Radiation Protection Association, was established with the aim of organizing “radon passive detectors in-field intercomparisons".

In this paper, the experiences and the main results of two in fields radon passive intercomparison exercises up to now organized (Lurisia, 2015, 46 participants; Milan, 2017, 49 participants) are presented and discussed. In the first one the radon dosemeters were exposed to very high radon concentration and to severe environmental condition (relative humidity approaching 100%), in the latter the dosemeters were tested for a longer time in two different workplaces and the response to a mixed radon-thoron atmosphere was also evaluated.

The organisation of third radon in field intercomparison is on the way and will be announced by the end of 2018: this intercomparison, scheduled for 2019-2020, will be focused to other specific experimental issues.

Subject: Radon / Thoron

Radon Levels in New Homes built with radon protection in high radon areas in Northamptonshire, UK

Antony Denman

Radon, a naturally occurring radioactive gas generated underground by radioactive decay of certain types of rocks, can concentrate inside buildings, where it poses the second-largest risk factor for lung cancer, after smoking. The highest levels of domestic radon in the UK occur in the south-west in Devon and Cornwall, but certain areas in Northamptonshire and surrounding counties in the English Midlands also have high levels. It has been shown that it is possible both to reduce the radon levels in existing houses, and to build new homes with appropriate protection. Since 1999, the UK's Building Regulations have specified that all new homes should be built with a combined radon-proof / damp-proof membrane plus, in Radon Affected Areas, a sump under the building. However, the building regulations do not require that the radon level is measured once the house is built and so there is little information on the effectiveness of these measures. Builders generally do not mention radon, and when asked, just confirm that their houses are built to current standards. Recently, Public Health England (PHE) recommended that householders should test radon levels in the first year of occupancy.

1056 Householders in 18 new estates, built by a number of contractors from 2014 to 2017, in high radon areas in Northamptonshire were invited to apply for a free radon test, and 122 replied (10.6%); 306 reminders were sent, with a further 12 replies (3.9%). 94 detectors were returned (76%), of which 2 were spoiled, giving a total of 92 results.

No results exceeded the UK Action Level of 200 Bq.m-3, but three were in the range 120 to 130 Bq.m-3, which is over the UK Target Level of 100 Bq.m-3. The results formed a log-normal series, with an arithmetic mean 45% of the arithmetic mean of the radon levels in existing houses in the postcode sector areas where the houses were built.

The results suggest that the radon-proof membranes in general ensure that radon levels in new homes constructed in accordance with the Building Regulations in radon affected areas are satisfactorily low. However, there is a statistical probability that levels in a small number of homes will be close to, or above, the Action Level. As a result, the PHE recommendation for testing in the first year of occupation should be adopted as a legal requirement.

Subject: Radon / Thoron

Radiation exposure from natural radionuclides in Dutch workplaces and public buildings

Pauline Goemans

The National Institute for Public Health and the Environment (RIVM) has recently carried out a survey on radon, thoron progeny and gamma radiation in Dutch workplaces and public buildings. The results are used to support the implementation of relevant parts of directive 2013/59/Euratom into Dutch legislation. More than 450 companies received passive detectors in the autumn of 2016. Radon was measured over periods of six and twelve months, thoron progeny over twelve months and gamma radiation over a six month period. Measurements were carried out at regular above ground workplaces and public buildings such as offices, schools and hospitals as well as at specific workplaces and public buildings with potentially high radon or thoron progeny concentrations. These specific workplaces include marlstone caves, groundwater treatment facilities, underground subway stations and the natural stone and concrete industry. Additional schools and children day-care centers were included in regions with more natural radioactivity in the soil and correlating higher radon concentrations in Dutch dwellings.

The Dutch government will adopt a fairly low national reference level for radon in workplaces and public buildings of 100 Bq/m3. Preliminary results of the 'six months radon measurements' show only a few regular workplaces with radon concentrations exceeding this reference level. From the specific workplaces, however, we obtained a significant number of data exceeding 100 Bq/m3, a few even exceeding 5000 Bq/m3. Radon levels above 100 Bq/m3 were found at water treatment facilities, marlstone caves and greenhouses.

The remaining raw data sets are foreseen at the beginning of 2018. In June, we are able to present the full results of this survey. Analyzed data will be compared with results obtained earlier from similar measurements in Dutch dwellings. Moreover, we will present possible correlations with relevant parameters such as ventilation system and location and demonstrate how this survey supported the implementation of directive 2013/59/Euratom.

Subject: Radon / Thoron

Additive and multiplicative risk models of lung cancer risk from radon and smoking

Ladislav Tomasek

The presentation aims at evaluation of lung cancer risk from combined exposure to radon and smoking. Methodologically, it is based on case-control studies nested within two large Czech cohort studies of nearly 11 000 uranium miners and 12 000 inhabitants exposed to high levels of radon in homes. In addition to radon exposure, these studies use individual information on smoking collected from the subjects or their relatives. A total of 1 076 and 379 cases with smoking information have been observed in the occupational and residential studies, respectively. The control subjects have been individually matched to cases according to sex, year of birth, and age. Exposures are given in terms of WLM in the occupational study and in kBq m-3year in the residential study. Similarly, smoking exposure is given in pack-years reflecting duration and intensity of smoking. In order to account for temporal effect, cumulated exposures to radon and smoking are considered in two exposure windows – 5-19 and 20+ years before current age. The combined effect from radon and smoking is analysed in terms of geometric mixture models suggested in BEIR VI of which the additive and multiplicative models are special cases. The resulting models are close to the additive interaction. This model is in line with results of Hiroshima Nagasaki study. The impact of the resulting model in the residential radon study is illustrated by estimates of lifetime risk in hypothetical populations of smokers and non-smokers. In comparison to the multiplicative risk model, the lifetime risk from the best geometric mixture model is considerably higher, particularly in the non-smoking population.

Subject: Radon / Thoron

Indoor radon control based on tabulated values of temporal radon variation

Hannah Wiedner

Mass measurements of indoor radon concentrations have been conducted for about 30 years. In most of the countries, a national reference/action/limit level is adopted, limiting the annual average indoor radon (AAIR) concentration. However, until now, there is no single and generally accepted international protocol for determining the AAIR with a known confidence interval, based on measurements of different durations. Obviously, as the duration of measurements increases, the uncertainty of the AAIR estimation decreases. The lack of the information about the confidence interval of the determined AAIR level does not allow correct comparison with the radon reference level. This greatly complicates development of an effective indoor radon measurement protocol and strategy.

The paper proposes a general principle of indoor radon regulation, based on the simple criteria widely used in metrology, and introduces a new parameter – coefficient of temporal radon variation KV(t) that depends on the measurement duration and determines the uncertainty of the AAIR. An algorithm for determining KV(t) based on the results of annual continuous radon monitoring in experimental rooms is proposed. Included are indoor radon activity concentrations and equilibrium equivalent concentration (EEC) of radon progeny. The monitoring was conducted in 10 selected experimental rooms located in 7 buildings, mainly in the Moscow region (Russia), from 2006 to 2013. The experimental and tabulated values of KV(t) and also the values of the coefficient of temporal EEC variation depending on the mode and duration of the measurements were obtained. The recommendations to improve the efficiency and reliability of indoor radon regulation are given. The importance of taking into account the geological factors is discussed. The representativity of the results of the study is estimated and the approach for their verification is proposed.

Subject: Radon / Thoron

Measurement of Radon Concentration and Radon Exhalation Rates in Commonly Used Building Materials from South-Western Nigeria Using Nuclear Track Detectors

Luis Neves

Radon concentration with radon exhalation rates from commonly used building materials in South-Western region of Nigeria has been measured using solid state track detectors (CR-39) in 173 samples. While indoor radon measurements are currently under study, this research is to assess the relative contributions of the building materials to the total radon concentration in dwelling places for the region. The results of the average radon concentrations in the selected building materials ranged from 41 ± 10 Bq/m3 in plaster of paris to 1775 ± 4416 Bq/m3 in gravels. The mass and surface exhalation rates varied from 1.38 ± 0.34 mBq/kg.h, 0.07 ± 0.02 Bq/m2.h, to 75.77 ± 181.89 mBq/kg.h, 3.94 ± 9.44 Bq/m2.h respectively. The results have been compared with other ones found in the literature reviewed.

Subject: Radon / Thoron

Indoor Radon Dose Reassessment in Taiwanese dwellings

Ming-Chi Horng

In 2009, WHO suggest to keep indoor radon level below 100 Bq/m3 and national action level setting not more than 300 Bq/m3. While the current reference level of indoor radon in Taiwan is 150 Bq/m3. After a island-wide survey project for total of 289 dwellings with active radon monitors collected valid indoor radon data of bed room and living room in each dwelling. The weighted average Radon concentration is 19.3 Bq/m3. There was no obvious difference between data of bed room and living room and all less than 100 Bq/m3. Radon induced population radiation dose assessed to Taiwanese is about 0.64 mSv/y which is 78% higher than the 25-year-ago estimated results of 0.36 mSv/y. The reason might be due to air conditions are more catholically applied in Taiwan than before that consequence the indoor air exchange rate is much lower than ever. However, it is only about 53% of the world average of 1.2 mSv/y by UNSCEAR report 2008.

Subject: Radon / Thoron

A radioecological study of radon and thoron in soil gas and water

Katharina Newrkla

Inhalation of radon is the second largest cause of lung cancer in Europe after smoking. The new EU council directive 2013/59/Euratom, the implementation of which into national law is currently ongoing, stipulates national action plans for the protection of the population from excessive radon exposure. The aim of this project is a radioecological study of radon and thoron activity concentrations in soil gas and water in selected locations with increased radon potential in Austria. Soil gas measurements were carried out at eight different locations by inserting steel probes into the ground and pumping the soil gas into measuring instruments based on ionization chambers. Additionally, the radon content in water samples was determined using an ionization chamber and the activity concentrations of radionuclides of the uranium-radium and the thorium decay chains in soil samples were measured using low-level gamma spectrometry. Activity concentrations of radon and thoron of over 100 kBq/m³ were detected in soil gas. The radon content in the water samples was found to be between about 30 to 90 Bq/L. Indoor radon measurements show the increase in radon concentration during the night and the effect of ventilation on the radon concentration.

Subject: Radon / Thoron

A new regulatory framework for radon in France

Alain Rannou

Public Health and Environment codes:

A reference level of 300 Bq/m3 and 'guide values' for indoor air are introduced. The national territory is divided into three areas according to the potential for exhalation of radon from soils. Health information and recommendations shall be disseminated by the authorities to the public concerned by the radon risk. Buyers or tenants of houses in radon prone areas are informed by the seller or the lessor.

Integrated radon measurements shall be performed using passive devices provided by accredited laboratories and the results and the associated data communicated to IRSN.

The radon management framework in buildings open to the public is reviewed: the reference level of 300 Bq/m3 replaces the action levels of 400 and 1,000 Bq/m3 in force until now. The owner (or operator) is required to carry out measurement of radon concentration by an approved organization or IRSN, to undertake remediation actions whenever 300 Bq/m3 is exceeded, to inform people attending the building and to communicate the measurement results to the French Nuclear safety authority.

Labor Code:

The action levels of 400 Bq/m3 and 1,000 Bq/m3 are also replaced by the reference level of 300 Bq/m3 and the effective dose criterion of 6 mSv/year is introduced. The scope is extended to workplaces located on the ground floor, in addition to those located in the basement and some specific workplaces. The employer shall inform the competent authority when the radon concentration cannot be reduced despite the implementation of remedial actions.

If the reference level is likely to be exceeded, the employer shall carry out measurements using passive dosemeters provided by an accredited laboratory. He transmits the results > 300 Bq/m3 to IRSN and implements the appropriate collective protection measures: remedial actions, organization of work. If the exposure of workers is likely to exceed 6 mSv/year (assuming permanent working time), he delineates a "radon working area" and limits access. Individual dosimetric monitoring is required for workers whose exposure is likely to exceed 6 mSv/year. The employer shall inform the workers about the effects of radon on health and about the incidence of smoking when exposed to radon. It should be noted that a worker exposed only to radon is not classified as a radiation worker.

Subject: Radon / Thoron

European Basic Safety Standards Directive in Ireland - An opportunity for the improved regulation of radon in Workplaces

David Fenton

The transposition of EU Directive/2013/59 Euratom Basic Safety Standards Directive (BSS Directive) provides a unique opportunity to strengthen the regulation of radon in workplaces in Ireland and to address regulatory gaps identified within the framework of Ireland's National Radon Control Strategy (NRCS). The NRCS, which itself is a requirement of the BSS Directive, was launched by the Irish Government in April 2014, shortly after the adoption of the Directive by the European Council in 2013. The Strategy provides for an across Government approach to reducing the risk from exposure to radon gas in workplaces (and in homes). Development of the NRCS took account of the experience gained in implementing the previous 1996 EU BSS Directive and identified areas where regulatory improvements were needed. In addition, the IAEA Integrated Regulatory Review Services (IRRS) mission to Ireland in 2015 also made recommendations around the need to strengthen the regulations governing radon in workplaces. Therefore, the transposition of the BSS Directive has provided an opportunity to align these policy frameworks while bridging regulatory gaps.

In this presentation, the particular provisions deemed necessary to strengthen will be reviewed. These ere

• specific provisions on the duties of employers around testing, re-testing and remediation,

• radon in underground workplaces

• the issuing of enforcement actions and penalties

In addition, the provisions of Ireland's National Radon Control strategy will be described.

The ICRP dose conversion factors, published in January 2018, attribute a higher dose per unit activity of radon than previously. This is likely to require a re-think of the approach Competent Authorities will take on radon in workplaces. Some of the issues this may raise for Ireland will be explored in this presentation.

Subject: Radon / Thoron

Implementation of a regulatory framework for the protection against indoor radon exposure in the Netherlands

Frans van de Put

The European basic safety standards (Council Directive 2013/59) have been transposed in Dutch regulation in 2018. This transposition included the implementation of a regulatory framework for the protection against indoor radon exposure in The Netherlands. This framework aims to provide protection for members of the public as well as for workers against indoor radon exposure. The ministerial responsibility is shared between the following Ministries: Ministry of Infrastructure and Water Management (protection of members of the public and the environment), Ministry of Social Affairs and Employment (protection of workers), Ministry of Health, Welfare and Sport (public health), Ministry of the Interior and Kingdom Relations (building regulations).

The framework consist of the following elements

1) Established national reference level for indoor Radon exposure.

A national reference level of 100 Bq/m3 has been laid down in Dutch regulation for the annual average indoor Radon activity concentration. This value is in line with international recommendations, including that from WHO. This national reference level is based on the observation that the annual average Radon concentration in Dutch dwellings is relatively low (mean 16 Bq/m3). The Radon concentration hardly exceeds 100 Bq/m3 even in identified areas with more elevated Radon levels. Moreover, indoor Radon concentrations in dwellings that are in excess of 200 Bq/m3 are indeed very rare in The Netherlands.

2) Regulatory basis for a Radon action plan

The regulatory basis for a radon action plan has been laid down in the current Dutch Regulation (Basic Safety Standards for Radiation Protection Decree). The Authority for Nuclear Safety and Radiation Protection (hereafter Authority) is responsible for the coordination of the radon action plan.

3) Regulatory basis to manage indoor Radon exposure in workplaces and publicly accessible buildings.

There is in particular attention for situations where indoor Radon concentrations are in excess of the national reference level. When, despite measures taken, the indoor Radon concentration remains to exceed the national reference level, these situations (i) are managed as a planned exposure situation and (ii) need to be notified to the Authority. A graded approach may be applied for those situations where optimisation measures fails to reduce the radon activity concentration to a level below 100 Bq/m3. In line with the European Basic Safety Standard, a higher reference level of up to 300 Bq/m3 may be applied for identified areas or for specific types of workplaces or publicly accessible buildings.

Subject: Radon / Thoron

Optimized protection from radon exposure in workplaces and dwellings: challenges related to the implementation of the European Directive 2013/59/Euratom

Francesco Bochicchio

Based on results of large epidemiological studies on lung cancer risk and radon exposure in dwellings and mines, the most recent European directive on basic safety standards for protection against the dangers arising from exposure to ionising radiation, i.e. the Council Directive 2013/59/Euratom, have introduced protection from radon exposure in dwellings as well as increased the protection from radon exposure in workplaces. Similar requirements have been introduced in the International Basic Safety Standards on Radiation Protection and Safety of Radiation Sources, jointly sponsored by several international organizations and agencies (EC, FAO, IAEA, ILO, OECD/NEA, PAHO, UNEP, WHO). These regulations take into account specific documents and recommendations produced by international organizations and agencies such as WHO, ICRP, UNSCEAR, IAEA, ecc. An optimized implementation of these regulations poses several challenges, some of which are discussed in this presentation. A significant challenge is due to the replacement of the concept of “action level” with the much more ambitious concept of “reference level”, which require that exposure is optimized also for levels below the reference level. Another challenge is the implementation of optimized protection in dwellings: this is not usual for radioprotection, which is generally related to occupational exposures. A considerable role is given to a National Action Plan, which gives a lot of flexibility to Member States. Another unusual challenge is how to deal with the interaction between radon and smoking. Developing specific tools is also very useful or necessary, such as cost-effective evaluations, national archives aimed to collect data and information on radon concentration measurements and remedial actions. Some examples and proposals will be reported, taken from the experience and discussions in Italy and other countries.

Subject: Radon / Thoron

Regulating natural radiation sources in Belgium: The national radon action plan

Boris Dehandschutter

For the first time in history of European Basic Safety Standards, the Directive 2013/59/Euratom explicitly addresses radon in dwellings as a regulatory issue in the framework of an existing exposure situation, requiring a reference level with optimisation above and below. All aspects of the management of radon in both dwellings and workplaces have to be described on a national (member-state) level in a National Radon Action Plan. This contribution describes the implementation of the Directive in national legislation based on the national radon action plan. The Belgian radon action plan is published and updated annually. The plan considers the activities and strategies to develop and put in practice each year, in order to achieve the general goal. This long term objective is a general reduction of the exposure to radon for both the public and workers. This implies a stand-still of the exposure in the parts of the territory with low indoor radon levels (average around 40 Bq/m³), and a reduction towards these values of exposure in the radon affected areas. The stand-still has to be assured by limiting radon ingress and guaranteeing appropriate ventilation in buildings and by regulating radioactivity in building materials. The reduction of the exposure has to be assured, in addition to the above mentioned measures, by protective measures against radon ingress in new buildings and mitigation of existing buildings with high radon levels. The road towards the objectives comprises themes like communication plans, measurements campaigns, data management and mapping, training programmes and regulatory initiatives on reference levels and building protection, each with their specific tasks and milestones.

Subject: Radon / Thoron

Requirements on indoor radon in Council Directive 2013/59/Euratom – the Basic Safety Standards Directive

Stefan Mundigl

Exposure to indoor radon constitutes an important part of the overall exposure to ionising radiation of the public and of workers in certain geographical areas or specific types of workplaces.

With the publication of the latest Basic Safety Standards Directive (BSS) , the European Community modernises and consolidates the European radiation protection legislation based on Articles 2 and 30 of the Euratom Treaty. In line with the 2007 ICRP philosophy, the BSS Directive applies to any planned, existing or emergency exposure situation, which involves a risk from exposure to ionising radiation which cannot be disregarded from a radiation protection point of view. With this, the BSS applies to all relevant radiation sources with no distinction made between artificial "man-made" radiation and natural radiation, thus coherently covering radon, cosmic rays, gamma radiation from building materials, and naturally occurring radioactive material (NORM).

The BSS Directive introduces binding requirements on indoor exposure to radon and on radon in workplaces. In particular, the Directive requires the establishment of a national radon action plan addressing long-term risks from radon in buildings and workplaces for any source of radon ingress, whether from soil, building materials or water. Further to this, Member States need to define national reference levels for indoor radon exposure in dwellings and in workplaces of maximum 300 Bq/m3.

Transposition and implementation of the BSS requirements on indoor radon certainly poses a challenge for the radiation protection community in the coming years.

Regulation

Subject: Regulation

Radiation protection instrumentation: IEC international standards for performance requirements

Miroslav Voytchev

The presentation will discuss the newly published IEC (International Electrotechnical Commission) standards on radiation protection instrumentation as well as the most important projects in development. Instruments performance requirements covering the detection of illicit trafficking of radioactive and nuclear material, active and passive dosemeters and ratemeters, security inspection systems using active interrogation with radiation and the contamination meters and monitors will be illustrated. The measurement devices for environmental radiation and radon and radon daughter measuring instruments are included as well. The updates of the IEC Sub-committee 45B "Radiation Protection Instrumentation" charged with the preparation of these standards will also be discussed.

Subject: Regulation

Chemical and radiological risk-assessment methodology for soil contamination in Belgium: a comparison

Stéphane Pepin

In Belgium, the environmental authorities have published detailed guidance on the chemical risk-assessment methodology for contaminated sites. These methodologies address both the risk-assessment to human health as to ecosystems and to groundwater and allow deriving generic as well as site-specific clean-up levels. For assessing the impact on human health of carcinogenic contaminants, a reference value of excess lifetime cancer risk of 10-5 is used; if the risk induced by the exposure to the contaminant exceeds this value, the soil contamination is considered to be a substantial threat. Moreover, the measured or predicted concentration of the contaminant in the environment has to be compared with relevant regulatory values, such as drinking water standards.

The clean-up levels are derived on basis of standard exposure scenarios defined for the five following ground-use: natural, agricultural, residential, recreational and industrial. The evaluation of human health risk from soil contaminant is made using the S-Risk model developed by the Flemish environmental institute VITO and used as reference model in all regions of Belgium. A former version of the S-Risk model was used a few years ago by soil contamination experts to assess the chemical risk of a Belgian site contaminated with uranium.

This methodology for assessing chemical risk to human-health is very similar to the methodologies used for assessing radiological risk for contaminated sites and could be used to derive clean-up levels for radioactive contaminants. A comparison between the methodologies for chemical and radiological human risk-assessment will be presented, focusing especially on the exposure scenarios and the associated parameters. These parameters will also be compared to standard exposure parameters for radiological dose-assessment from the literature. The present study confirms the conclusion of a recent US EPA paper where the consistency of US EPA and UK Environmental Agency methodologies for chemical and radiological risk-assessment of contaminated sites was demonstrated.

Subject: Regulation

How Regulators Assess Radiological Protection For New Build

Paul Butler

The Office for Nuclear Regulation (ONR) has been assessing new reactor designs for viability of implementation within Great Britain through the Generic Design Assessment (GDA) process.

GDA is a four step process where the claims, arguments and evidence supporting the safety of the design are assessed against the legal requirements and regulatory guidance. A key aim is to reduce risk to the design by ensuring it meets regulatory expectations at this early stage. This includes assessment of radiological protection aspects to ensure the design is optimised.

Examples of areas which ONR may choose to assess within its sampling approach include:

- Source Term.
- Radiation Shielding.
- Radiation and Contamination Zoning.
- Worker and Public Dose.
- Monitoring.
- Post-Accident Accessibility.
- Contamination Control.

The Requesting Party (Design Authority) is required to demonstrate risks and exposures are restricted So Far As Is Reasonable Practicable (SFAIRP) thus ensuring risks and exposures are As Low As Reasonably Practicable (ALARP) or As Low As Reasonably Achievable (ALARA) and as such are optimised. The Requesting Party has to show that they have evaluated the risks and consider whether it would be reasonably practicable to implement further safety measures beyond the initial proposals. This is a goal setting approach which supports optimisation of the design.

This paper will give an overview of several reactor designs which have been subjected to the GDA process and provide an insight into the regulatory approach and the tools that are used when undertaking assessments.

GDA enables ONR to engage with designers at an early stage, where it can have the most influence, including aspects of the design important for radiological protection. Application of the GDA process helps to underpin the sustainability of radiation protection within the design by making best use of resources of all parties involved in the process.

Subject: Regulation

Optimisation of Radiation Protection (ALARA): a Guidebook

Fernan Vermeersch

The radiological protection system recommended by the International Commission on Radiological Protection (ICRP) is based on three principles: justification of radiation exposures, optimisation of radiation protection (ALARA) and application of individual dose limits. According to ICRP Publication 103, optimisation of protection is the process by which: “The likelihood of incurring exposures, the number of people exposed, as well as the magnitude of their individual doses should be kept As Low As Reasonably Achievable taking into account economic and societal factors”.

In late 1980's, the ALARA process benefited from many theoretical developments aiming at elaborating the "ALARA procedure" to support its implementation. Since then, this procedure has been put into practice in different exposure situations and resulted in an efficient improvement of the management of radiation protection.

The Working Group on ALARA Culture of the European ALARA Network (EAN) decided to gather feedback of these experiences in order to provide a comprehensive overview of the ALARA process and to disseminate this essential element of radiation protection culture to all stakeholders who wish to improve their knowledge in this field.

This guidebook explains in detail the different steps of the ALARA process, the actors and their responsibilities. It then provides elements of this process that are specific to exposure situations (planned, existing, emergency) and to exposure categories (workers, public, patients). Finally, for each of these situations and categories, the guidebook proposes an illustration of the ALARA process implementation through the presentation of practical examples, provided by EAN members or collected during 20 years of EAN Workshops.

Subject: Regulation

Graded approach to the implementation of the European basic safety standards in the Netherlands

Frans van de Put

The possibility to apply a graded approach to regulatory control allows Member States to develop instruments that are commensurate with the magnitude and likelihood of exposures resulting from practices with source of ionising radiation. During the implementation of the European basic safety standards (Council Directive 2013/59) in Dutch regulation, consideration was given to further develop instruments for a graded approach. One of the aims was to keep the regulatory burden for undertakings as low as reasonably achievable. The outcome of this optimisation process is presented for the following three areas.

1. Practices that require authorisation

A graded classification from low, medium and high exposure of was used to classify practices. This classification was not only based on normal exposure situations but takes also into account the magnitude of expected or potential doses as well as the complexity of practices. Practices with an (expected) low exposure require notification. Practices leading to medium or high exposure require authorisation through registration or licensing. In the Dutch situation for more than 80 % of the practices, registration was shown to be the most proportionate regulatory instrument. Along with the regulatory implementation The Authority for Nuclear Safety and Radiation Protection (ANVS) has developed ICT-tools for the most common practices that require registration. Rather than demanding licenses for all practices that require authorisation, this differentiated approach has led to a substantial reduction of the regulatory burden that is associated with the implementation of the Directive.

2. Exemption and Clearance

Also the instruments of exemption and clearance were further developed and differentiated during the implementation process. Undertakings can now submit requests for regulatory approval for exemption or clearance for specific situations or practices. In addition, conditional clearance values have been established for specific situations with very limited radiological risks for individuals. These instruments allows the (conditional) release from regulatory control of justified practices with a very low risk.

3. Building materials

Reference levels have been established for indoor exposure to gamma radiation emitted by building materials that have been identified as being of concern from a radiation protection point of view. The directive provides a tool for the screening of building materials. An alternative screening tool was developed and allows the screening of the constituents of building materials rather than the end product. This cost-efficient tool can be used to screen building products that are available on the Dutch market.

Subject: Regulation

Benchmarking the staffing level of radiation protection departments: a comparison between the Netherlands and the US

Peter Görts

In order to fulfil its designated tasks a radiation protection department needs sufficient staffing. This staffing level can be a matter of debate between management, licensing government and the radiation protection officer. Benchmarking of the staffing levels can be an effective tool to assist in this debate. In a recent study, benchmark parameters have been determined for US medical facilities. In this work similar benchmark parameters for Dutch medical and non-medical facilities are determined and compared to the US.

The benchmark parameters used to assess the staffing levels are mostly comparable or higher in the US than in the Netherlands. Valuable information on benchmarking parameters can be deduced from the variation in the answers. The subjects that showed low variation overlap to a large extend in the US and Dutch medical facilities. The variation in benchmarking parameters for the Dutch non-medical facilities appears to be somewhat higher than for medical facilities.

The most useful benchmark parameters for both US and Dutch facilities are those related to the number of I-131 therapy patients, gamma camera's, dosimetry wearers, CT scanners, linacs and PET/CT scanners and CT scanners. Useful benchmark parameters, specific for the Netherlands, are the number of High Active Shielded Sources and the involvement of the radiation protection department with quality assurance of radiation measurement equipment and the leak-check of radioactive sources. Some additional corrections can be applied to facilitate the incorporation of these results for licensing purposes.

The amount of staffing of the radiation protection department was considered to be sufficient by most Dutch respondents.

Subject: Regulation

IAEA and EU Basic Safety Standards – Analysis of Differences

Helena Janzekovic

The harmonization of basic safety standards related to radiation protection (BSS) has been in the focus of international organizations for years. A list of reasons to this fact can be very long. The harmonization is needed to enable free movement of people and goods, e.g. food and feedings staff, in line with national legislations. In particular, harmonization is required to control exposure of workers involved in practices with radiation sources in other countries. When acquiring a radiation source from other countries the understanding of BSS in the country of origin is necessary in order to understand the basis of safety measures posed by source or equipment producer. The European Union (EU) as well as the IAEA have been publishing BSS for decades following ICRP recommendations.

In 2013 the EU published the new standards "for protection against the dangerous arising from exposure to ionising radiation" as given in the Council Directive 2013/59/Euratom. The directive was published after more than 15 years of thorough analyses of radiation protection issues. It is based on experiences with implementation of five Euratom Directives already transposed in EU Member States (MS), on the ICRP 103 published in 2007 and on new scientific data.

On the other hand, in 2014 the IAEA published International BSS, i.e. IAEA SS GSR Part 3. The basis for this document lies in experiences of more than 160 IAEA Member States and on the ICRP 103.

Despite the fact that both texts have been drafted in the same period of time and are based on the ICRP 103, i.e. introducing three exposure situations, there are some significant differences in both documents, e.g. some dose limits in planned exposure situations, incorporation of security issues in management of practices, managing exposure situations related to industries using natural occurring radioactive materials and controlling exposure of emergency workers. The differences span from variations in basic principles of radiation protection to distinctness in technical standards, such as the standard related to the exposure due to radon in workplaces. The present analysis of about ten basic differences between both documents focusing in particular on consequences of the differences shall facilitate communication among EU MS and other countries. Such communication is particularly important taking into account world market of equipment producing ionising radiation, world market of materials and control of exposure of itinerant workers in all exposure situations.

Subject: Regulation

Sustainability as a strategic element of radiation protection

Rainer Gellermann

In December 2016 the German Commission on Radiation Protection (SSK) adopted a recommendation concerning the protection of the environment in the context of radiation protection. In this recommendation, the SSK examined how the principle of sustainability can be applied with respect to radioactive substances. It is stated, that the principle of sustainability is a strategic concept in environmental policy. Its elements should be treated as strategic management principles to ensure sustainable development and as such should also be made an integral part of environmental protection in the context of radiation protection. Objectives to be attained are the protection of human health and the protection of non-human species. But moreover, it should be ensured that sufficiently negligible contamination of environmental media remains stable over time. This exceeds the scope of any precautionary principle. To achieve strong sustainability, the latter must be applied, though, as an instrument both of risk prevention and resource preservation when decisions are taken in relation to substantial environmental effects. The contribution will explain this framework and give some examples.

Subject: Regulation

Integration of Risks from Multiple Hazards into a Holistic ALARA / ALARP demonstration

Peter Bryant

The principle of As Low As Reasonable Achievable (ALARA) stems from the field of Radiological Protection. In the UK, this principle has been incorporated into the Health and Safety at Work Act 1974 and rather than applying solely to radiological hazards, applies to all hazards in totality. Given the current methods for assessing hazards are somewhat isolated, in that one hazard is assessed independently of another, it can be challenging to ensure a truly holistic view of the risks, and demonstrate they have been reduced to ALARA or As Low As Is Reasonably Practicable (ALARP) as required in the UK Regulatory Regime.

In practice, taking a balanced view of a range of hazards and risks, is something that operational safety staff do every day, and the context of the prevailing safety culture in the organisation plays an important aspect. What is often missed though is recording the basis of decision making, so that one can learn from non-optimal situations. As the complexity of situations increases it becomes more and more important to have clear, systematic and integrated processes for making assessments and judgements; with demonstrable underpinning.

The proposed talk is an updated version of that presented at the 2017 IRPA workshop on reasonableness in the implementation on the ALARA principle. It presents a framework building on the work that has been undertaken within the UK Nuclear Industry, where increasing emphasis has been placed on ensuring a balanced view of all hazards. Examples are also presented of some of the key challenges that have been encountered when trying to produce a holistic ALARA / ALARP demonstration.

It is hoped this talk will provide useful guidance to the attendees for the integration of risks not only within the UK Nuclear Sector, but also within other fields such as Medical, both within the UK and abroad.

Subject: Regulation

Collaboration of NDT industry in Radiation Protection, legislation and research projects and communication with Government Institutions

Paul van Rooijen

In 1996, four large Non-Destructive Testing (NDT) companies, applying High Activity Sources in Industrial Radiography set up an industry sector committee, operating independently under the Dutch Association for Quality, Inspection and Non-destructive Techniques (KINT). This committee acted as point of contact with the government. Initially, the prime subject was introduction of the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) into Dutch legislation.

Later, to achieve a higher level of compliance with legislation, the necessity to establish a code of practice for safe working with High Activity Sources with a broad level of support within Dutch NDT-industry emerged.

KINT, as independent platform for the Dutch NDT profession, with a long history of active participation in support to National, European and ISO standards, was asked to take the lead.

On July 10, 2015 therefore, a group of initiators established the KINT Committee for Radiation Protection in NDT. The aim of this KINT committee is to promote the safe operation of ionising radiation within the Dutch NDT industry, by creating a broader level of support and a level playing field for safe working with High Activity Sources within the NDT-profession and establishing clear channels for communicating with the government.

The implementation in Dutch legislation of the IAEA Specific Safety Guide SSG-11, taking into account known specific circumstances within the NDT industry, and the drafting of final terms for the training of radiation protection personnel were defined as initial objectives. On both subjects, open communication took place between working groups and the Government, in particular with the newly established Authority on Nuclear Safety and Radiation Protection (ANVS) and the Health and Safety Department of the Ministry of Social Affairs and Employment.

The initial objectives have now been reached. A code of practice (in Dutch: Praktijkrichtlijn) on radiation protection in NDT has now been established and is referenced in government licenses, as well as compliance and enforcement policies.

This code of practice is the result of extensive discussions, exchange of experience and views of parties, working in NDT. During the process, both trust and mutual respect have grown, both within the working group responsible for the creation of the document as well as within the committee itself. This has now grown into a solid basis for follow on projects, including joint research concerning radiation safety, by example establishing true capabilities and limitations of monitoring devices.

Subject: Regulation

Knowledge Management for the Radiation Protection and Criticality Specialism in the Office for Nuclear Regulation

Phil Morgan-Brown

Within the next 5 years the Office for Nuclear Regulation has the potential to lose valuable knowledge due to the age profile of the organisation.

How do we as an organisation react to this and develop sustainable processes for capturing and disseminating knowledge and information and that can used to train, develop and sustain the next generation of inspectors.

Our corporate gaol is to ensure ONR develops and maintains the necessary regulatory culture and appropriate understanding of standards, competency and regulatory history needed to regulate effectively and efficiently.

Within the Radiation Protection and Criticality specialism development of sustainable knowledge management processes is particularly important due to the age profile of the current inspectors, and in recognition that of the experience of new inspectors who may not have come from within the nuclear industry.

Within the Radiation Protection and Criticality specialism we aim to appropriately and effectively acquire, retain and maintain relevant knowledge to support the ONR mission, and make this accessible to all of ONR by:

• Facilitating knowledge from new starters, movers out of the specialism and leavers is appropriately captured and catalogued and accessible.

• Encouraging and facilitating collective input from all Radiation Protection and Criticality Inspectors.

• Provide on-going learning and development opportunities for specialism members to maintain expertise in their field.

• Encouraging specialism members to obtain and maintain membership of relevant professional societies and institutions.

• Core technical knowledge requirements defined

• Staff competencies assessed and Specialism Resilience Matrices developed and used to fill gaps.

• Knowledge management delivery plans and Information Maps in place

• Maintain two way communications between the specialism knowledge management group and other ONR knowledge management specialism sub-groups, and the ONR corporate knowledge management Lead.

Subject: Regulation

Practical implications/consequences of new Dutch legislation due to Council Directive 2013/59/Euratom of 5 December 2013

Andre Zandvoort

In the Netherlands, 30 institutes and companies have a so called “Complex Permit”. This permit gives the entrepreneur the obligation to form a radiation protection unit, managed by a general radiation protection expert. This radiation protection unit has the freedom to grant permits within the organization and execute the radiation safety under own responsibility within the legislation. Most of the 30 complex permit holders are united in an association called the “large permit holders”. This group meets three times a year to discuss issues regarding radiation protection in large institutes and companies. One of the main issue the past years is the implementation of the new Council Directive 2013/59/Euratom of 5 December 2013 and the practical implications and consequences for the new Dutch legislation

Due to the new European legislation a large part of the Dutch policy on radiation protection has changed.

Main implications/consequences

- Change of exposure situations (planned exposures, existing situations and incidents)
- Lower dose limit to the lens of the eye
- Lower clearance and exemption levels for a number of isotopes
- Change of system of licensing, registration and reporting
- Incorporation of dose as a result of exposure to radon
- Registration of dosimetric information of imaging systems
- Use of diagnostic reference levels

Because these changes directly influences the local policy on radiation protection in institutes and companies, these issues are addressed during “large permit holders” meetings. Working groups on several topics discuss consequences and propose adjustments of articles and chapters in new legal texts.

Formed working groups in combination with other parties and authority:

- NORM working group, mainly on exemption and clearance
- Working group on exemption and clearance of artificial isotopes
- Working group on writing termination plan of accelerators
- Working group on writing an emergency plan for the institute of company

Within the large permit holders group an extensive cooperation between the 30 institutes and companies is present. The main goal is working safely with ionizing radiation but where legislation subscribes regulations that are to strict or not practical, to discuss this with the government and in discussion adapt regulation to a more practical regulation, always with radiation safety as main goal.

By joining the expertise of radiation protection experts in a association that seeks the connection with the authorities a save but still workable legislation can be established.

Subject: Regulation

Justified Waste and Unethical ALARA

J. van den Eijnde

In this contribution two ethical aspects of the system of dose control are discussed: 'intergenerational justice' –as defined in the upcoming ICRP Publication 138 on ethical foundations- and 'overspending'.

It is accepted as ethical that the combined justification and ALARA approach can lead to situations where advantages and disadvantages are not evenly distributed. This situation is accepted because the disadvantages will be relatively small as they are controlled by limits/constraints in combination with ALARA. These small disadvantages are accepted because the situation is symmetrical: people will very often inflict small disadvantages to one another, and forbidding all actions that cause small disadvantages would really 'unduly limit desirable human actions'.

However, for future generations there are no limits or constraints, and –most important in this discussion-they will inflict no disadvantages to us. So the situation is not symmetrical. Inflicting small disadvantages to them is not a priori ethical.

As a method for an ethically correct treatment of future generations it is proposed in this article to make a separate justification procedure for them. The ethical treatment of future generations will then not be treated by an ALARA/optimisation procedure but by a justification procedure. This method fits in the current ICRP system. This justification procedure can lead to conclusions that an activity that produces radioactive waste can be justified, because not doing this activity will inflict more harm to future generations. So it can result in accepting 'justified waste'. Some possible ways of implementing this procedure will be discussed.

The issue will also be presented in economic terms, using the 'social rate of discount'.

In practice applying ALARA leads to relatively many situations with overspending for radiation protection. And overspending is unethical, so in these cases one can speak of 'unethical ALARA'. Examples will be given.

This situation arises because ALARA is a one way process: it only looks at the optimal ways to reduce a dose and not in the other direction, so at abolishing unnecessary costly measures. In these cases, ALARA will be optimised, but not the level of protection. As a solution it is suggested that ALARA should again be defined as an elaboration of an optimisation process and not the other way around. This means a new emphasis on cost-benefit analysis. The implications of this change will be discussed.

Subject: Regulation

Determination of quantities of radiological interest for the shipping of radioactive goods with Monte-Carlo simulations.

Philippe Bertreix

The European Organization for Nuclear Research (CERN) operates particle accelerators and facilities for high energy physics research. CERN experiments can lead to the activation of equipment which may require shipping to external workshops, institutes or repositories for radioactive waste.

Shipping of radioactive goods follows the recommendations provided in the IAEA safety standards. However, the high beam energies used at CERN can lead to the production of radionuclides for which no activity limits are provided in the shipping regulations.

Moreover, the new off-line isotope separation facility CERN-MEDICIS and the on-line isotope separation facility ISOLDE at CERN can provide a multitude of different radionuclides. Samples of some of these radionuclides have to be shipped to external laboratories for off-line experiments.

The activity limits are calculated on the basis of the so-called “Q-values”, which evaluate the dose received by the public in case of accidents depending on the release and exposure scenario. In particular, the Qb and Qd values, as defined in the TS-G-1.1 IAEA safety standard, concern the dose from beta emitters due to external exposure and due to skin contamination, respectively.

In this paper, we propose a determination of these coefficients, in order to define shipping limits for radionuclides of interest which values are not implemented in the regulation. These calculations are based on Monte-Carlo simulations to obtain the Qb and Qd coefficients, and we compare computed values with published ones from IAEA SSR-6 publication.

Subject: Regulation

Cosmic radiation exposure of Dutch military aviation personnel

Tjerk Kuipers

In the context of new radiological protection legislation on galactic cosmic radiation the need arose for the Dutch Ministry of Defence to review the cosmic radiation dose received by military aviation personnel. According to new legislation (Bbs 2018) the annual cosmic radiation dose of military aviation personnel working above sea level has to be monitored, where in former legislation the dose levels below 8 kilometers above sea level were exempted (Bs 2012). To comply with the new legislation it was necessary to review all flight movements and perform a dose estimate for all military aviation personnel within the Dutch Ministry of Defence. In addition, the target groups that are legally eligible for special attention and information provision were updated. The Royal Netherlands Air Force (RNLAF) provided data of flight movements (duration and altitude) that was processed by the CARI-6M computer program by the Defence Radiation Protection Unit (SBD). Calculations show that for a small part of the military aviation personnel the annual dose level does exceed the annual 1 mSv dose limit. Therefore individual dose levels of military aviation personnel are that low that long term adverse health effects cannot be attributed due to galactic cosmic radiation exposure.

Subject: Regulation

The impact of the new Swiss Radiation Protection Ordinance on the operational radiation protection at Paul Scherrer Institute

Lisa Pedrazzi

The new Swiss Radiation Protection Ordinance enters into force on 1st January 2018 implementing the Euratom Directive 2013/59. The implementation of radiation worker's categories, partially new dose limits for occupationally exposed persons and members of the public, lowering of exemption limits and regulations dealing with the protection against radon exposures are some of the key points of the new Ordinance.

The entry into force of the new Ordinance is an important step in the harmonization with EU-countries and improvement of radiological protection in Switzerland, but confronts experts and radiation protection workers with challenges in the introduction and implementation. Especially, at the Paul Scherrer Institute (PSI) the operational radiation protection is a very complex business. PSI consists of a wide range of activities in different facilities such as accelerator facilities, nuclear facilities and radioactive waste treatment. For all these affected aspects the impact of the new Ordinance had to be investigated.

The faced problems and possible solutions for the implementation of the new Ordinance at PSI are discussed.

Subject: Regulation

Control of Occupational Radiation Exposure across GB Nuclear Sites

Phil Morgan-Brown

Regulation 8 of the Ionising Radiations Regulations 1999 is concerned with the restriction of exposure to ionising radiations. It requires radiation employers to restrict, so far as is reasonably practicable (SFAIRP), the exposure of employees and other persons to ionising radiation. The main aim of the Regulations and the supporting Approved Code of Practice is to establish a framework for ensuring that exposure to ionising radiation arising from work activities is kept as low as reasonably practicable (ALARP) and does not exceed dose limits specified for individuals

The Office for Nuclear Regulation undertook a series interventions over a 3 year period across all of the nuclear licensed sites in the UK, specifically assessing the Control of Occupational Radiation Exposure (CORE), with the objectives:

- To provide assurance that licensees are broadly complying with the requirements of regulation 8 of IRR99.
- To identify any industry wide themes that could be considered to be areas for improvement.
- To identify examples of relevant good practice and to communicate in the form of a summary report.

CORE inspections examined the operator's arrangements, and how these were implemented at the operational level with respect to:

- ALARP Strategy
- Dose limits, Dose Targets / Budgets / Objectives / Action Levels
- Trending and Analysis
- Learning from Experience / Radiological Incidents and Near Misses
- Targeting of ALARP measures
- Work Scheduling
- Provision of information, instruction and training to workers on radiological protection
- Benchmarking and sharing of relevant good practice

The overall outcome confirmed that occupational radiation exposures were well controlled across all of the UK nuclear licensed sites, with areas of good practice being identified. Based on the outcomes of the CORE project, ONR is developing key topics for the next phase of radiation protection interventions that will focus on sustaining compliance. As many sites move towards decommissioning activities with a large reliance on external contractors, embedding a strong radiological safety culture for all workers is key to maintaining continued compliance.

Consequently, future areas of intervention may focus on:

- Radiological Protection Management Arrangements
- Risk Assessments & Setting to Work
- Radiological Contamination Controls
- Radioactive Material Controls
- Culture
- Control of Contractors
- IRR17 Implementation

Security

Subject: Security

Nordic Exercise for Unmanned Systems, NEXUS 2017

Magnus Gårdestig

Introduction

There are several measurement and sampling scenarios with high risks for humans to carry out, e.g. reactor accidents, such as Chernobyl and Fukushima, RDDs before and after explosion, search of MORC, or search inside buildings that are under the threat of collapsing. For these scenarios remotely controlled radiation measurements and sampling using unmanned aircraft systems (UAS) are developed.

The NKS-B activity SemUnaRS – Seminar on Unmanned Radiometric Systems, was held in 2014 in Linköping, Sweden. The seminar was the start-up and an inventory of the capacities for unmanned measurements in the Nordic countries. (Gårdestig, Pollanen et al. 2015).

The NKS-B activity NORDUM - Intercomparison of Nordic unmanned aerial monitoring platforms, was held in 2016 in Norway. The exercise gave five teams the opportunity to test their rotary wing UAS in three scenarios. (Tazmini, Robøle et al. 2016)

The NEXUS exercise

The objective of the exercise was to test unmanned aerial platforms with respect to locating, identifying and estimating the activity of radioactive sources under field conditions. Thereby acquire competence within the Nordic countries. The NEXUS exercise covered scenarios in these aspects:

- The use of fixed wing platforms that are beneficial in covering larger areas. They are intended to solve survey missions with assessments of ground activity concentrations or search for sources over larger areas. The scenario featured a contaminated area.
- The use of unmanned measurements in urban environments. Localization, identification, assessment of activities and recommendations of rescue routes. One large house and a figurative market hid point sources.
- Single point sources in open fields were used for verification and test of search strategies and assessment of time, covered area, altitude needed and MDA.

The exercise area was Björka exercise field in the south of Sweden. The enclosed area houses a runway, an artificial urban street, forest and grass fields.

Participants

Linköping University, Sweden, Norwegian Radiation Protection Authority, University of Oulu, Finland. The exercise was facilitated by the Radiation Physics department at Lund University. The activity was in part financed by the NKS-B programme, Nordic nuclear safety research.

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Subject: Security

Changing the paradigm for radiological terrorism preparedness

Cullen Case Jr.

Communities need to refocus their planning and response from what if we are hit to what if anyone is hit and we have to respond. The likelihood of a radiological disaster/IND/terrorism is low for any community. Some communities have higher risk than others, but all communities have a higher risk of being impacted by the medical surge and surge of refugees from a disaster in a city 500-1000 km away.

The RITN Regional Table Top Exercise Program has engaged 14 major metropolitan communities in the United States and challenged the public health, emergency management, hospitals, emergency medical service, fire service, law enforcement, NGOs, and political administrations to consider a new paradigm. It is unlikely to happen to us, but it is more likely to happen to someone and we will be involved in caring for the patients and evacuees.

This session will describe the exercises conducted, where they were conducted and review key lessons learned from each of the exercises. Additionally, the planning and implementation logistics necessary for each exercise was critical to the success of these exercises; applicable lessons from the planning of the exercises will be shared as well. Finally, exercise materials will be shared with participants in this session to help facilitate implement similar exercises in their communities.

Subject: Security

A third limb of influence to improve the adoption of radioactive source security at the global level

Chris Englefield

States around the globe keep and use radioactive sources. About 10 million transports of radioactive sources occur annually.

The security of radioactive materials has been given high priority since the terrorist events of 11 September 2001. Since then, the international community has invested in strengthening the security of radioactive sources, to keep them out of the hands of terrorists. New legally binding undertakings have been agreed by the international community to support the long-standing but non-binding Code of Conduct on the Safety and Security of Radioactive Sources (the CoC); the IAEA has established a comprehensive suite of nuclear security guidance, and States have invested in programmes of bilateral assistance. Further international efforts are not described here.

This global campaign to deny the adversary access to radioactive materials rests on two supporting limbs; the international and the national.

Yet, 17 years after "9/11", the uptake around the world is still highly variable. Is one limb in the foundation of radiological security missing? Implementation does not reach the level expected after nearly two decades of effort.

Operators carry responsibility for both safety and security, but do not contribute directly to the global radiological security system. The challenge is: how to reach and recruit the operators?

This paper points to the need for closer interaction with and involvement by operators, manufacturers and associated professionals as a third limb of the radiological security foundation. Operators, producers and manufacturers could be mobilised in support of improved radioactive source security at the global level. Diverse professionals could be recruited to assist, i.e.

• Radiation protection specialists

• International and national standards stakeholders

• The wider security community

We commend the considerable efforts expended by the international and national limbs of the radiological security foundation: this"top-down" approach is led by international best practice, governments and regulators. However, we submit that it is time to start a "bottom up" approach that is in line with the established international framework, notably the CoC, that fully recognizes the key contributions of operators and manufacturers. This parallel third leg could be driven by professional practice and channels.

The full paper will enumerate some potential opportunities for development of this third limb.

Subject: Security

Securing the HASS life cycle, from cradle to grave.

Joop Deeterink

One type of Co-60 HASS is used in brachytherapy after-loaders, whereas another type is used in the Leksell Gamma Knife®, a treatment device specifically developed for the irradiation of brain lesions. In terms of A/D ratios, brachytherapy sources are normally categorized as Category 3 sources according to the International Atomic Energy Agency's (IAEA) categorization scheme. However due to their 'level of attractiveness' they reside under Category 2, Security level B. Gamma Knife sources belong to Category 1, Security level A. Where the goal of security level B is to minimize the likelihood of unauthorized removal of radioactive sources the goal of security level A is to prevent any unauthorized removal of radioactive sources. Immediate detection and intervention during tampering with the Gamma Knife is therefore required. Since the publications of IAEA's Nuclear Security Series no 9, 11 & 14 measures have been taken in several countries to counteract theft, abuse or sabotage of HASS installed in clinically operating units. However, transportation of Category 1 & 2 sources remains challenging. Prior knowledge of transport information and the security measures applied to the transport shall be restricted to the minimum number of persons required. A Certificate of Trustworthiness and Reliability for the staff involved is sometimes hard to obtain due to privacy legislations. IAEA's recommendations that extra attention is paid to security requirements for radioactive material in transport are meant to be implemented by individual governments to minimize the likelihood of loss of control or malicious acts. Unfortunately a solid implementation is not the norm and this applies in particular to politically unstable regions and war-torn countries. Another flaw is that it is not a norm that national legislations are "matched" at the borders to enable seamless security measures for international transports. Furthermore, last year Wannacry's ransomware attack showed the vulnerability of computer systems worldwide. In theory, any transport containing dangerous goods can be diverted with relative ease by hacking computer systems. Therefore, companies must be meticulous and diligent in their implementation of secure storage of data and the methods used to communicate confidential information. The industry is lacking a clear standard, a clear directive how to work with this kind of sensitive information and in particular how to work with it in the field, close to where the actual operations occur, and where many "heterogeneous" entities need to be informed about aspects of the transport.

Subject: Security

Legislation and Communication as Part of a Security Theater in the Case of Asse II

Rainer G. Gellermann

The mine Asse II is a former salt mine in Northern Germany. It was established as a research mine for the final disposal of radioactive waste. But in the 1970ies the amount of disposed waste grew steeply up and the research purpose became less important than the disposal purpose. After recognizing that further operation would fail to meet the licensing requirements the closure of the mine was intended. As a basis of the decommissioning approval, the long-term safety was studied. For likely developments, the dose was estimated to comply with the limit of 0.3 mSv/a with a statistical certainty of 95%.

Due to its history Asse II has been controversial for many years. In 2008 an unauthorized handling of radioactive brines became public. In its consequence, the German Bundestag amended the Atomic Energy Act and declared the mine to be a subject under the atomic law. This decision provided a new framework and required a reassessment of options. In January 2010 the new operator (Federal Office for Radiation Protection, BfS) published a comparison of options for closing the mine and stated that the long-term safety of waste in the mine cannot be demonstrated with the required confidence. The retrieval of the waste and the transfer into an interim storage facility was declared as the preferred option. However, the BfS considered a further fact-finding necessary. But in February 2013 the German Bundestag adopted a special supplement of the German Atomic Energy Act (“Lex Asse”). In the parliamentary debate the justification and optimization were explicitly denied as principles that should be applied and the retrieval of waste from the Asse mine was defined as a binding target.

In December 2016 the German Commission on Radiological Protection (SSK) amended recommendations regarding radiation protection related to the Asse mine. First one of these recommendations states, that the three principles of radiation protection (justification, optimization and limitation of radiation exposures) should be respected and that these principles are adequately respected.

There are several lessons that radiation protection practitioners have to learn from the Asse story. One of these lessons is that basic principles of RP are of minor importance in the framework of political decisions. Another one is that is the process established for closing Asse II is mainly intended to provide the feeling of improved security while doing little or nothing to achieve it ("Security Theater").

Subject: Security

Analysis by Monte Carlo of the viability of an explosive detection system based on Am/Be neutron source

Eduardo Gallego

Neutron techniques to identify materials have a wide range of applications, with major developments recently in the field of identification of terrorist threats with CBRNE (chemical, biological, radiological, nuclear and explosive) materials. The key advantage is the high penetration of neutrons in matter, and therefore threats as explosives, drugs or landmines can be detected even when they are hidden under layers of earth, or materials of high density.

The design of the studied Explosive Detection System (EDS) would be composed by a 111 Gbq 241Am/Be neutron source, polyethylene cylinders as neutron moderator, and finally, a gamma detector. The final aim of this work has been the design and selection of the geometry of the system optimizing the thermal neutrons flux, taking advantage of multiple scattering of neutrons with the walls of the cavity of polyethylene cylinders, in order to improve the efficiency and sensitivity for detection of explosives or other substances through the the PGNAA (Prompt Gamma Neutron Activation Analysis) method.

Three different sizes of cylinders have been used, in four different configurations of the EDS. The different configurations of the EDS have been evaluated by Monte Carlo techniques using the MCNP6 code. Once the geometry and configuration of the system has been optimized, a prototype of the model has been tested in the neutronics hall of the Energy Engineering Department at the Universidad Politecnica de Madrid, taking different experimental measurements. A high agreement between calculated and experimental values has been obtained.

The optimized configuration can be used in future laboratory experiments, both to complete the EDS development but also for the calibration of neutron dosimetry equipment.

Waste management

Subject: Waste management

Fate of Radionuclide ^{14}C in Soil-Plant-Atmosphere Continuum: Uptake of Soil ^{14}C into plants

Soroush Majlesi

Radioactive waste is generated at all stages of the nuclear fuel cycle. Finland and other countries support deep geologic disposal as the best method for isolating highly radioactive waste. However, there is still risk that release might take place and pose a threat to health or the environment. One of the radionuclides that have been identified as being potentially significant in terms of release from deep geological disposal is radiocarbon (14C). It has a high potential to escape (as CO2) from radioactive waste repositories, and actively taken up by plants. However, the amount of 14C possibly taken up through plant roots or assimilated within the sub-canopy is largely unknown.

We investigated the potential transfer of soil-derived C into two plant species (reed canary grass, Phalaris arundinacea and Scots pine, Pinus sylvestris) by using a new approach to separate soil-derived carbon from that originating from the atmosphere. The principal idea of this approach is to study uptake of soil carbon into plants in cultivated cutaway peatlands, where a distinct natural 14C pattern exists (very large difference in 14C content between modern plants with “normal” 14C levels and the up to 8000-year-old leftover peat strongly depleted in 14C). Samples of soil, plants (roots and leaves) and CO2 respired from the soil were collected and analyzed for 14C content by accelerator mass spectrometer (AMS). Two-pool isotope mixing model was applied to calculate the relative contribution of atmospheric C and soil-derived C in the plants.

The results revealed that the contribution of soil-derived C in both plant species was insignificant, implying that plants mostly acquire carbon through photosynthesis. Furthermore, the results showed that, although abundant soil-derived carbon was available in plant canopy air for assimilation, no or a small trace of soil-derived carbon was found in the aboveground parts of the plants. This may have been affected by the fact that the actively growing plants were small and the canopy was not fully developed during assimilation of C from the atmosphere. The concentration of soil-derived C was higher in pine roots than in reed canary grass roots, which might be related to the high mycorrhizal infection level in pine. Further work is needed in other ecosystems with different plants and soil types to investigate the transfer of 14C and contribution of soil-derived C to ascertain to what extent these results are generalizable.

Subject: Waste management

Radioecology of tritium in sewage water discharges of a landfill in northern germany

Rainer Gellermann

In purified sewage water (permeate) of a landfill in northern Germany, a tritium concentration of 576 Bq/l was measured in 2011. On the basis of this finding, further studies were conducted on tritium in the permeate and in surface waters in order to be able to elucidate the concerns of citizens on the basis of a professional basis. From the data gathered up to 2016, it can be estimated that a total activity of about 330 GBq of tritium in the waste deposits of the landfill has occurred in 2011. In order to evaluate the measured values for their radiological significance, radiation exposures of persons of the public were modeled on the basis of the German “AVV zu § 47 StrlSchV”. In some parameters, the concrete location conditions clearly differed from the assumptions used to derive the clearance values in 2004. The highest annual doses were obtained for the age group of infants and are below 1 µSv for 2015. The main contribution comes from the consumption of mother's milk. A comparison of the site-related model parameters with such which are used for the derivation of clearance values for landfills shows that the scenario "use of surface water" is not conservative for the landfill considered here.

Subject: Waste management

Study of radon and descendants in the nuclear facility for storage of radioactive low and intermediate level waste of “El Cabril”

Teresa Ortiz

Since 2010 to 2017, it has made in the Storage Facility for Low and Intermediate level Radioactive Waste in Spain, the C.A. El Cabril four campaigns for measuring radon and their daughters in the most representative points of work’s areas in which are stored waste that might contribute to increasing their concentrations, with differents levels of ventilation and occupation.

They were chosen five locations such as Local Sources, Cell 29 (inside and outside), Cell 30, Storage Modules (module 1, 2 and 3) and Galleries (North Platform, Cell 16 and South Platform). Measurement campaigns were carried out by two methods, with the Alphaguard equipment continuously taking samples every hour and manually. The manual method consisted in sucking air through a filter of nitrocellulose of 0.48 µm pore size as a Kusnetz method. The samples were measured in the laboratory with a low background proportional counter. Radon concentrations were estimated from the concentrations of their progeny, whereas the corresponding equilibrium factor.

The results of both methods are similar and are within the same order of magnitude. The values obtained in every campaigns are similar in the same sampling points. Higher values corresponds to the interior of the Cell 29, while for Module 1 and the Platform North and South, galleries values are very low and similar to those obtained by exposure for the Cell 29. The average concentrations of radon and progeny are much lower than guide values or reference values.

Subject: Waste management

Special activities of the radiation protection unit of ENRESA

Teresa Ortiz

As a result of an incident in a hospital before the withdrawal of a set of sources of a brachytherapy device, that had never been authorized or used, the CSN required to ENRESA creating a Radiation Protection Unit (RPU), whose authorization was granted on June 1990.

Since then the RPU of ENRESA has undertaken more than 5,000 actions related to removal of residues of radioactive and non-regulated facilities, controlling more than 8,000 radioactive sources. One of the most important activities is the characterization of radioactive sources without information about their characteristics and waste materials from activities of the past and of those sources and material from non-regulated facilities. These special performances include those related to the radiological surveillance of metallic materials Protocol, as well as those related to the Protocol Megaport.

In the same way, the RPU also has participated, since June 1989, in the dismantling and removal of heads of units of teletherapy and irradiators, making the accompaniment of transport from the radioactive installation up to the storage facility ("C.A. Cabril"), when the corresponding ministerial decision established it.

The objective of this work is to present these special activities that have occurred in these fields of application since the creation of ENRESA.

Subject: Waste Management

Management of radioactive waste in the Netherlands

Jeroen Welbergen

The Central Organisation for Radioactive Waste (COVRA), is responsible for the management of Dutch radioactive waste, from collection to the eventual disposal.

Collection: Management of low-level waste (LLW) starts with collection of the radwaste (isolation) at the producers site. Packages are transported to COVRA mainly in type A (e.g. medical radwaste) and in type B transport containers (e.g. HASS) . High-level waste (HLW) from spent fuel of Research Reactors (including spent targets from Molybdenum production) and from recycling of spent fuel from Nuclear Power generation are transported in type B containers. Transport of radwaste is notified to the regulator and European transport rules (ADR) based upon IAEA Transportation regulations apply .

Treatment: Annually some 500 m3 of LLW is produced. Most of it is conditioned at the COVRA facilities. Only resins and evaporator sludges are directly conditioned with cement at the nuclear power plant Borssele. At COVRA, various installations are available in the treatment building, such as a super compactor, an incinerator for biological waste, an incinerator for organic liquids, shearing and cutting installations, a cementing station and wastewater treatment systems. The final conditioned waste form is a cemented package.

Storage: Radwaste is stored in concrete or steel plate buildings, designed for a storage period of at least 100 years. Quality control is done by inspection during restacking of the drums.

LLW is stored in a concrete building. Blocks of waste packages are placed in rows, which leave open corridors for inspection. Lower dose rate packages are stored along the outer walls of the modules, and on the top layers in order to provide additional shielding for higher dose rate packages (2-10 mSv/h) at the interior and at the fence of the facility (ALARA). LW is stored in a concrete bunker with 2 m thick walls to withstand extremities (earth quakes, plane crashes, flooding etc.) and to reduce the dose at the fence (ALARA).

Dismantling and disposal: The modular (robust) construction of the facilities simplifies the decommissioning and dismantling (D&D). Much attention has been spent to compartmentation of the storage buildings and to keep the facility as clean as possible(good practice). However in case of contamination a detailed registration of contamination incidents is in place and spreading of the contamination is mapped.

For all radioactive waste which has not been decayed during storage, geological disposal is foreseen.

Subject: Waste Management

International Network of Laboratories for Nuclear Waste Characterization IAEA-LABONET - Facts and Future

Leo van Velzen

LABONET was launched early 2011 by the International Atomic Energy Agency (IAEA). Its objective is to improve the quality of, and harmonize, activities related to the characterization of radiologically contaminated materials (e.g. waste) in IAEA Member States. It is widely accepted that proper characterization of radioactive materials through its entire flow-sheet is a key activity. A main concern within LABONET are in particular the needs and problems in waste characterization in the participating countries. LABONET is working in facilitating the sharing of international experience in the application of proven, quality assured practices in characterization e.g. nuclide inventory, physical and chemical properties, which will be beneficial for the less developed countries. Its focus is on topics dealing with very low, low and intermediate level waste, and the free release of radioactive contaminated materials to improve sustainability, reuse and recycling of materials. These objectives of LABONET will be achieved via different actions: a) exchange of information and expertise; b) expert meetings on particular topics of interest, e.g. e-learning; c) training sessions in less developed countries, e.g. on non-destructive assay; d) facilitate the exchange of information amongst member countries; and e) assist member states in establishing characterization plans fitting the member state's needs, cost effective and of good quality. At present some 45 countries joined LABONET, which is managed by a scientific secretary of IAEA with the assistance of a designated Steering Committee. Technical Meetings have been held in Slovakia, Italy, Austria, France, Belgium and Czech Republic, as well as training sessions and dedicated expert meetings. Topics covered in the presentations during these meetings can be grouped into 5 categories (1) overviews of national programs on waste management, (2) determination of radionuclide inventories through analysis, modelling, scaling factors, (3) other characterization techniques, (4) immobilized waste, (5) other topics. All presentations and meeting reports have been made available on a dedicated website. LABONET is continuously encouraging organizations and professionals who need assistance or can help in solving questions and challenges about characterizations to be a member. Currently, LABONET is preparing for its future, projects addressing common problems of its member states. Aiming at the dissemination of this important network for the professionals involved in radioactive waste characterization, the presentation will discuss the following issues: (1) the objectives of the LABONET network, (2) its structure, membership and organization of meetings, (3) achievements, (4) plans for the future.

Subject: Waste Management

Clearance from regulatory control in Switzerland of CERN's radioactive waste

Charlotte Duchemin

Clearance from regulatory control of potentially radioactive material is a regulated practice in several European countries bringing benefits to society and the environment. The cleared material can be recycled instead of being stored in repositories for many years, and its resale brings a return of investment when compared with its conditioning and disposal as radioactive waste. CERN produces a wide variety of potentially radioactive waste due to maintenance, upgrade and dismantling of accelerators and experiments. This waste is then eliminated according to a tripartite agreement between CERN and its Host States France and Switzerland: it is either disposed of in the national repositories of the Host States, or cleared from regulatory control in Switzerland. CERN, as an environmentally-aware research laboratory, is committed to limit the production of radioactive waste, sort it effectively and ensure safe disposal. In this context, a number of projects were conducted starting from the decommissioning of LEP.

LEP and its four experiments were decommissioned in 2000-2001 to allow reusing the tunnel and associated infrastructures for the LHC. Most of the equipment (approximately 30,000 tons) was eliminated as conventional material for recycling, following an extensive study submitted to the French authorities. At that time, the superconducting radiofrequency (RF) system was kept for a possible future use, until the recent decision to dispose of it.

In 2016 the CLEAR (Clearance of LEP Acceleration RF system) project was mandated to study the feasibility and then clear from regulatory control the 71 modules (approximately 450 tons). The project included a theoretical and experimental study to pre-characterize the materials on the bases of its radiological history, chemical composition, extensive γ-spectrometry measurements and radiochemical analyses, dose rate and contamination measurements, FLUKA Monte Carlo simulations and calculations with the ActiWiz code. The operational phase started in March 2017 and was completed in October with the elimination of 414 tons of material as conventional, representing 95% of the total.

Another project is currently under way to clear high purity copper cables removed over the past 40 years from accelerator tunnels and controlled and supervised radiation areas. Calculations, γ-spectrometry measurements and radiochemical analysis were performed to determine the nuclide inventory. Around 39 tons of shredded copper were considered for clearance through the ELISA (ELImination of Shredded cAbles) project, which will be completed by the end of 2017.

The presentation will discuss the clearance practice applied to the CLEAR and ELISA projects.

Subject: Waste Management

Bioinformatics analysis of complex DNA-sequencing data to assess microbial diversity in geological radioactive waste disposal environments

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Safe implementation of geological disposal of nuclear waste involves studying the impact of microbial processes, an aspect which has been ignored in most studies published about this issue. Given the extreme environment where those microbes survive (i.e. high pressure, low-nutrient environment, etc.), identifying microbial communities living within those geological layers under laboratory conditions is far from straightforward. However, recent developments in new high-throughput sequencing technologies have revolutionized molecular biology, including the study of microorganisms without the need for culturing them in the lab, an approach often referred to as metagenomics. This technological progress has led to an explosive growth of the biological information, creating new opportunities in the field of bioinformatics in order to computationally deal with the dramatic increase of data. This approach has nowadays been adopted in many project studying the risk of microbial activity in clay formations for the risk assessment of radioactive waste disposal.

The first objective of this work was to test different combinations of technologies and algorithms to ultimately find the optimal combination of technologies and algorithms that can be used to assess the microbial diversity in environments using 16S ribosomal RNA genes. As the suitability of existing algorithms for this type of large-scale community analysis was unknown, benchmarking and further optimization of existing open-source algorithms was necessary, and the development of novel bioinformatics algorithms was required to address this fast evolving issue. In this context, three tools were developed to deal with chimera (Mysara, Saeys, et al., 2015) and sequencing errors (Mysara, Leys, et al., 2015; Mysara et al., 2016) which were found to outperform the other existing state-of-the-art tools. Additionally, a new method was introduced to bring closer correspondence between the number of microorganisms detected and the actual diversity within the samples (Mysara, Vandamme, et al., 2017). A one stop-shop software was delivered assembling these various algorithms, leading to a highly accurate preprocessing pipeline (Mysara, Njima, et al., 2017).

These tailored algorithms were applied to assess the deep subsurface geological clay formations, which were selected and currently studied as candidate host rocks for geological radioactive waste disposal (HADES, Boom clay, Belgium; and Mont Terri, Opalinus clay Swiss, Moors et al. 2013). Thus it was possible to perform a risk assessment of the presence of microbial activity in deep subsurface geological clay formations in the context of radioactive waste disposal.


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