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Abstracts of the NordicNORM 2015 Workshop

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Liisa Sirkka (Ed.)

Säteilyturvakeskus
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1 Introduction

The NordicNORM 2015 workshop is organised on 15-16 September 2015 in Helsinki, Finland. The workshop is hosted by Radiation and Nuclear Safety Authority (STUK), in cooperation with fellow Radiation Protection Authorities in other Nordic countries. The workshop is targeted primarily on regulator, industry and research organisations from Nordic countries. This workshop is part of CONCERT - European Joint Programme for the Integration of Radiation Protection Research which has received funding from the *Euratom research and training programme 2014-2018* under grant agreement No 662287.

1.1 Background

Naturally Occurring Radioactive Material (NORM) was identified as a potential source of occupational and public exposure already several decades ago. However, the discovery of high radon levels in homes and ordinary workplaces in the 1980's started to draw the utmost attention and, unfortunately, pushed NORM issues slightly in the shadow. However, NORM is still a significant cause of occupational and public exposure warranting optimized radiation protection measures.

The Council Directive 2013/59/Euratom (BSS Directive) shall be implemented by the EU Member States by January 2018. Reflected in the BSS Directive, the new division to planned, existing and emergency exposure situations supports the understanding that some practices involving NORM should be considered as planned exposure situations and also regulated as such. The Directive anticipates that NORM practices requiring regulation would be formally licensed like any other practice.

1.2 What is NORM

NORM i.e. Naturally Occuring Radioactive Material exists everywhere in earth's crust. All natural materials such as minerals and ores; namely, any rock, gravel, sand, clay etc. contain uranium and thorium and their various daughter products. Concentrations vary significantly depending on the type of the rock origin. For example, granites often contain elevated levels of uranium and thorium.

NORM may thus lead to human exposure where natural resources are utilized. Perhaps the most common situation for excess exposure to NORM is due to building materials where the exposure to external gamma radiation is increased also because of the modified exposure geometry (from 2π-geometry outdoors to 4π-geometry indoors). Another example of NORM exposure is in metal production where material is heated and the natural radionuclides Pb-210 or Po-210 may be released as vapor. Inhalation of airborne Pb-210 or Po-210 can cause significant human exposure and condensation of such vapor in filters or on pipeline surfaces may result in high localized contamination.

Indoor radon is not included in NORM in the current definition. This is because of its unique feature of being a gas and delivering exposure solely via inhalation, while for NORM, direct gamma radiation, inhalation of particulates and ingestion with water or food, may all be significant exposure pathways. The other difference between radon and NORM is that high radon concentrations are mainly caused by the natural, unmodified soil under the building, whereas in case of NORM, possible exposures are nearly always

associated with some type of active human operations, such handling, use or treatment of some material.

Practices involving NORM may lead to exposures of workers and the members of the public which are significant from the radiological protection point of view. Occupational exposures of the order of a few mSv/yr may occur. Usually public exposures are in the order of a some tenths of a mSv/yr, except in case of building materials where 1 mSv/yr can easily be exceeded.

1.3 Objectives of the workshop

Throughout decades the Nordic Countries have co-operated intensively and successfully in finding common approaches to deal with natural radiation ("Nordic Flag Book" titled Naturally Occurring Radioactivity in the Nordic Countries -recommendations, The Radiation Protection Authorities in Denmark, Finland, Iceland, Norway and Sweden, 2000). The implementation of the BSS Directive regarding NORM presents a clear call for continuing the Nordic co-operation in finding common approaches to deal with natural radiation.

Content of the workshop included:

- Identification of NORM practices in the Nordic Countries
- Discussion on potential ways to co-operate in the implementation of the ICRP recommendations and the EU BSS Directive regarding NORM
- Presentations of research studies on NORM
- Discussion on needs to update the "Nordic Flag Book" on NORM and whether to extend it to cover practices such as mining and milling industry involving NORM

Indoor radon or drinking water issues was not included in the workshop.

2 Programme

Opening session
Chair: Päivi Kurttio, STUK – Radiation and Nuclear Safety Authority, Finland

- Welcome and opening of the workshop: Tarja K. Ikäheimonen, STUK, Radiation and Nuclear Safety Authority, Finland
- The new Euratom Basic Safety Standards Directive – requirements on natural radiation sources: Stefan Mundigl, European Commission
- Organisation of the BSS implementation in Finland: Mikko Paunio, Ministry of Social Affairs and Health, Finland
- Introduction to European joint programming in radiation protection research: Sisko Salomaa, STUK – Radiation and Nuclear Safety Authority, Finland

- Research and innovation supporting the implementation of the revised European Basic Safety Standards: Géza Sáfrány, National Public Health Center - National Research Directorate for Radiobiology and Radiohygiene, Hungary

Organisation of regulatory control and challenges of NORM issues in the Nordic Countries
Chair: Mika Markkanen, STUK – Radiation and Nuclear Safety Authority, Finland

- Norway: Marte Varpen Holmstrand, NRPA - Norwegian Radiation Protection Authority
- Sweden: Markos Koufakis, SSM - Swedish Radiation Safety Authority
- Denmark: Charlotte Nielsen, SIS - The National Institute of Radiation Protection, the Danish Health and Medicines Authority
- Finland: Mika Markkanen, STUK – Radiation and Nuclear Safety Authority, Finland

Discussion on NORM Flagbook update
Chair: Mika Markkanen, STUK – Radiation and Nuclear Safety Authority, Finland

NORM in building materials and waste
Chair: Pia Vesterbacka, STUK – Radiation and Nuclear Safety Authority, Finland

- Are radioactivity measurements of building materials justifiable? Finnish data from the 2000s: Tuukka Turtiainen, STUK – Radiation and Nuclear Safety Authority, Finland
- Assessing ionizing radiation from construction products under Construction Product Regulation CPR: Pekka Vuorinen, Finnish Association of Construction Product Industries RTT
- International survey of management practices for NORM contaminated metal scrap: Bertil Grundfelt, Kemakta Konsult AB, Sweden

Metrology and research
Chair: Jarkko Kyllönen, STUK – Radiation and Nuclear Safety Authority, Finland

- MetroNORM – Metrology for processing materials with high natural radioactivity: Alexander Mauring, NRPA - Norwegian Radiation Protection Authority
- Lead-210 and polonium-210 in environmental samples in Northern Finland based on archived analyses data: Jussi Paatero, Finnish Meteorological Institute
- Overview of NORM-related research conducted at the University of Tartu, Estonia: Taavi Vaasma, University of Tartu, Estonia
- Radioecology research working group on NORM issues: Maarit Muikku, STUK – Radiation and Nuclear Safety Authority, Finland

- Research needs on exposure to naturally occurring radioactive materials (NORMs) identified by the CRPPH Expert Group on Radiological Protection Science: Sisko Salomaa, STUK – Radiation and Nuclear Safety Authority, Finland

Mines
Chair: Tuukka Turtiainen, STUK – Radiation and Nuclear Safety Authority, Finland

- Radiological baseline studies in the vicinity of Finnish mines: Pia Vesterbacka, STUK – Radiation and Nuclear Safety Authority, Finland

- Evaluation of the mobility of radionuclides during Talvivaara production process: Mila Pelkonen, University of Helsinki, Finland

- Mobilization of radionuclides and heavy metals from mill tailings in a northern boreal environment: Hanna Tuovinen, University of Helsinki, Finland

- Natural radionuclides (U, Th, Po) in pit lakes waters from Sweden: Juan Mantero, University of Gothenburg, Sweden

Closing remarks:
Päivi Kurttio, STUK – Radiation and Nuclear Safety Authority, Finland

At the end of the workshop, there is also an optional laboratory tour at STUK organized: Kaisa Vaaramaa and Vesa-Pekka Vartti, STUK – Radiation and Nuclear Safety Authority, Finland.

3 Abstracts of the workshop

3.1 Opening session

3.1.1 The new Euratom Basic Safety Standards Directive – requirements on natural radiation sources

Mundigl, Stefan[1]

[1]European Commission, Directorate-General Energy, Radiation Protection and Nuclear Safety Unit, EUFO 4492, L-2920 Luxembourg, LUXEMBOURG

With the publication of the new Euratom Basic Safety Standards Directive, the European Community modernises and consolidates the European radiation protection legislation. The new Directive offers in a single coherent document basics safety standards for the protection against the dangers arising from ionising radiation which take account of the status-quo of science and technology, cover all relevant radiation sources, including natural radiation sources, integrate protection of workers, members of the public, patients and the environment, cover all exposure situations, planned, existing, emergency, and harmonise numerical values with international standards. European Union Member States are now challenged with the transposition and implementation of this comprehensive piece of legislation – the deadline for transposition is 6 February 2018.

Following the new ICRP philosophy, introduced in publication 103, the new Basic Safety Standards 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, including radon, cosmic rays and naturally occurring radioactive material (NORM), with no distinction made between artificial "man-made" radiation and natural radiation. The major challenge in this new approach is the coherent application of the Basic Safety Standards to natural radiation sources, in particular to radon in buildings and in workplaces and to industrial sectors involving NORM.

This presentation will introduce the new BSS and, in particular, its requirements on natural radiation sources, including NORM.

3.1.2 Organisation of the BSS implementation in Finland

Paunio, Mikko[1]

[1]Ministry of Social Affairs and Health, FINLAND

Ministry of Social Affairs and Health has started a process to rewrite the Radiation Act (1991). The work should be carried out between January the 15, 2015 and June 30, 2017 in eight working groups under the steering group. The current Radiation Act has been amended 16 times over the years and has become partly obsolete due to changes in the operational environment and as well as legislative context. Among other things - such as the new EU BSS directive - Finnish constitution also requires full revision of the Radiation Act by demanding that many current safety requirements that are now implemented at lower level, should be written into the law. Although BSS-directive does not cover non-ionizing radiation, it was considered necessary to rewrite - in part - also safety requirements of non-ionizing radiation in the new law due changes in the operational environment.

The new law is to enter into force on the 1, January 2018. However, before the national parliament procedure the draft law as well as other statutes should be subordinated to the European Commission for a possible comment for three months' period of time. BSS directive should finally be notified to the European Commission by the 6, February 2018.

The work has been organized as following. A steering group - represented by key stakeholders and other ministries was set up to oversee the work. Eight working groups have been established: 1) medical use of radiation, 2) intentional non-medical use of radiation, 3) natural radiation, 4) occupational and public health, 5) inspection and enforcement in practice (permits, notifications, personnel qualifications) and coercive enforcement, 6) radiation safety and education (basic professional training, continuous and additional training), 7) preparedness and accidents and 8) non-ionizing radiation.

Ministry of Social Affairs is providing one legal expert, while Finnish Radiation and Nuclear Safety Authority (STUK) provides 1,8 substance experts who provide secretarial services for the whole process. The basic workload is carried out in working groups, which will meet after the secretariat and each working group chairman have agreed upon paragraphs and their reasoning to be considered and discussed in the working group. These discussed paragraphs and their reasoning are then fed to the steering group, which considers and amends them in due course.

3.1.3 Research and innovation supporting the implementation of the revised European Basic Safety Standards

Safrany, Geza[1]; Salomaa, Sisko[2]

[1]NRIRR, National Research Institute for Radiohygiene and Radiobiology, HUNGARY; [2]Radiation and Nuclear Safety Authority, FINLAND

The European Joint Programme on Radiation Protection Research (CONCERT) aims to contribute to the sustainable integration of European and national research programmes in radiation protection by focusing resources and efforts in five key directions:

1. Bring together the elements of the European scientific communities in the fields of radiation effects and risks, radioecology, nuclear emergency preparedness, dosimetry and medical radiation protection, whose joint expertise is essential to continue the development of radiation protection knowledge in a multidisciplinary mode to reduce further the uncertainties in radiation protection.
2. Strengthen integrative activities between the various areas of expertise, in particular biology, biophysics, epidemiology, dosimetry and modelling as well as fostering the use of existing infrastructures and education and training activities in radiation protection.
3. Stimulate and foster scientific excellence, by setting up and co-funding advanced research programmes with the potential to enhance current knowledge and the scientific evidence base for radiation protection.
4. Exchange and communicate with all stakeholders, including the professional organizations concerned with radiation protection, the regulatory organizations across Europe, the public and media where necessary, and the international community of scientific, technical, legal and other professional experts in radiation protection.
5. Foster the harmonious application of available scientific basis for radiation protection practices across Europe, by bringing together scientific and technical expertise in radiation protection issues, standard setting know how, particularly with respect to the implementation of the Euratom Basic Safety Standards (BSS) at the legal, administrative and operational level.

As for the last key direction, a dedicated Task 2.7 is devoted for the Research and innovation supporting the implementation of revised European Basic Safety Standards. Due attention will be paid to the communication of knowledge from research and innovation conducted within CONCERT and outside laying the scientific basis for the revised European BSS. This will be done to help those who are involved in the transposition and implementation of these Basic Safety Standards, which will require changes in national regulations and practices. Further, topics and priorities for research will be identified in workshops, such as the NordicNORM workshop, bringing together the research platforms and national authorities and regulators. In particular, HERCA and EURATOM Article 31 group of experts will be consulted. This Task will serve as input to Joint Programming of integrative research actions.

The CONCERT project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 662287.

3.2 NORM in building materials and waste

3.2.1 Are radioactivity measurements of building materials justifiable? Finnish data from the 2000s

Turtiainen, Tuukka[1]

[1]Radiation and Nuclear Safety Authority, FINLAND

The first survey on radioactivity in Finnish building materials was carried out in the early 1980s and the latest was completed in May 2015. Since 1993, the producers have been obliged to ensure that their building materials do not cause effective doses exceeding 1 mSv/year for the residents. In this presentation, the results from different surveys as well as measurements commissioned by the companies are reviewed. Benefits of this long-term work cooperation will be discussed.

3.2.2 Assessing ionizing radiation from construction products under Construction Product Regulation CPR

Vuorinen, Pekka[1]

[1]Finnish Association of Construction Product Industries RTT, FINLAND

Aspects like compressive strength or fire resistance are familiar requirements for construction products, and have been addressed by product standard developers for decades. New requirements concerning health and environmental aspects of construction products have appeared gradually during the last two decennia. The EU legislation for construction products has promoted the performance approach. To assess a product's emission performance reliable test methods are needed and any requirements must be backed up with test methods. This article reviews the development and harmonization of assessment methods for the release of hazardous substances and ionizing radiation from construction products and presents the results achieved so far in standardization.

The work of CEN/TC 351 "Construction products: Assessment of release of dangerous substances" addresses also naturally occurring radioactive materials (NORM), which may be used in building materials under radiological constraints. The main task identified in case of ionizing radiation (WG3 "radiation from construction products") is to develop a standardized measurement method for determining the activity concentrations of three naturally occurring radionuclides using gamma spectrometry. The activity concentration index (I) is an established screening tool in Europe for identifying materials that might be of concern. For the calculation of the activity concentration index (I) measurements of Radium-226, Thorium-232 and Potassium-40 are relevant.

In addition to the test method for determining activity concentrations a technical report on dose assessment of emitted gamma radiation is prepared. The results are intended to serve as a basis for development of a harmonized European approach regarding dose modelling in order to avoid transboundary issues or inconsistent restrictions for building materials, i.e. construction products under the Construction Products Regulation, (EU)305/2011 and the Basic Safety Standards Directive, 2013/59/Euratom.

3.2.3 International survey of management practices for NORM contaminated metal scrap

Keith-Roach, Miranda[1]; Grundfelt, Bertil[1]

[1]Kemakta Konsult AB, SWEDEN

This paper presents an investigation into the handling of scrap metal contaminated with naturally occurring radioactive material (NORM) in different countries and the financing of the management options applied. The objective was to provide the Swedish Radiation Safety Authority with information to support the development of guidelines for managing orphan NORM contaminated scrap generated and stockpiled in Sweden.

The study was performed in three steps. The first step involved posing open questions on the NORM and Natural Radiation discussion group page of the social network site LinkedIn. This was then followed by a review of relevant national strategies and guidelines, and the final stage involved the construction and distribution of a questionnaire to selected persons in 13 countries. The questionnaire contained questions about the amount of orphan NORM contaminated metal waste handled, handling methods applied, radioactivity limits for disposal of NORM waste, methods for financing the handling options applied, importance of sustainability aspects in the handling approach selected, rules for import and export of NORM waste, and ways by which stakeholders are made aware of NORM issues and stakeholders are involved in the development of management options and legislation.

The results showed that very different approaches are taken in the countries investigated. The choice of handling system is influenced by the available infrastructure for management of radioactive waste. Other governing factors affecting the choice of handling system are radiation safety, technical feasibility and economic efficiency. Sustainability aspects that are important in conventional waste management, e.g. the waste hierarchy that prioritises reuse before recirculation or disposal, have a lower priority in the handling of NORM contaminated metal waste. In most countries, the costs are covered by the holder of the waste material.

3.3 Metrology and research

3.3.1 MetroNORM – Metrology for processing materials with high natural radioactivity

Mauring, Alexander[1]; Pöllänen, Roy[2]; Maringer, Franz-Josef[3]

[1]Norwegian Radiation Protection Authority, NORWAY; [2]STUK - Radiation and Nuclear Safety Authority, FINLAND; [3]Bundesamt für Eich- und Vermessungswesen, AUSTRIA

Naturally occurring radionuclides are present in many natural resources. Industrial activities that exploit these resources may lead to enhanced potential for exposure to NORM in products, by-products, residues and wastes. These waste materials, generated from current and past activities, constitute a huge economic and ecological burden if they are not properly disposed of or re-used as input materials for the industry. When such materials are handled or processed, it is necessary to identify the nuclides present and to determine their activity concentrations as accurately as possible. Traceable, accurate, and standardised measurement methods and systems, in particular for in-situ applications, are needed to decide on the re-use of waste materials without increasing costs. At the same time, avoiding contamination of the environment and exposure to the public is of key importance. Reference materials are necessary to validate the radioanalytical procedures involved as well as methods for analysis and interpretation of the results.

The joint research project MetroNORM, launched in September 2013, aims to develop measurement systems, methods and techniques to ensure effective and safe production in a variety of NORM industries. The project is funded by the European Metrology Research Programme (EMRP), and has participants from 12 different countries. Scientific and technical objectives include:

- Design of traceable measurement procedures for industrial NORM raw material, products, by-products, residues and waste.
- Development and establishment of traceable metrological reference materials and standard sources needed for calibrations in NORM measurement.
- Improvements to decay data for selected natural radionuclides, focusing on decay chains description, gamma-ray intensities and half-life improvement.
- Testing of developed systems, standards and reference materials in industrial processing situations.

The MetroNORM project is scheduled to run for a three-year period until September 2016. Cooperation and dialogue with Nordic NORM industries, authorities and stakeholders during the course of the project is highly welcome.

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

3.3.2 Lead-210 and polonium-210 in environmental samples in Northern Finland based on archived analyses data

Paatero, Jussi[1]; Leppänen, Ari-Pekka[2]

[1]Finnish Meteorological Institute, FINLAND; [2]Radiation and Nuclear Safety Authority, FINLAND

Among the most abundant natural radionuclides in the environment are radon-222 and its daughter nuclides. Among these is lead-210 (^{210}Pb) which, owing to its long half-life (22.3 y), together with its progeny (^{210}Bi and ^{210}Po) can cause a significant fraction of the internal radiation exposure of man both by inhalation and by ingestion.

Several hundred ^{210}Pb and ^{210}Po analyses from environmental samples were made at the Regional Laboratory in Northern Finland of STUK - Radiation and Nuclear Safety Authority in 1979-1989. The analyses were made with the conventional method: spontaneous deposition onto silver disks followed by alpha spectrometry. Three subsequent depositions were made, the first to obtain the ^{210}Po activity, the second to verify the quantitative deposition during the first deposition, and the third one to obtain the ^{210}Pb activity. This dataset was, however, never processed and published. In this work we retrieved archived ^{210}Pb and ^{210}Po analysis reports and digitized them. Thus we obtained a dataset concerning the ^{210}Pb and ^{210}Po content of various environmental sample matrices in northern Finland. The sample types reported here are fresh water sediment, phosphorus mineral ore, lichen, moss, mineral soil, peat soil, timothy grass, wavy hair-grass, silvery sedge, marsh horsetail, cloudberry leaves, pine needles, hare's-tail cottongrass, willow-herb, bilberry twigs, bottle sedge, dwarf birch leaves, tea-leaved willow leaves, downy willow leaves, birch leaves, juniper boughs, crowberry twigs, and horsetail. Also some fertilizer and fly ash samples had been analysed.

The activity content of ^{210}Pb in the samples varied over three orders of magnitude, from 1 to 4200 Bq/kg dry weight. The lowest activity concentrations were in various grass samples and the highest ones in phosphorus mineral ore and sediment samples. The ^{210}Po content of the samples varied even more, from 0.03 to 1070 Bq/kg d.w. Again the lowest activity concentrations were measured from various grass samples and the highest ones from phosphorus mineral ore and sediment samples. The highest ^{210}Po/^{210}Pb activity ratios were observed in soil samples and the lowest ones in grass samples.

Acknowledgements

This study was financially supported by the EU Kolarctic ENPI CBC program managed by the Regional Council of Lapland. Ms. Satu Asikainen is thanked for technical assistance.

3.3.3 Overview of NORM-related research conducted at the University of Tartu, Estonia

Vaasma, Taavi[1]; Tkaczyk, Alan Henry[1]; Kiisk, Madis[1]; Realo, Enn[1]; Suursoo, Siiri[1]; Isakar, Kadri[1]; Jantsikene, Alar[1]

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The research work on mapping natural and artificial isotopes in the Estonian environment at the University of Tartu began in the 1990's. This work focused on the distribution of natural (U- and Th- series) and artificial (Cs-137, Cs-134) isotopes. From that time, the number of lab personnel has constantly grown and currently amounts to 10 persons including researchers and lab assistants. This research group has been responsible for conducting scientific work on NORM-related topics in Estonia and producing the newest research findings.

The latest projects have concentrated on various industrial enrichment processes to study the build–up of NORM:

a) Characterization of the enrichment processes of environmentally occurring U- and Th-series isotopes in oil-shale power plants, assessments of atmospheric emissions and propagation in the vicinity of the industrial area;

b) Characterization and development of water treatment technologies designed to remove elevated concentrations of radium from ground water for human consumption.

The latest results have indicated that oil shale power plants have a potential to be considered as emission sources for natural radionuclides, as the isotopes become significantly enriched in the finer ash fractions, with enrichment factor up to 5. The magnitude of these emissions depends on the technology used in the plants: both pulverized fuel and circulating fluidized bed boilers are currently operational. Additional research is being undertaken to (1) determine the contribution of Po-210 in inducing additional doses from the industry, and (2) assess the atmospheric propagation of natural radionuclides by collecting environmental samples, such as peat.

The water industry will be also the subject of further research, as the latest findings have revealed an extended range of water treatment plants where accumulation of natural radionuclides exhibit elevated levels from the viewpoint of the national legislation.

Although the aforementioned issues have received the strongest attention, research topics such as oil shale chemistry, mining activities, production of concrete and building materials, and rare earth processing will be included under more thorough studies in the coming years.

3.3.4 Radioecology research working group on NORM issues

Muikku, Maarit[1]; Sachs, Susanne[2]; Arnold, Thuro[2]; Garnier-Laplace, Jacqueline[3]; Vandenhove, Hildegarde[4]

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The Strategic Research Agenda (SRA) for radioecological research in Europe has been developed under the EC-STAR Network of Excellence and complemented with a first phase roadmap developed by the COMET project and the European Radioecology Alliance. The roadmap serves as a basis for the development of a 5-year implementation plan to initiate research activities that have been identified as priorities in the SRA. Seven working groups are contributing to different research areas of the roadmap, one of them working on NORM issues. Descriptions of the seven areas can be found on the Radioecology Exchange websites (www.radioecology-exchange.org).

The main issue in view of NORM is how to assess and regulate the management and clean-up of NORM-impacted sites, such as radium contaminated sites, uranium liabilities and wastes arising from industries processing or generating other kinds of NORM. This involves amongst others:

1. Sampling strategies and associated measurements for characterization of NORM-contaminated sites;

2. The practical use of hydro-geological and hydrogeochemical mechanistic modelling together with a process-based understanding of the radionuclide migration in the environment, including transfer into biota and finally into the human food chain;

3. Prospective environmental assessment with modelling inferring timescales from years to millennia.

Due to the complexity of NORM sites, which is characterized, for instance, by complex mixtures of different chemical substances (either radioactive or stable) and minerals as well as disequilibria in radionuclide decay chains, difficulties arise not only from the lack of data but also from the inadequacy of existing model concepts and hypotheses. Therefore, a promising strategy is to identify and parameterize key processes that influence the radionuclide behaviour and to transfer this knowledge into a mechanistic model sufficiently complex to describe the radionuclide behaviour in the environment, however, simultaneously simple enough to be practical and transferable between different NORM sites.

3.3.5 Research needs on exposure to naturally occurring radioactive materials (NORMs) identified by the CRPPH Expert Group on Radiological Protection Science

Salomaa, Sisko[1]; Lund, Ingemar[2]

[1]Radiation and Nuclear Safety Authority, FINLAND; [2]Swedish Radiation Safety Authority, SWEDEN

The OECD/NEA Committee on Radiation Protection and Public Health (CRPPH) set up a Working Group on Radiological Protection Science in 2013 to review scientific, societal, implementation and regulatory challenges of radiological protection. The EGRPS report will be finalized during 2015. A summary on the research needs related to NORM will be presented. While naturally occurring radioactive materials exist everywhere in varying concentrations, NORM exposure levels in some situations are not yet well characterized. Issues such as residence times, dust concentrations and factors affecting the equilibrium of decay products can affect exposures. Radiological protection in NORM industries is addressed by the International Basic Safety Standards (BSS), and by the European Basic Safety Standards Directive. However, the application of these safety standards in specific areas is not fully addressed.

In addition to well-known NORM industries, new situations may arise, for instance in ground water treatment plants or fish hatcheries, or in gas production by hydraulic fracturing. Once exposure levels are well characterized, how to apply radiological protection to NORM exposure in various situations could also be a challenge, recognizing that exposure may have only a minor ranking in overall health and safety issues at work. The management of occupational exposure NORM industries as a planned exposure situation requires a clear definition on where dose limits for workers should apply.

Disposal of NORM wastes, especially those with technologically enhanced radioactivity, needs to be included in NORM management. Research is needed to find good, practical solutions, including the identification of situations where mixing of NORM residues with high activity and with low activity concentration may be justified. NORM guidelines need also to be harmonized internationally, especially as they apply to international trade and transportation of ores, building materials and finished products. Such guidelines should be based on an assessment of doses to those buildings with or using such NORM materials.

A well-designed communication strategy needs to be developed for radiological protection of exposures to NORM, and to raise awareness among the concerned industries. Public awareness of exposures resulting from building materials should be improved, and international standards should be developed to appropriately control and facilitate trade of such materials.

The exposure of workers in NORM industries (handling or processing naturally occurring radioactive materials) is the direct consequence of their work. Hence, in principle, these industries should be managed in the same way as practices involving artificial, man-made, radiation sources. They should be managed within the overall framework of planned exposure situations. A similar situation arises with the exposure of workers to radon in their place of work.

3.4 Mines

3.4.1 Radiological baseline studies in the vicinity of Finnish mines

Vesterbacka, Pia[1;] Kallio, Antti[1], and Vaaramaa, Kaisa[1]

[1]Radiation and Nuclear Safety Authority, FINLAND

In Finland, mining became popular in the mid-1990s when changes in legislation made mining activities easier for foreign companies. The price of the minerals rose and mining in Finland became economically profitable. The expanding mining industry brought new challenges to radiation safety aspects, since radioactive substances occur in nearly all minerals. In Finnish soil and bedrock the average abundances of uranium and thorium are 4 ppm and 10 ppm, respectively. It is not always easy to predict beforehand how radionuclides behave in the mining and enrichment processes, which is why they need to be taken into account in mining activities.

Radiation and Nuclear Safety Authority (STUK) of Finland has given a national guide ST 12.1 based on the Finnish Radiation Act. The guide sets the limits for radiation doses to the public also from mining activities. In general, no measures to limit the radiation exposure are needed, if the dose from the operation liable to cause exposure to natural radiation is no greater than 0.1 mSv per year above the natural background radiation dose. If the exposure of the public may be higher than 0.1 mSv per year, the responsible party must provide STUK with a plan describing the measures by which the radiation exposure is to be kept as low as is reasonably achievable. In that case the responsible party also has to make a radiological baseline study.

In Finland, radiological baseline studies have been done at the Sokli phosphate deposit, Talvivaara nickel mine (which also recovers uranium as a by-product), Kuusamo gold deposit and Suhanko PGE- copper-nickel deposit. Radiological baseline studies have focused on the environment that could be influenced by the mining activities. A radiological baseline study describes the occurrence of natural radioactivity in the environment before any mining activities have started. Samples have usually been collected from terrestrial and aquatic environments. The total number of samples collected has been between 100 - 200 samples per year. A radiological baseline study of a mine site normally takes two to three years to complete.

This paper presents results from different radiological baseline studies in the vicinities of Finnish ore deposits and mines. Detailed information on the existing levels of radioactivity in the environment is attained from these studies.

3.4.2 Evaluation of the mobility of radionuclides during Talvivaara production process

Pelkonen, Mila[1]; Tuovinen, Hanna[1]; Lehto, Jukka[1]

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Elevated levels of radionuclides in soil are considered as a risk due to their effect on the soils ecological functions and the potential health effect on humans and wildlife when absorbed from food chain transfer. The aim of this study was to evaluate the mobility and bioavailability of radionuclides in the ore and gypsum pond samples collected from the Talvivaara Sotkamo Nickel Mine in North-Eastern Finland by using sequential extractions. The ore at Talvivaara is fairly low-grade black schist from which the metals are extracted using bioheapleaching. The samples studied consisted of unleached ore, primary leaching ore, secondary leaching ore and gypsum pond samples. The sequential extraction procedure was modified from that of Outola et al. and the studied extracted fractions were tris fraction, exchangeable fraction, acid-soluble fraction, reducible fraction, oxidizable fraction and residual fraction. The concentrations of extracted metals were determined by Inductively Coupled Plasma Mass Spectrometry.

The results show that from all ore types the highest concentrations of uranium and thorium were released from fresh ore samples and the highest percentage of uranium and thorium was leached in the residual fraction indicating that they are tightly bound to the sample matrix. It is important to note that uranium starts dissolving from all ore types in the acid-soluble fraction as the pH of the solution decreases. From the gypsum pond samples uranium and thorium were mostly dissolved in the acid-soluble fraction. This shows that these radionuclides in the gypsum ponds are loosely bound and become more mobile as the pH of the solution decreases. The concentration of thorium remains low in all of the sample types. Elevated concentrations of uranium were found in the gypsum pond samples due to the enrichment of uranium in the metals recovery process.

References

Outola, I.; Inn, K.; Ford, S.; Markham, P.; Outola, P. Optimizing standard sequential extraction protocol with lake and ocean sediments. J. Radioanal. Nucl. Chem 2009; 282: 321-327

3.4.3 Mobilization of radionuclides and heavy metals from mill tailings in a northern boreal environment

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Many new ore prospecting projects have been launched recently in Finland. At the same time, there is increasing awareness of the radiological impact of non-nuclear industries that extract and/or process ores containing naturally occurring radioactive material (NORM). These industrial activities may result in significant environmental problems if the waste generated during processing is not adequately managed.

In 2010, a new project was launched in Finland, the object of which was to study the mobility of radionuclides and heavy metals from diverse mill tailings in a northern boreal environment. The project was funded by the Academy of Finland and involved the Universities of Helsinki and Loughborough, the Geological Survey of Finland and the Finnish Radiation and Nuclear Safety Authority (STUK). Three sites were being investigated: Talvivaara nickel mine, a former phosphate mine in Sokli, Lapland and a former pilot scale uranium mine in Paukkajanvaara.

The aim at Paukkajanvaara site was to examine the possible further mobilisation of radionuclides from the tailings repository and waste rock pile in the remediated area. At Sokli site, the mobilisation of radionuclides and heavy metals from the mill tailings was examined in order to assess the potential environmental impact of past and future mining activities. The study at Talvivaara site was focused on the behaviour of uranium and its radiotoxic daughters ^{226}Ra, ^{210}Pb and ^{210}Po in bioheapleaching process applied by Talvivaara mine. The studies led to a better understanding of the behaviour of radionuclides and heavy metals in these three diverse mine sites. The results will also play an important role in estimating radiation doses to the local population resulting from past and anticipated disposal of mill tailings. A short summary of the results gained from each site is given in the presentation.

3.4.4 Natural radionuclides (U, Th, Po) in pit lakes waters from Sweden

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The effect of mining activities on hydrological regimes has been studied at many locations worldwide where one of the major threats is the acid mine drainage water. On the other hand, Sweden is a major metal mining country in the European Union what implies enormous quantities of generated mining wastes. In this work, acid mine water open pits will be studied, so called pit lakes. There is a growing awareness of the environmental risk associated with these mining lakes, where several studies focus their attention in metallic elements, and/or remediation activities, however few data up to date, related to radionuclides behavior at those pit lakes can be found in the literature.

This work presents the first stage of a project financed by the Swedish Radiation Safety Authority (SSM). A database with results of Uranium, Thorium and Polonium naturally occurring isotopes (^{238}U, ^{234}U, ^{232}Th, ^{230}Th and ^{210}Po) in waters from these sites will be generated within the frame of this project. Due to anthropogenic activities in those mining areas, these water bodies may enhance their activity concentrations affecting the surrounding areas through drainage waters or even contribute to increase the external doses received by people visiting these sites for recreation purposes.

Alpha spectrometry with PIPS detector was performed within a set of 25 water samples belonging to 15 different mining sites from the Southern part of Sweden. It was found a wide range of activity concentration in U isotopes: from 2 to 800 mBq/kg of ^{238}U and from 2 to 1100 mBq/kg of ^{234}U, low levels of Po isotopes (environmental levels) and very low levels of Th (below Minimum Detectable Activity, MDA, in most of cases). Having into account that an average value of U isotopes in non-affecting environmental waters is around 20-30 mBq/kg it is quite clear that some of the studied scenarios have enhanced the U levels in superficial waters. Apart from that, other parameters as T, pH, Oxidation-Reduction Potential (ORP), Specific Conductance, Dissolved Oxygen or Salinity will be shown.

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