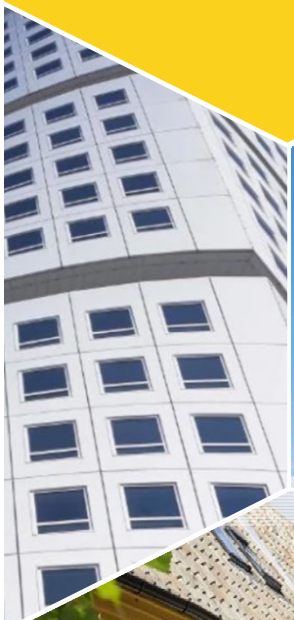
NSFS

Nordic Society for Radiation Protection

NSFS *XIX* Conference, June 5-9, 2023

"Sharing and caring"

Book of abstracts and conference programme



Clarion hotel Malmö Live, Malmö Sweden

www.nsfs.org

Strål säkerhets myndigheten

Swedish Radiation Safety Authority

SWE-RAYS

SWEDISH RADIATION RESEARCH ASSOCIATION FOR YOUNG SCIENTISTS

NSFS XIX congress partners

Strål
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IRPA

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LUND UNIVERSITY

UNIVERSITY OF
GOTHENBURG

Dear colleagues,

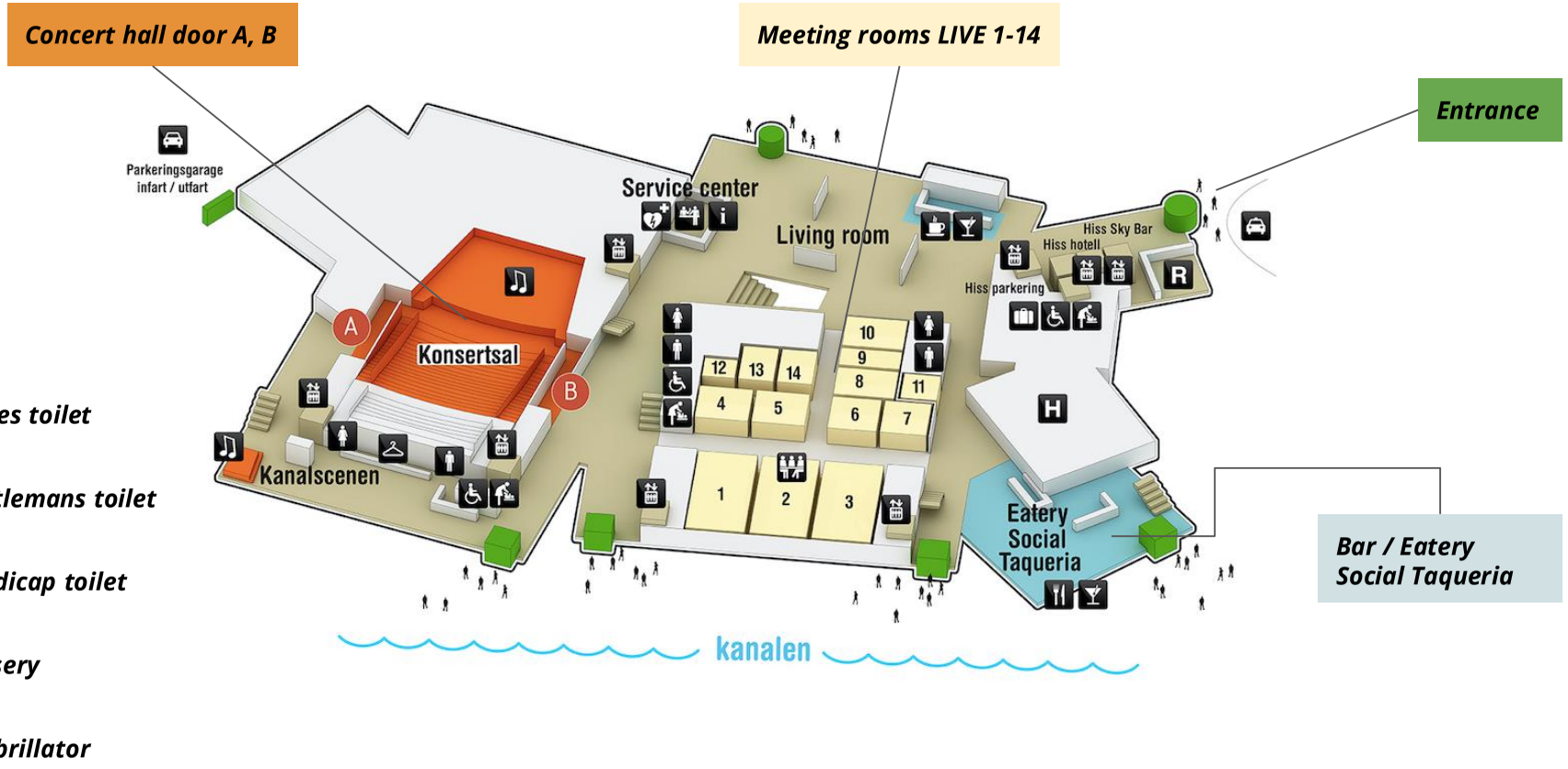
It is with great pleasure that we welcome you to the XIX conference of the Nordic Society for Radiation Protection, held at Malmö Live, Malmö, Sweden, June 5-9, 2023. Since the previous NSFS conference in Espoo, Finland in 2019, the COVID-19 pandemic has affected not only the society in general but also the work of NSFS. Planned activities could not be realized, and we needed to communicate on-line and arrange virtual meetings.

The theme of the conference is “Sharing and Caring”, that can be interpreted as sharing of knowledge and caring about negative effects of radiation and its benefits for individuals and the society. The conference starts with excursions to the European Spallation Source (ESS) in Lund, Lund University Bioimaging Centre (LBIC) and historical sites in Lund, and the Emergency preparedness laboratory in Malmö. Many abstracts of high-quality were received and evaluated by the scientific committee, and formed the basis of the program, consisting of 58 oral presentations and 24 posters on a variety of radiation protection aspects plus 8 presentations from related societies in Sweden and sponsors. Furthermore, the conference will start with Bo Lindell lecture. Invited presentations will be given by the IRPA President Bernard Le Guen and the ICRP Chair Werner Rühm. Jack Valentin and Sören Mattsson will present the history of NSFS, a topic valuable both for present, new and potential NSFS members. Other themes are the R/N situation in Ukraine and possible consequences, AI in radiation protection, future competence supply of radiation professionals, and a special session organised by and for young radiation professionals.

Since travelling and participation in meetings have decreased after the pandemia, we are pleased that around 100 participants from 11 countries will attend the conference. We look forward to inspiring presentations and discussions, and last but not least the joy of meeting radiation protection professionals in the Nordic countries again.

In these Proceedings of the conference, the program and abstracts are printed. Full papers of some of these contributions will later be published as special issues of the Radiation Protection and Dosimetry journal.

Eva Forssell-Aronsson, President 2019-2023
Christian Bernhardsson, Vice president 2019-2023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Eatery
Social
Taqueria
kanalen
Bar / Eatery
Social Taqueria
Ladies toilet
Gentlemans toilet
Handicap toilet
Nursery
Defibrillator

Committees of NSFS XIX conference

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Edda Lína Gunnarsdóttir	Icelandic Radiation Safety Authority
Jack Valentin	International Commission on Radiological Protection
Jens Søgaard-Hansen	Danish Decommissioning
Magnus Båth	University of Gothenburg
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Sören Mattsson	Lund University
Tone-Mette Sjømoen	Norwegian Radiation and Nuclear Safety Authority

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Johan Spetz	conference@nsfs.org
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Crister Ceberg	Swedish Association for Radiobiology, SfRB
Fredrik Nordström	Swedish Medical Physicist Association, SSFF
Mats Eriksson	National Committee for Radiation Protection, NKSSF
Christian Bernhardsson	Swedish Society for Radioecology, SFREK
Mikael Elvborn	Swedish Radiation Research Association for Young Scientists, SWE-RAYS
Per Roos	European Spallation Source, ESS
Per Seltborg	Swedish Radiation Safety Authority, SSM
Ulrik Kautsky	Swedish Nuclear Fuel and Waste Management, SKB
Åsa Palm	Swedish Association for Radiation Physics, SFfR

Monday, June 5		
Excursions		
Morning	Start at 09:00 End at about 11:00	European Spallation Source (ESS), in Lund https://europeanspallationsource.se/
		Emergency preparedness lab at the Medical Radiation Physics group, Lund University, in Malmö https://www.msf-malmo.lu.se/
		Guided tour in medieval Lund including a visit to Lund cathedral, in Lund
		Lund University Bioimaging Center (LBIC), in Lund www.lbic.lu.se
Afternoon	Start at 13:00 End at about 15:00	European Spallation Source (ESS), in Lund https://europeanspallationsource.se/
		Emergency preparedness lab at the Medical Radiation Physics group, Lund University, in Malmö https://www.msf-malmo.lu.se/
		Giuded tour in medieval Lund including a visit to Lund cathedral
		Lund University Bioimaging Center (LBIC), in Lund www.lbic.lu.se
Registration (from 15:00) and Get-Together reception at Malmö Live (@18:00)		

For more information see https://nsfs.org/?page_id=2161 or contact conference@nsfs.org.

NSFS
Nordic Society for Radiation Protection

Tuesday, June 6		
Session 1: Opening and Bo Lindell award *08:30-10:00 Chair: NSFS board*		
08:30	Opening of the Conference	NSFS board
08:40	Bo Lindell award	To be announced
09:20	International Radiation Protection Association, IRPA	Bernard Le Guen IRPA president
10:00	**Coffee and posters**	
Session 2: Nordic cooperation & general RP *10:30-12:00 Chair: Christian Bernhardsson*		
10:30	NSFS history	Jack Valentin & Sören Mattsson
11:00	PIANOFORTE - the European Partnership for Radiation Protection Research	Andrzej Wojcik
11:20	Application of dose constraints: Nordic cooperation concerning shielding of medical facilities	Anja Almén
11:40	Evaluation of Occupational Exposure to Ionizing Radiation, UNSCEAR 2020/2021 Report, Annex D	Peter Hofvander
12:00	**Lunch**	
Session 2: Nordic cooperation & general RP (cont´d) *13:00-13:40 Chair: Eva Forssell-Aronsson*		
13:00	The Radiation Protection Professional's Communication; Expectations, Actual Practice and Further Development	Åsa Ek
13:20	45 years of Nordic cooperation	Hanne N Waltenburg
Session 3: Radon *13:40-14:10 Chair: Eva Forssell-Aronsson*		
13:40	Occupational exposure to radon in Finland	Tuukka Turtiainen
13:55	Indoor radon survey in Greenland and Whitehorse, Canada, and dose assessment	Violeta Hansen
Session 4: Short presentations by organisations and sponsors *14:10-15:00 Chair: Marie Sydoff*		
14:10	Presentations by sponsors and organisations	Sponsors and Swerays, SAINT, NKSSF, SfRB, SFREK, SSFF, SFfR
15:00	**Coffee and posters**	
Session 5: Radiobiology 1 *15:30-16:20 Chair: Siiri-Maria Aallos Ståhl*		
15:30	Importance of better knowledge on radiobiological mechanisms for improvement of radiation protection	Eva Forssell-Aronsson
15:50	The importance of cell death regulation in radiation protection	Johan Spetz
16:05	Radiobiological characteristics of ^{131}I exposure in radiation-induced thyroid cancer after the Chernobyl accident	Anja Schroff
Session 6: Focus session 1 *16:20-17:00 Chair: Hanne Waltenburg*		
16:20	Focus session: AI	
17:00	**Lobby talk**	

Wednesday, June 7		
Session 7: Medical applications 1 *08:00-09:00 Chair: Anja Almén*		
08:00	Cost-benefit analysis – focusing on occupational radiological protection in the healthcare system of Sweden	Andreas Engström
08:15	Considerations for the release of patients after radionuclide therapy	Jukka Liukkonen
08:30	Management of radioactive release and waste from radiopharmaceuticals in Norway	Shawn Christopher Apan
08:45	Lead aprons: to be, or not to be?	Andreas Engström
Session 8: European Spallation Source *09:00-10:00 Chair: Jens Søgaard-Hansen*		
09:00	Source term estimation at the European Spallation Source	Yvonne Hinrichsen
09:15	Accident analysis methods for the European Spallation Source target station	Zsófia Kókai
09:30	Investigation of detection limits for ESS-specific radionuclides	Guillaume Pédehontaa-Hiaa
09:45	Time-dependence and radionuclide contribution to external dose from an accidental release of ESS target products	Christopher Rääf
10:00	**Coffee and posters**	
Session 9: Focus session 2 *10:30-11:15 Chair: Sören Mattsson*		
10:30	Current plans of the ICRP towards a revision of the system of radiological protection	Werner Rühm ICRP chair
11:00	Comments on the new system & general discussion from audience	
Session 10: Environmental monitoring *11:15-12:00 Chair: Ulrik Kautsky*		
11:15	Radioecological survey of the Kvarntorp area in Sweden	Mats Isaksson
11:30	Environmental Monitoring at Swedish Nuclear facilities - A matter of trust	Karin Aquilonius
12:45	Radiocarbon in the marine environment at Ringhals nuclear power plant	Kristina Eriksson Stenström
12:00	**Lunch**	
Session 11: Radioecology *13:00-13:45 Chair: Christopher Rääf*		
13:00	Radionuclides and stable elements in algae from Swedish coastal waters during a period of 55 years	Sören Mattsson
13:15	Radiological implications of ^{210}Po in seafood consumed in Sweden	Francisco Piñero García
13:30	Determination of ^{137}Cs and ^{90}Sr in wood and wood ash purchased in Austria	Viktoria Grill
Session 12: Short presentations of posters and by sponsors *13:45-15:30 Chair: Klara Insulander Björk*		
13:45	Rapid poster presentations	
15:30	**Coffee, poster viewing and meeting sponsors and organizations**	
16:30	**NSFS General Assembly**	
19:00	**Conference dinner**	

Thursday, June 8		
Session 13: The R/N situation in Ukraine *08:00-09:20 Chair: Christian Bernhardsson*		
08:00	Ukraine at war - historic perspective with focus on the radiological situation	Vadim Chumak
08:50	Possible consequences in Sweden of nuclear events/explosions in Ukraine	Jan Johansson
Session 14: Emergency preparedness *09:20-10:10 Chair: Andrzej Wojcik, Ann-Sofie Gustafsson*		
09:20	Re-establishing the use of nuclear weapons as a scenario in civilian emergency preparedness and response planning	Øyvind Gjølme Selnæs
09:35	Network of modular and integrated radiation detection systems for radiological and nuclear safety and threats response	Ferdinando Giordano
09:50	Advice to health care and medical treatment bodies on consequences of acute radiation/radionuclear incidents	Jack Valentin
10:10	**Coffee and posters**	
Session 14: Emergency preparedness (cont´d) *10:40-12:00 Chair: Andrzej Wojcik, Ann-Sofie Gustafsson*		
10:40	Establishing an operational preparedness for current nuclear and radiological threats	Kasper Andersson
11:00	Visits from nuclear-powered submarines in Northern Norway	Inger Margrethe Eikelmann
11:15	Measurement of gross alpha and gross beta activities at low alpha-to-beta activity ratios using LSC - a method for emergency preparedness	Karl Norlin
11:30	Calibration of medical gamma cameras for estimation of internal contamination in radiological and nuclear (RN) event emergency preparedness	Martin Hjellström
11:45	Comparing decontamination procedures by mapping kerma rate within Monte Carlo simulated suburban areas affected by radioactive fallout	Marius-Catalin Dinca
12:00	**Lunch**	
Session 15: Radiobiology 2 *13:00-14:00 Chair: Mats Eriksson*		
13:00	Synergism of X-rays and alpha particles on alternative transcript expression and chromosomal aberrations and implications for mixed exposures	Milagrosa Lopez-Riego
13:15	qPCR analysis of peripheral blood lymphocytes exposed to a combination of gammas and neutrons	Tomas Palmqvist
13:30	Radiobiological effects of ^{131}I exposure in the in vivo situation	Anja Schroff
13:45	Long term effects on the thyroid proteome after ^{131}I exposure	Klara Insulander Björk
14:00	**Coffee and posters**	
Session 16: Radiation dose modeling *14:30-15:15 Chair: Per Seltborg*		
14:30	Protracted exposure to ^{134}Cs and ^{137}Cs gives substantial contribution to long-term thyroid dose after nuclear power plant accidents	Robert Wålinder
14:45	Presenting LARCalc: a tool to estimate age and sex-specific Lifetime Attributable Risk after a Nuclear Plant Release	Jonathan Sundström
15:00	Age- and sex-specific cancer risk predictions from some important radionuclides for a Swedish population, using the updated ORNL computation method for chronic exposure	Martin Andersson
Session 17: Focus session 3 *15:15-16:00 Chair: Christopher Rääf*		
15:30	Focus session: SSM competence supply	Per Seltborg
Young RP evening (@16:30)	**Lobby talk (@19:00)**	

Friday, June 9		
Session 18: Environmental radiology *08:10-09:25 Chair: Tone-Mette Sjømoen, Sara Brockstedt*		
08:10	Revisiting external dose rate and ground deposition of Chernobyl fallout in the Gävle region in Sweden	Christopher Rääf
08:25	Modelling redistribution of ^{137}Cs in the Kymijoki watershed, Finland	Emma Nilsson
08:40	Investigating the impact of climate change on radiocesium from moose in Västernorrland and Gävleborg counties, Sweden	Vanda Jakabová
08:55	Radiometrical characterization and comparison of vertical profiles in three pit lakes from Southern Sweden	Juan Mantero
09:10	Naturally occurring radionuclides assessment in the Arctic	Violeta Hansen
Session 19: Decommissioning *09:25-10:10 Chair: Kristina Eriksson Stenström*		
09:25	Final disposal of nuclear waste – status in Sweden	Georg Lindgren
09:40	Hot Cell Decommissioning at the Former Research Center Risø	Marie Lund Traulsen
09:55	Exposure and dose assesssment of future humans and other organisms from the low and intermedial level repository SFR	Ulrik Kautsky
10:10	**Coffee and posters**	
Session 20: Medical applications 2 *10:40-12:10 Chair: Karin Aquilonius, Johan Spetz*		
10:40	IDAC- BioDose, a complete biokinetic and dosimetric software tool designed for nuclear medicine and built on the ICRP computational framework	Martin Andersson
10:55	A Regulatory Perspective in Practice: Radiation Safety in Selective Intravascular Radiotherapy	Jukka Liukkonen
11:10	From Cobalt-60 to megavoltage accelerator based calibrations for radiotherapy dosimetry	Claus E. Andersen
11:25	Radiation Protection in interventional radiology; comparison between dose delivered to patients and dose received by performing physician	Ingunn Løvik
11:40	Characterization of optically stimulated luminescence dosimetry using NaCl pellets in breast radiography applications	Anna Bjerkén
11:55	Assessment of radiation dose and image quality for small animal imaging protocols in micro-CT	Richard T. Deyhle Jr
12:10	**Lunch**	
Session 21: Final session *13:10-14:00*		
13:10	Summary and highlights of the conference	Sören Mattsson & Jack Valentin
13:30	Closing of the Conference	NSFS board

Scientific poster contributions, in alphabetic order of the first author´s name

Posters (Session 12)	
Title of abstract	Authors
Residual learning-based deep network for nuclide identification in gamma-ray spectroscopy	A Helwan, M Eriksson, A Malusek
Internal dose and risk assessment from European Spallation Source releases	B Ramljak, K E Stenström, C Rääf
Assessment of radiological consequences to biota from radioactive discharges from Ringhals nuclear power plant - A comparison of different approaches	C Andersson, Å Henning, E Settervik
Early apoptotic response in kidney after ^{177}Lu-octreotate administration with or without potential radioprotector α1-microglobulin	C Andersson, K Simonsson, E Shubbar, M Gram, K Helou, E Forssell-Aronsson
A new method in mobile gamma spectrometry to determine the distance, shielding and activity of a lost source when searching along a road passing the source	C Rääf , M Jönsson, M Catalin Dinca, R R Finck
Municipality Averaged Uranium Bedrock Concentration Predicts Lung Cancer Incidence in Sweden after Adjustment for Smoking Prevalence	C Rääf, M Tondel, R Wålinder, M Isakssson
Robustness of gene expression signatures as a readout of radiation exposure	E Schüler, J Spetz, J Swanpalmer, E Forssell-Aronsson
Opportunities and limitations with modern radiobiological methods (radiogenomics) for improvement of radiation protection	E Forssell-Aronsson, H Bakr, M Elvborn, N Rassol, A Romiani, A Schroff, T Parris, D Pettersson, K Insulander Björk, K Helou, J Spetz
Estimating releases of ^{137}Cs and ^{210}Po from boreal forest soil and peat in the event of a wildfire	G Pédehontaa-Hiaa, V Malmborg, D Madsen, C Rääf, J Martinsson
Uranium aerosol dissolution in simulated phagolysosomal fluid	I Yusuf, E Hansson, M Eriksson, H B L Pettersson
Experimentally determined concentration factors of radionuclides in marine phytoplankton	K Insulander Björk, R Thomas, S Holgersson, Y Ali, M Isaksson
Can direct alpha spectrometry be used for analysis of radioactive aerosols emitted from the European Spallation Source?	K Eriksson Stenström, G Pédehontaa-Hiaa, B Ramljak, C Rääf
Estimation of external exposure from a ^{137}Cs-deposition on the ground: Influence of type of humanlike reference phantoms used and depth distribution of ^{137}Cs in soil	M Andersson, M Hiller, Ü Ören, C Bernhardsson, S Mattsson
The development of a mobile app to simplify and improve accessibility (for clinical hospital physicists) of ICRP dose data intake of radionuclides in patients, staff and members of the public	M Andersson
Age and sex specific cancer risk estimations for healthy tissues in Swedish patients treated with ^{131}I-iodide for benign thyroid diseases	M Andersson, S Mattsson, E Forssell-Aronsson
S-coefficients for steady state distribution of ^{134}Cs and ^{137}Cs in the human body	M Isaksson, M Tondel, R Wålinder, C Rääf
Influence of biological sex on the biodistribution and biokinetics of ^{131}I (iodide) in mice	M Elvborn, C Andersson, J Spetz, B Langen, E Forssell-Aronsson

Scientific poster contributions and contributions from sponsors and organisations, in alphabetic order of the first author´s name

Posters (Session 12)	
Title of abstract	Authors
Radioactive material in Consumer Products	N Boesen, H Hannesson
Proteomic response in thyroid from mice early after ^{131}I exposure	N Rudqvist, J Spetz, E Schüler, T Z Parris, B Langen, C Sihlbom, K Helou, E Forssell-Aronsson
Evaluation of RBP4 as urinary biomarker for kidney injury and A1M as kidney radioprotector after administration of ^{177}Lu-octreotate	N Rassol, C Andersson, D Pettersson, A Al-Awar, H Bakr, K Helou, M Gram, E Forssell-Aronsson
Degree of intra-, and inter-individual variability for the risk of developing second malignant neoplasms after radiotherapy for cancer	P Kumar Meher, M Płódowska, H Lisowska, A Wegierek, J Braziewicz, A Baeyens, A Vral, A
Economic aspects of decontamination after a radiological accident	R Javida, M Isaksson, R R Finck, C Rääf
Some historical incidents with nuclear submarines along the Norwegian coast	S A Fagerjord
^{137}Cs and isotopic ratios of Pu and U in lichen and moss from Russian Arctic areas sampled in the 1990s	S Salminen-Paatero, P Dutheil, T Sundström, I Rodushkin, A-P Leppänen, J Paatero
Abstracts by sponsors and organisations (Session 4)	
The current NKS program: some new R&D developments	K Andersson, S M Magnússon, F Physant (NKS)
Radon Exposure in Swedish Workplaces	T Rönnqvist (Radonova)
Swedish Society for Radioecology	C Bernhardsson, M Gårdestig, R Thomas, U Kautsky, K Aquilonius, M Lanz, M Jönsson (SFREK)
Swedish academic initiative for radiation sciences and nuclear technology	C Rääf, M Andersson (SAINT)
The Swedish Radiobiological Society	C Ceberg, P Bernhard, M Granström, Siamak Haghdoost, K Sjögreen Gleisner, B Stenerlöw, T Tran, K Viktorsson, A Wojcik, L Lundholm (SFfRB)
The Royal Swedish Academy of Sciences National committee for Radiation Protection Research	M Eriksson (NKSSF)
SWE-RAYS: Illuminating the Path for Young Radiation Researchers in Sweden	N Rassol, F Westerbergh, M Hjellström, N Boroumand, M López Riego, T Mohajershojai, M Elvborn (SWE-RAYS)
Swedish Society of Radiation Physics (SFfR) – a force for a stimulating exchange of experiences and knowledge in the field of radiation physics	Å Palm (SFfR)

International Radiation Protection Association activities

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ABSTRACT

The primary objective of IRPA is to provide a medium to promote co-operation for the protection of people and the environment from ionizing and non-ionizing radiation. Several Priorities for the current Term has been established. One of them is to contribute practitioners' perspectives to the review and revision of the System of Radiological Protection by Coordinating IRPA efforts through the IRPA Task Group on Review of the System of Radiological Protection.The goal is to inform Associate Societies (AS) about the ICRP initiative on the revision of the System of Radiological Protection that will lead to new General Recommendations, encouraging them to organize feedback through IRPA and independently, and consolidating views reflecting areas of broad consensus and the spectrum of views of the profession. IRPA's consultation has resulted in feedback from 17 Associated Societies, so representative of over 20 different countries across different regions. This feedback has given a very clear picture of what RP practitioners see as priority areas for review. Underpinning all of these is a desire for simplicity and no unnecessary changes to the current System. The key priority area is tolerability & reasonableness which ties in with the impact of uncertainties, particularly at low dose and a holistic approach to optimization.
Another IRPA priorities is to promote sustainability and excellence for the radiation protection profession by promoting young professionals particularly through the IRPA Young Generation Network, by developing professional guidance on radiation protection topics such as NORM through a specific IRPA TG . IRPA is an inclusive and collaborative organisation by engaging with radiation protection practitioners outside existing Societies, promoting a gender balance in Radiation Protection. The objective of this new TG on Women in Radiation (WiR) is to promote a wide exchange of experiences and values for a gender perspective in RP within IRPA. These elements will permit to evaluate the real opportunities, roles and mandates that are exercised in the workplace in different countries to promote and trigger actions with a view to equal opportunities.
IRPA encourage deeper engagement with the public on radiation protection issues, including risk communication, by Continuing the IRPA Task Group on Public Understanding and developing radiation safety culture in healthcare through an IRPA Task Group. The new approach of this TG is to publicise the IAEA/IOMP/IRPA/WHO document to AS, to encourage local adaption of the RS culture framework and tools provided, to assess the impact of local initiatives to improve RS Culture in Healthcare and to provide a forum for sharing experiences of implementation & further guidance as necessary.

Keywords: IRPA Priorities, System of Radiological Protection , Radiation Safety Culture, healthcare, NORM, gender balance

Nordic Society for Radiation Protection
An important forum for radiation protection

Jack **Valentin**[1*] and Sören **Mattsson**[2]

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ABSTRACT

The Nordic Society for Radiation Protection (NSFS) was founded on June 10, 1964 at the initiative of Rolf Sievert, who was then the head of SSI, the Swedish Radiation Protection Authority. It has the task of activating the exchange of knowledge and experience in the Nordic countries regarding protection against ionizing and non-ionizing radiation, both in terms of occupational exposures, exposures of patients for diagnostic or therapeutic purposes and exposures of members of the public. The presentation will highlight some instances when NSFS contributed to important developments in radiological protection. Right from the start, the society included members from all the five Nordic countries and in the same year the society became a (founding) member of IRPA, the International Radiation Protection Association. The first regular meeting was held in 1966. Since then, regular meetings with conferences have been organized at three-year intervals, in turn in each of the Nordic countries (more recently, 4-year intervals so as to facilitate co-ordination with the 4-yearly IRPA Congresses and the 4-yearly European Regional IRPA Congresses (the third of which was organised by NSFS and held in Helsinki in 2010). The current meeting in Malmö will be number 19 in the series. In addition to these meetings, the arranged or co-arranged themed meetings for example around "Radon" 1980, 'Radiological protection in nuclear installations', 1985 and "Quality in radiation protection work", 2004. The meetings of the Society have been characterized by a familiar and good collaborative climate and been a boost to radiation protection and also an important forum for transfer of skills between generations. The activities have stimulated Nordic co-operation regarding nuclear safety research, nuclear waste, radioecology, medical radiology and clinical physics as well as joint Nordic postgraduate courses. NSFS has every reason to be proud of the way it has lived up to the IRPA motto of being the international voice of the RP profession.
There will also be a discussion about future possibilities and reasons for continued co-operation.

Keywords: NSFS, IRPA, Nordic co-operation, radiological protection.

PIANOFORTE - the European Partnership for Radiation Protection Research

Jean-Christophe **Gariel**[1], Radia **Tamarat**[1], Florian **Rauser**[2], Mandy **Birschwilks**[2], Filip **Vanhavere**[3], Andrzej **Wojcik**[*4] Anne **von Euler**[4], Simon **Bouffler**[5], Elizabeth **Ainsbury**[5], Marie **Davidkova**[6], Jolanta **Drozdz**[7], Hanna **Sroczynska**[7], Christoph **Hoeschen**[8]

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ABSTRACT

PIANOFORTE is a 5 year, co-funded EU Partnership bringing together 58 partners representing 22 EU countries as well as the United Kingdom and Norway (https://pianoforte-partnership.eu). It is coordinated by the French Institute for Radiation Protection and Nuclear Safety (IRSN). It started in May 2022 with the aim to improve the protection of the public, workers, patients and the environment from environmental, occupational and medical exposure to ionizing radiation. To this end PIANOFORTE will organize three open calls for research projects on topics identified by the 6 European radiation platforms (www.meenas.eu) and consulted with a board of stakeholders. The total budget for the three calls coming in 2023, 2024, 2025 is 34 M€, with a co-fund rate by the EU of 63%. Moreover, PIANOFORTE has a budget of 0.9 M€ for education and training activities focused on early career scientists that include support of mobility programmes and training courses. Support of European radiation research infrastructures is also included in the budget. Through the research activities that will be carried out within its framework, PIANOFORTE will contribute to the implementation of European policies such as the European plan to combat cancer, the green pact for growth, and the implementation of the roadmap for reducing industrial and natural risks. Project details including the content of project calls will be presented and discussed.

This partnership has received funding from the European Union's "EURATOM" research and innovation program under the 101061037 grant agreement.

Keywords: Radiation protection, European partnership, EURATOM, PIANOFORTE

Application of dose constraints: Nordic cooperation concerning shielding of medical facilities

Anja **Almén**[1*], Peter **Kaidin Frederiksen**[2], Jónína **Guðjónsdóttir**[3], Atte **Lajunen**[4] and Kristine **Wikan**[5]

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ABSTRACT

Dose constraints were introduced into the ICRP radiation protection system as a tool to optimize radiation protection. Dose constraints have been adopted in international radiation protection standards was well as the European Radiation Protection Directive necessitating implementation into national legislation in EU countries. In some countries, the concept of dose constraints is included in the legal requirements, for example for structural radiation shielding on premises. Knowledge of the application of dose constraints is important both for the national authorities and for the facilities that apply them.

Following the initiative of the Nordic Group on Medical Applications, a working group was formed to discuss application of dose constraints in general and, if possible, develop guidelines for shielding. A lack of consistency in the current recommendations of lead equivalencies by the Nordic authorities was also identified as an item for discussion.

The application of dose constraints in the legal framework differs between Nordic countries, some do not apply dose constraints as such but do apply similar concepts. In some cases, dose constraints have been set for the general public and other values for workers working in the facilities. This makes it difficult to give Nordic recommendations on radiation shielding. However, a general framework for the application of dose constraints was derived. Different input parameters were used to study how these affected the need for shielding for dental intraoral radiography facilities. Furthermore, common guidelines for lead equivalencies were derived.

This presentation will discuss the application of dose constraints and more specifically shielding for dental intraoral radiography facilities and the assessment of lead equivalence.

Keywords: dose constraints, optimization, shielding, ICRP

Evaluation of Occupational Exposure to Ionizing Radiation, UNSCEAR 2020/2021 Report, Annex D

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ABSTRACT

This presentation provides an overview of the content of the report Evaluation of occupational exposure to ionizing radiation, which is the annex D of the UNSCEAR 2020/2021 report, published in September 2022. UNSCEAR has been collecting and evaluating sources and levels of occupational exposure since 1975 and this evaluation include assessments of individual and collective doses to workers and estimates of worldwide levels of occupational exposure for the time period between 2003 and 2014. The report also include analysis of exposure trends. As in previous reports the evaluation is done for different work sectors and subsectors involving exposure to natural and human-made sources. The results are presented as annual averages over five-year periods and for the first time uncertainties is addressed. Data for the evalutation has been collected through UNSCEAR Global Survey of Occupational Radiation Exposure, from peer-reviewed literature and from different international organizations. For exposure to natural sources the estimate of worldwide annual number of workers was approximately 12.6 million of which 94% is employed in mining industry. The annual collective effective dose from exposure to natural sources was about 24,300 man Sv, and the average annual effective dose about 2 mSv. No evaluation was conducted for gas and oil extraction and for radon at workplaces, due to lack of data and the figures are most likely underestimated. For human-made sources estimate of the worldwide annual number of workers was about 11.4 million, the collective effective dose about 5,500 man Sv, and the average effective dose about 0.5 mSv. The medical sector dominate and account for about 80% of the workforce and 75% of the collective dose. Worldwide, the estimates for the period 2010-2014 are as follows: annual number of workers approximately 24 million and the average annual effective dose about 1.2 mSv.

Keywords: occupational exposure, ionizing radiation, effective dose, worker

The Radiation Protection Professional's Communication; Expectations, Actual Practice and Further Development

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ABSTRACT

Radiation protection professionals are engaged in risk communication with various stakeholders to contribute to risk awareness, trust building, informed risk decisions, and advice for action. The newly launched IRPA guideline on risk communication has the objective to enthuse communication on radiation protection and provide experiences and techniques regarding this task. However, radiation protection communication has always been an important task for the professionals, but the guideline is a sign of a move forward in the development of communication practices. Radiation protection professionals exist in various organizational contexts and communication goals and practices has evolved in these contexts. The aim of this qualitative research study is to contribute to increased knowledge on professionals' current communication strategies and practices and make recommendations for possible development. Qualitative interviews with radiation protection professionals was conducted in three contexts: an authority, a university hospital, and a municipal rescue service. The interview focuses on issues such as the radiation protection professionals' views on communication and their own role; their developed communication strategies, approaches, and solutions; what kind of support they have for the communication task in their organizations; as well as opportunities for development. Based on the interview results the study identifies communication approaches and practices that seem to be important to the interviewees and how certain practice is supported by their organisation and how it, taken together, results in implicit communication strategies. The study also identifies areas or aspects in communication that can be further developed. The IRPA guide can contribute to increased awareness of risk communication in practice as well as to the discussion about risk communication in the community. The current study results may contribute to deepening the discussion.

Keywords: risk communication, radiation protection professional, organization, communication approach, communication strategies

45 years of Nordic cooperation

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ABSTRACT

The Nordic Group on Medical Applications (NGMA) is part of the cooperation between the Nordic Radiation Protection Authorities. Since 1978, NGMA has addressed common challenges within radiation protection issues related to medical exposures, and has sought solutions through common projects and discussions. In the beginning, the focus was on x-ray diagnostics and interventional radiology, while in the last 15 years radiotherapy and nuclear medicine has also increasingly been in the scope of the work. As all five Nordic countries are relatively small countries, pooling ressources is a great advantage. One challenge in smaller countries is having sufficient amounts of data for setting diagnostic reference levels (DRLs), and several projects within this area have been carried out. Most recently, common DRLs have been established for pediatric conventional x-ray and CT examinations, and the results in terms of DRLs for weight/age groups as well as DRL curves have been published in peer reviewed journals. Setting DRLs for pediatric examinations is particularly difficult for smaller countries due to the lower number of examinations as well as larger spread in patient size compared to adults. Another area that has been in focus recently is the use of dose constraints, in relation to shielding of facilities as well as to release of patients after radionuclide treatments. Common guidelines in these two fields are planned to be published in the spring of 2023. Another ongoing common project focuses on optimization of imaging in nuclear medicine. In addition to these larger projects, there has recently also been focus on automatic dose registries and safety assessments. Finally, sharing experiences through exchange of inspectors and common inspections has been a focus area over time. Highlights from recent discussions and projects will be presented.

Keywords: Radiation protection, Medical applications, Cooperation

Occupational exposure to radon in Finland

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ABSTRACT

In Finland, the reference value for radon in the workplace is 300 $Bq \cdot m^{-3}$ and is defined as the annual average radon concentration during working hours. We investigated the exposure of Finnish workers to radon in conventional, above-ground workplaces. We carried out integrated radon measurements at 700 workplaces, over a three-month period and with at least two detectors. We supplemented these measurements with continuous measurements at 334 workplaces, lasting from 1 to 14 weeks. Based on the results, we validated a method for calculating the annual mean radon concentration during working hours based on the integrated measurement and the ventilation correction factor calculated from the continuous measurement. Measurement results were analysed using both deterministic and probabilistic (Monte Carlo) methods, weighting the results by the number of workers in the provinces. The geometric and arithmetic mean of the annual mean radon concentration in conventional, above-ground workplaces was 19 and 33 $Bq \cdot m^{-3}$, respectively. Based on the probabilistic analysis, there are about 34 000 workers in Finland exposed to radon concentrations above the reference value.

Keywords: radon, occupational safety, regulatory control, existing exposure situation, natural radioactivity

Indoor radon survey in Greenland and Whitehorse, Canada, and dose assessment

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ABSTRACT

Indoor radon and its decay products are the primary sources of the population's exposure to background ionizing radiation and one of the leading causes of lung cancer, with a higher risk for smokers due to the synergistic effects of radon decay products and cigarette smoking. In the Arctic and sub-Arctic, winters are longer than at lower latitudes, and people spend more time indoors than in more temperate climate regions. The permafrost acts as an effective radon barrier, reducing indoor radon exposure, but permafrost is now thawing due to climate change, and its effect on indoor radon exposure is unknown. A total of 459 year-long radon measurements in 257 detached and semi-detached residential homes in southwest and south Greenland were carried out and a dose assessment was performed. A community-driven long-term radon survey was completed in 232 residential homes in different subdivisions of sub-Arctic Whitehorse, Canada, during the heating season from November to April in 2016 – 2017 and 2017 – 2018. The annual arithmetic and geometric means of indoor radon concentrations were 10.5 ± 0.2 Bq m^{-3} and 8.0 ± 2.3 Bq m^{-3} in Nuuk, 139.0 ± 1.0 Bq m^{-3} and 97.3 ± 2.1 Bq m^{-3} in Narsaq, and 42.1 ± 0.7 Bq m^{-3} and 22.0 ± 3.1 Bq m^{-3} in Qaqortoq. The arithmetic and geometric means of indoor radon activity concentrations in different subdivisions of Whitehorse ranged from 52 ± 0.6 Bq m^{-3} and 37 ± 2.3 Bq m^{-3} in Downtown to 993.0 ± 55.0 Bq m^{-3} and 726.2 ± 2.4 Bq m^{-3} in Wolf Creek. Underlying geology and the glacial surfaces may partly explain these variations in indoor radon concentrations. The estimated annual average dose to adults in Greenland and Whitehorse is higher than the world's average annual effective dose of 1.3 mSv due to inhalation of indoor radon.

Keywords: natural radioactivity, inhalation dose, Arctic, sub-Arctic, house metrics, permafrost thawing

Importance of better knowledge on radiobiological mechanisms for improvement of radiation protection

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ABSTRACT

To enhance radiation protection and radiation risk assessment, a better understanding of radiobiological mechanisms and adverse effects of radiation in an organism is necessary. Classical radiobiology is focussed on radiation induced DNA damage and mutations, as well as effects on cell death and cell cycle. Modern radiobiology also includes e.g. genomic instability, non-targeted effects (e.g., bystander and abscopal effects), effects on chromatin remodelling and epigenetics, regulation of gene and protein expression, protein degradation, effects on inter- and intracellular signalling pathways, adaptive response and hypersensitivity, as well as systemic effects on the organism. At low and moderate doses and dose rates, the main risk is increased cancer incidence, but the actual dose-response relationship is debated. There is also a presumed risk of heritable effects although no direct observations have been reported. Better knowledge of the mechanisms behind possible effects would be most helpful. At higher doses and dose rates, there are also radiation-induced acute, delayed or late effects on various tissues and organs. Better knowledge of the underlying mechanisms could be used for effect reduction and biomarker evaluation. The aim of the presentation is to give an overview of the importance of better knowledge of mechanisms behind radiobiological effects, the challenges in this research and the potential for radiation-related biomarker identification and future improvements for radiation protection. Examples will be given from our own previous and ongoing research, together with examples from the literature.

Keywords: biomarker, biological mechanisms, signalling pathways, non-targeted effects

The importance of cell death regulation in radiation protection

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ABSTRACT

Apoptosis, a form of programmed cell death, is an evolutionarily-conserved pathway that is vital for normal tissue development and homeostasis. Ionizing radiation preferentially induces an apoptotic cell death in cells by damaging ubiquitous cellular components or disrupting essential signaling pathways. However, depending on absorbed dose, cell phenotype, status of components in the apoptosis pathway, cell cycle phase, and inter-cellular heterogeneity of radiation-induced damage, as well as the status of the microenvironment, many other forms of cell death can be induced by ionizing radiation. Examples of other modes of cell death that have been implicated in the response to ionizing radiation are: necrosis, autophagy-dependent cell death, pyroptosis, ferroptosis and mitotic catastrophe. These different forms of cell death have many overlapping components, especially in the initiating phases, leading to crosstalk between different pathways as well as a difficulty in identifying the specific cell death form that is active in each circumstance. This presentation will describe the differences between the different cell death types that can be induced by ionizing radiation, in terms of how the molecular mechanisms differ, which conditions trigger specific forms of cell death, which forms of cell death are the most destructive to the surrounding tissues and the organism at large. Establishing the mode of cell death, which is most likely to occur in different radiation exposure conditions, is of importance in radiation protection, especially considering the possibility of modulating the choice of cell death pathway through pharmacological intervention to force the cells to die through less harmful means.

Keywords: radiation biology; apoptosis, cell death

Radiobiological characteristics of ^{131}I exposure in radiation-induced thyroid cancer after the Chernobyl accident

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ABSTRACT

The Chernobyl nuclear accident resulted in an increase in pediatric thyroid cancer through the environmental release of ^{131}I. Why only children were affected was unclear and much research was conducted to identify the radiobiological mechanisms involved in the development of thyroid cancer after low-dose ^{131}I exposure. A literature review of the post-Chernobyl studies was performed to obtain a general view of the radiobiological effects of ^{131}I exposure in connection with cancer induction. Most studies focused on finding genetic alterations to distinguish naturally occurring sporadic thyroid cancer from radiation-induced post-Chernobyl thyroid cancer and to clarify the molecular mechanisms triggered by ^{131}I. Commonly described alterations were mutation in the *BRAF* gene, as well as rearrangement of the *RET* gene, whereby the later occurred with higher frequency. A higher prevalence of gene rearrangement over mutations was explained as a consequence of double-strand breaks from radiation damage. Both genetic variations also affect the mitogen-activated protein kinase pathway, important for cell division, cell differentiation, and apoptosis. Also, copy number alterations were frequently distributed throughout the genome, whereby amplifications were more prominent than deletions. Recent studies focused on the investigation of gene expression differences and sets of significantly regulated genes were proposed which were unique for each study. It is important to highlight that the commonalities of the studies were low, and the results varied widely depending on age at exposure, age at diagnosis, absorbed dose, and cancer type. The review emphasises that although the carcinogenic potential of low doses of ^{131}I is well established, it is not fully understood yet which radiobiological changes are drivers for cancer induction and that subsequent research is necessary for improving radiation protection and preventing negative effects of ^{131}I exposure.

Keywords: biomarker, *BRAF* gene, *RET* gene, copy number alteration, gene expression

Cost-benefit analysis – focusing on occupational radiological protection in the healthcare system of Sweden

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ABSTRACT

In theory the ALARA principle is straightforward, in practice it can be problematic. A solution that seems "as low as reasonably achievable" to one college seems unreasonable to another. An attempt to work less with personal judgement is to use a decision-aiding technique such as cost-benefit analysis. One of the basic concepts in cost-benefit analysis is the α-value, which represents the monetary value assigned to a unit of collective dose for radiation protection purposes. Numerous examples of α-values have been reported in the literature, but few of them originates from research. In a publication in 2021 we converted values of a statistical life recommended by Swedish authorities into α-values useful for occupational radiological protection, ending up in an interval between $45 and $450 per man-mSv. In this way resources spent on radiological protection will equal other risk domains through society. However, people value risks differently from different risk domains. In an ongoing survey, we give staff exposed to ionizing radiation in the healthcare system a scenario, and ask them about their willingness to pay to avoid a small risk of radiation induced cancer death and about their willingness to get compensated for accepting the same risk. One of the obstacles with using cost-benefit analysis is described by culture theory, where people are divided along two dimensions (the group-dimension and the grid-dimension) ending up in four different "ways of life": hierarchists, egalitarians, individualists, and fatalists. Hierarchists tends to love the concept of cost-benefit analysis, the others not so much. ICRP introduced the concept of cost-benefit analysis for 50 years ago, since then its popularity as a decision-aiding technique has varied over the years. The purpose of the present contribution is to discuss the use of cost-benefit analysis in occupational radiological protection and give examples of our current research in the field.

Keywords: ALARA priniciple, cost-benefit analysis, α-value

Considerations for the release of patients after radionuclide therapy

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ABSTRACT

In the Nordic countries, an increasing number of patients undergo radionuclide therapy. In addition, new radionuclide therapies and new radiopharmaceuticals are continuously being introduced. Release of patients following such therapies prompts consideration of several aspects regarding radiation protection, in particular related to potential exposures of persons in close contact with the patient, e.g. family members, home nurses, chauffeurs and co-workers.

Release of patients after radionuclide therapy has been addressed by international radiation protection organizations, national regulatory authorities and the European Commission. In the framework of the Nordic Group on Medical Applications, a working group performed a survey of regulatory approaches and practices exist for release of patients after radionuclide therapy in the Nordic countries. The working group also addressed the applicability of dose constraints for such situations.

The study surveyed exposure pathways related to release of patients according to particular circumstances and included scenarios for both external and internal exposure, including with regard to management of radioactive waste. Furthermore, the study summarized experiences and identified areas where practical guidance and specific recommendations on this topic may be of relevance in all Nordic countries.
The findings of the working group will be published as a Technical Report in the Nordic Radiation and Nuclear Safety Series.

Keywords: release of patients, exposure scenarios, dose constraints

Management of radioactive release and waste from radiopharmaceuticals in Norway

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ABSTRACT

Use of radiopharmaceuticals for therapy or diagnostics generally leads to production of a wide range of radioactive waste. Hospitals are one of the largest sources of radioactive waste in Norway, only second to the petroleum industry. In the coming years, the use of nuclear medicine is predicted to increase fivefold, which naturally also entails an increase in the amount of radioactive waste produced. For legal and regulatory purposes, radioactive waste is defined as material which no further use is foreseen that contains, or is contaminated with, radionuclides at activity concentrations greater than the clearance levels established by the regulatory body. Generally, discharge containing radioactive matter is regarded to the sewer system as radioactive release and is forbidden by law unless a permit from DSA has been issued.

In this presentation, we wish to show the application procedure and casehandling process behind the issuance of a so-called “permit to pollute” from the Norwegian regulatory body. We will present the legislation we use, which considerations are taken, challenges that arise, solutions for diminishing the waste produced and the responsibilities of the permitee upon being issued such a permit.

Keywords: radiopharmaceuticals, legislation, radioactive waste

Lead aprons: to be, or not to be?

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ABSTRACT

In recent decades we have seen a dramatical decrease in occupational radiation exposure within the healthcare sector and at the same time an increase in the use of radiation protection tools, therefore we ask ourselves – how safe is safe enough? Wearing lead aprons for long periods of time have a subjective component: to balance the effective dose reduction with the extra effort and risk of carrying a heavy load. The purpose of the present study was to investigate staff's willingness to wear lead aprons for long periods of time. In a survey, staff at Skaraborg Hospital in Sweden were asked about discomforts (bothersome warmth, fatigue, ache or pain) associated with wearing lead aprons. They were also asked about their willingness to tolerate radiation dose and their willingness to tolerate an increase of future cancer risk to avoid wearing this radiation protective tool. Of the 245 respondents, 50.8 % reported on bothersome warmth, 35.7 % on fatigue and 25.9 % on ache or pain which they believed were associated with wearing lead aprons. Half of the respondents would tolerate a personal dose equivalent of 0.1 mSv/year to avoid wearing lead aprons, however, only one quarter would tolerate the corresponding increase of future cancer risk (from 43 % to 43.02 %). For the respondents' willingness to tolerate personal dose equivalent to avoid wearing lead aprons, significant differences could be seen between male-physicians and male-nurses and between female-physicians and female-nurses. In conclusion, discomforts associated with wearing lead aprons for long periods of time are problematic for the staff using them. However, even at low levels of exposure of ionizing radiation only a minority of the staff would tolerate the small increase of future cancer risk which would follow from working without them.

Keywords: lead apron, radiation protective apron

Source term estimation at the European Spallation Source

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ABSTRACT

The basic principle of the European Spallation Source is that protons are accelerated by a linear accelerator to collide with a rotating, helium-cooled tungsten target for the purpose of producing neutrons via spallation. These neutrons are further moderated and redirected to various instruments. As a side effect, this process produces a wide range of radionuclides that can get discharged to the air. This includes:

- Activated air from the operation of the accelerator
- Leakage of radioactive gases and tritium diffusion from the target primary cooling system
- Activated air and moisture from leakages from the primary water cooling systems in the monolith and proton beam window vessels that are extracted by the monolith rough vacuum pump system
- Venting of radioactive gases from the radiolysis gas treatment system and the gas-liquid separation tanks as part of the primary water cooling system
- Dust from the cutting and dismantling of the monolith components and release of tritium from stored components in the active cells
- Evaporation of tritiated waste water originating from the different parts of the ESS facility after purification at the radioactive waste treatment facility

The estimation of the source terms is based on Monte Carlo calculations in order to determine the radioactive inventories. The final source terms are then estimated via process calculations using these inventories as a basis. This study does not intend to present detailed numbers, but to give an overview on all factors and assumptions including their conservatism in order to show how they influence the final source terms.

Keywords: Source term, radioactive emissions, spallation

Accident analysis methods for the European Spallation Source target station

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ABSTRACT

The European Spallation Source, ESS, consists of a linear proton accelerator, a target monolith building with a tungsten target, neutron instruments and experimental laboratories. The accelerated protons impinge on the rotating target wheel and initiate spallation reactions, releasing neutrons from tungsten nuclei. During the operational time the structural materials will be activated. In case of temperature increase, due to loss of cooling accident (LOCA) or target rotation failure, radioactive release can occur. The release and its effect on the public representative person has been estimated in different accident scenarios. The inventories were calculated using MCNP6 and CINDER codes. The thermohydraulic estimations have been done using hand-calculations based on textbook formulas. The dose rates were calculated using ESS Doctor, a special tool calculating activity concentrations and doses to workers and to the public, based on accident sequence specifications designed to Target station at ESS.

Keywords: radiation safety, accident analysis, spallation, activation, dose rate

Investigation of detection limits for ESS-specific radionuclides

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ABSTRACT

The European Spallation Source (ESS) is an upcoming neutron research facility under construction near Lund, Sweden. Spallation reactions inside the tungsten target of the facility will produce neutrons but also a wide range of radionuclides as byproducts. Radionuclides will also be produced by activation of air and surrounding materials of the linear accelerator of the facility. Environmental releases of these radionuclides could occur during normal operation, maintenance operations or accidents. The Swedish Radiation Safety Authority (SSM) has established a list of the most dangerous ESS-related radionuclides in term of human absorbed doses after potential major accidents. This list includes, but is not limited to, ^{148}Gd, ^{187}W, ^{172}Hf, ^{182}Ta and ^{178m2}Hf. Through the course of several projects, our research group has investigated which radiometric and non-radiometric analytical techniques would be the most suitable to measure these radionuclides in environmental samples using a combination of simulations, laboratory experiments and surveys of the local environment around the ESS. In this work, we present the main results and conclusions of our studies focusing of the limits of detection for some of the important ESS-related radionuclides when measured by gamma spectroscopy, alpha spectroscopy and ICP-MS in soil samples. According to our results, ICP-MS can measure increases in W concentration of soil in the range of a few mg kg^{-1} thus can be considered an appropriate technique to detect environmental contamination by ESS materials. The presence of ESS-related Hf and Ta isotopes in soil would be harder to detect due to their resistance to conventional extraction methods.

Keywords: Environmental monitoring, environmental radioactivity, European Spallation Source

Time-dependence and radionuclide contribution to external dose from an accidental release of ESS target products

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ABSTRACT

The Swedish Radiation Safety Authority has presented a report on severe accident scenarios at the European Spallation Source (ESS) for dimensioning the emergency preparedness zones around the facility. The source-term in the scenario consisted of more than 80 tungsten-target spallation products with a physical half-life ($T_{½}$) exceeding 1 hour. In analogy with accidents at nuclear power plants, where the fission product Cs-137 is a key nuclide for estimating projected external doses to affected residents, a similar key nuclide for relating the corresponding doses from an accidental ESS fallout is useful for the emergency preparedness. This nuclide should i) be a gamma emitter readily detectable by in-situ gamma spectrometry, with ii) a high enough $T_{½}$ to monitor the long-term trend in the external dose rate, and iii) together with progenies contribute substantially to the 50 y projected dose. In terms of 50 y dose from a dry deposition of the released source-term, Lu-172 ($T_{½}$=6.7 d, supported by Hf-172 with $T_{½}$=1.87 y) contributes up to 50% of the 50 y dose, depending on the ecological half-times for the element. The isomer Hf-178n ($T_{½}$=31 y) is the second most contributor to gamma dose, followed by Ta-182 ($T_{½}$=115 d) that contribute with about 15% and 10% of the 50 y dose, respectively. For a final selection of a key nuclide remains an assessment on the detectability of these nuclides by in-situ gamma spectrometry in terms of i) full energy gamma peak integrity (free from perturbations of other peaks) and ii) minimum detectability. Furthermore, to fully understand the time-dependence of external dose from an ESS accident reliable estimates of element specific ecological half-times for Tantalum and Hafnium are imperative.

Keywords: ESS, emergency preparedness, 50 y projected external dose, Ta-182, Hf-172, Hf-178^{n}

Current Plans of the ICRP Towards a Revision of the System of Radiological Protection

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ABSTRACT

Since its foundation in 1928 the ICRP has continuously developed recommendations to contribute to an appropriate 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. The ICRP System of Radiological Protection is based on science, ethics, and experience. Key principles are Justification (any decision that alters the radiation exposure situation should do more good than harm), Optimisation (doses should all be kept as low as reasonably achievable, taking into account economic and societal factor), and Dose Limitation (the total dose to any individual should not exceed the appropriate limits). While the system is robust and applicable and used all over the world, it requires regular review to make sure that it is still up to date and fit for purpose. Recently, ICRP has recently embarked on a review and revision of the System that will update the General Recommendations in ICRP Publication 103 from 2007. This paper informs about the System and describes first steps taken and future plans by the ICRP towards the review and refinement of the System.

Radioecological survey of the Kvarntorp area in Sweden

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ABSTRACT

Due to the lack of imported fuel during World War II, oil was extracted from alum shales and the Kvarntorp site became an important site for mining and processing between 1942 and 1966. The alum shale has an elevated concentration of naturally occurring radioactive materials (NORM), especially uranium, and Kvarntorp is one of the most contaminated areas in Sweden regarding Technologically Enhanced NORM (TENORM). The uranium concentration in the burnt alum shale is high: a few hundred ppm (a few kBq/kg), compared to the world average of about 3 ppm. The distribution and redistribution of NORM, as well as the radiological impact on the environment, has, to the best of our knowledge, not been studied. The aim of this study was to conduct a radiological characterization of the Kvarntorp area by sampling and analyzing soil, plants and water, and to perform dose rate measurements in the area. The activity concentration in samples was determined by alpha and gamma spectrometry, and dose rate maps were constructed from measurements with a mobile system. The activity concentration in shale ash was higher than for other sample types, and about a factor of 2-3 higher than in the soil; while in plant roots, the activity concentration was about ten times lower than in the soil. The water samples showed significantly higher activity concentration of the uranium isotopes in two nearby lakes (former mining pits), although the activity concentration of ^{210}Po was highest at the inlet to the ponds that constitutes a filtration system. The highest measured ambient dose equivalent rate at the pile was 1.8 µSv/h, with a mean ambient dose equivalent rate of 0.7 µSv/h. (Financed by the Swedish radiation safety authority, SSM2019-7854)

Keywords: NORM, TENORM, environmental, survey

Environmental Monitoring at Swedish Nuclear facilities

- A matter of trust

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ABSTRACT

Public trust is an important issue in connection with the upcoming plans for nuclear new build in Sweden. Environmental monitoring of radioactive substances (EMR) close to the nuclear facilities plays an important role in order to gain public trust. The results from the EMR has to be reliable and unquestionable. Until now, the EMR-program has been developed and designed by the competent authority (today SSM), whereas the license holders (LH) have conducted the sampling and measurements. The last extensive revision of the EMR-programs was due in 1994 and since then the programs has been essentially unchanged. Based on EMR experience and with the ambition to increase the LHs competence in environmental matters, the responsibility to design and develop the EMR-program was transferred to the LHs in 2022.

In order to gain trust in the results from the EMR-programs, SSM review and approve the site-specific programs, the annual reporting of EMR and supervise the performance of the LHs. SSM also conduct inter laboratory comparisons with samples from EMR collected by the LHs.

In 2023, an IRRS team from the IAEA questioned the independence of the EMR in Sweden and submitted a recommendation to make provisions for an independent monitoring program. This raises the question about trust and independency. It could be questioned how trustworthy the results are if the LH designs the program, performs the sampling and the measurements. SSM therefore investigates the possibilities to develop a fully independent complementary EMR-program under SSM's auspices.

Keywords: Environmental monitoring, radioactive substances, trust and independency

Radiocarbon in the marine environment at Ringhals nuclear power plant

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ABSTRACT

Carbon-14 (^{14}C) normally dominates the committed effective dose to the public from operational radioactive releases from nuclear power plants (NPPs). Water-borne ^{14}C effluents from NPPs are usually significantly less than releases to air. The latter are currently routinely monitored at the Swedish NPPs, whereas liquid effluents of ^{14}C are not. The dispersion of radionuclides released to the marine environment is however much slower than for releases to the atmosphere, leading to less dilution of the released activity concentration in water than in the atmosphere. We have recently demonstrated that the ^{14}C concentration in marine biota in the vicinity of Ringhals NPP on the Swedish west coast is higher than normally found in the terrestrial environment of such light-water reactors. We have also recently shown that part of the excess ^{14}C in the marine environment of Ringhals NPP stems from long-range transport from foreign reprocessing facilities for spent nuclear fuel. An ongoing project, financed by the Swedish Radiation Safety Authority (SSM2022-4035), further investigates the radioecological behaviour of ^{14}C at Ringhals NPP, by ^{14}C analysis of e.g. algae and marine organisms at various trophic levels. The project also aims to study long-term trends and temporal variations in the marine ^{14}C background. which aims to apportion the anthropogenic ^{14}C on the Swedish west-coast and at Ringhals NPP to the Swedish nuclear power industry and to foreign sources. Analysis of ^{129}I and ^{99}Tc analysis will aid the apportionment of foreign sources of ^{14}C on the Swedish west coast. Recent results from the project will be presented.

Keywords: Radiocarbon, marine environment, Ringhals nuclear power plant

Radionuclides and stable elements in algae from Swedish coastal waters during a period of 55 years

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ABSTRACT

The concentration of radionuclides and stable metals in *Fucus serratus* and *F. vesiculosus*, collected at about fifty locations along the Swedish coasts has been measured. At one location on the west coast, these brown algae have been regularly collected and analysed since 1967. By studying the radionuclide composition over distances and over time it is possible to gain an increased understanding of the amount and transport routes of radionuclide discharges, in risk assessments and in case of emergency situations to provide background levels of relevant radionuclides. The studies show increasing levels of ^{129}I and decrease of ^{137}Cs, ^{99}Tc and $^{239+240}$Pu with time. The ^{14}C analyses indicate an inflow from the North Sea as well as a contribution from Ringhals NPP. Interesting and so far unexplained variations in the ^{7}Be content of *Fucus* have been found. Toxic heavy metals such as lead, cadmium and mercury and metals of interest for assessing transport pathways for radionuclides generated in new radiation facilities, e.g. gadolinium isotopes from the European Spallation Source (ESS) have also been analysed. From 2011 to 2020, levels of lead and nickel doubled and the levels of cadmium and cobalt increased by 50% in *Fucus* from the west-coast. For mercury, a 10-fold decrease was recorded between 2011 and 2016, likely an effect of the phasing out of mercury and then a minor rise in concentration between 2016 and 2020. For gadolinium, a sharp increase of about a factor of 5 was seen from 2011 to 2020, likely explained by the increased use of gadolinium-containing contrast agents in magnetic resonance diagnostics in healthcare. The highest concentrations of Gd were found close to Ringhals NPP.

Keywords: *Fucus*, Sweden, radionuclides, metals, environmental monitoring

Radiological implications of ^{210}Po in seafood consumed in Sweden

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ABSTRACT

Aproximately 40% of Swedes consume seafood at least twice per week, and the Swedish National Food Agency advises to increase that ratio. However, seafood is one of the main exposure route to ^{210}Po, which could have a potential effect on human health, even in very small quantities, due to its high radiotoxicity. Therefore, in order to investigate the radiological implications of ^{210}Po intake via fish and shellfish consumption, a large survey of fresh and processed seafood products consumed in Sweden, was carried. In total, 114 samples, representing 52 different species, were analyzed by alpha spectrometry to determine activity concentration of ^{210}Po.

The range of the activity concentration of ^{210}Po was 0.01 – 26 Bq/kg for fish and 0.1 – 240 Bq/kg for shellfish with an average value of 4 Bq/kg and 18 Bq/kg, respectively. In general, the activity concentration of ^{210}Po in processed products were lower than fresh products, due to the decay of ^{210}Po during processing and storage until consumption. One of the exceptions was the boiled Norway Lobster, with higher concentration of ^{210}Po compared with fresh product. The annual intake of ^{210}Po via seafood consumption increased exponentially by age and was slightly higher in males than females. As a result, the annual committed dose varied between 60 and 150 μSv (average 100 μSv), being controlled by fish consumption below 14 years old and by seafood consumption above 14 years old. The annual committed effective dose could increase up to 480 μSv/y for population groups with higher seafood consumption. In conclusion, in order to minimize the committed effective dose received by seafood, the consumption of suspension feeders, zooplankton feeders and tuna should be reduced.

Keywords: Natural radioactivity, Fish, Shellfish, Alpha spectrometry, Biodistribution.

Determination of ^{137}Cs and ^{90}Sr in wood and wood ash purchased in Austria

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ABSTRACT

The aim of this study was evaluation of public radiological risk from purchases wood fuels in Austria and due to the use of wood ash as a fertilizer in private gardens. The wood fuels analysed were logs, chips, briquettes and pellets. The ^{137}Cs activity concentration in wood fuels (69 samples) and their ashes (27 samples) was determined using gamma spectrometers with high purity germanium detectors. Additionally, 12 ^{90}Sr analyses of ash samples were performed after chemical separation by liquid scintillation counter of Perkin Elmer 1220 Quantulus ™.

The measurements of the wood fuels indicated no necessity for special regulations on wood imported to Austria. ^{137}Cs activity concentration ranges between 0.327±0.077 and 8.36±0.78 Bq kg^{-1} (the arithmetic mean resulted to 2.1 Bq kg^{-1}).

The accumulation of radionuclides in the ash depends on the type of the burned wood fuel. ^{137}Cs activity concentration ranges between 11.80±0.87 and 867±68 Bq kg^{-1} (the arithmetic mean resulted to 310 Bq kg^{-1}); ^{90}Sr activity concentration ranges between 363 ± 53 and 1,200±180 Bq kg^{-1} (the arithmetic mean resulted to 655 Bq kg^{-1}).

The ratios of ^{90}Sr activity concentration and ^{137}Cs activity concentration of the wood fuel or the ash showed a high variability. The ratios depend, inter alia, on the used tree part, the species and the origin. Therefore, the ^{137}Cs activity concentration is no indicator of the ^{90}Sr activity concentration.

The dose assessment for a member of the public using the highest concentrations of ^{137}Cs and ^{90}Sr measured in this study results in a calculated dose of 0.193±0.028 mSv per year. The main part of the dose arises from the ingestion of locally produced foods fertilized with pellet ash.

Summarising, no significant implication from ash from wood fuels purchases in Austria are expected unless significant amounts of contaminated ashes are used for fertilisation.

Keywords: Cs-137, Sr-90, wood fuels, wood ash, dose

UKRAINE at war – Historical perspectives with focus on the radiological situations

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ABSTRACT

Ukraine is located in the Eastern part of Europe, a country with a pre-war (2014) population of about 45 million and a land area of 603,628 km^2 (largest in mainland Europe). Ukraine possesses radiation technologies in all application areas, except of military, such as medicine, industry, nuclear power and nuclear fuel cycle, research. The world's third largest nuclear arsenal was given up in 1994 under the provision of the Budapest memorandum against guaranties from nuclear states including Russian Federation. Today in Ukraine, there are 15 reactors at 4 nuclear power plants (NPPs), which produce >50% of electricity. Chornobyl NPP is at decommissioning stage and, along with the unique New Safe Confinement over the destroyed Unit 4, is under constant supervision of Ukrainian professionals. In Ukraine activities continue in all areas related to radiation protection and safety, especially within various applications in medicine, industry, research, education, as well as handling spent nuclear fuel. According to the national registry of sources (2020) there are 25,248 radiation sources (RS), in particular – 8,728 sealed isotopic sources and 16,520 generators, that are operated by 4,531 users of RS (74% - medical use), of whom 549 use sealed isotopic sources.

Since 2014 Ukraine experiensed undeclared hybrid war with Russia, which began with annexation of Crimea by Russia in February 2014 and evolved into a proxy war in Donbass region in the Eastern Ukraine, where parts of Donetsk and Luhansk oblasts of Ukraine are under Russian control since April 2014. On February 24, 2022, the Russian Federation launched a full scale invasion into Ukraine, waging unlimited warfare and attacking sites all over the territory of Ukraine.

The ongoing war includes not only battlefield operations but also bombardment of the peaceful cities and civilian infrastructure (hospitals, living blocks, shopping malls, electric and central heating facilities), causing relocation and displacement of millions of citizens, occupation of

significant territories and demolishment of the populated areas under attack (most known is the city of Mariupol with ca.450 thousand pre-war residents).

Unfortunately, the current war with Russia has much deeper roots than simple unprovoked aggression or madness of a single person. For centuries, if not millennia, the territory of modern Ukraine was a back-door of Western European mainland and experienced military invasions. This is determined by geography as Ukraine lays at the western edge of the Great Steppe – the plains starting as far as Mongolia in the East and not having natural obstacles for movement of pedestrians and riders (infantry or cavalry in military terms). Dnipro river flowing from North to the Black Sea was significant trade waterway between Baltic and Black Sea and Kyiv (capital of the medieval state called Rus) arose as an important hub of trade and military power in X century. The last round of the everlasting history of invasions from the East originates from Mongolian invasion in XIII century which resulted in establishing Moscovia, at that time – part of Golden Horde. At the same time, to-be-Ukrainian population remained the part of European civilization and maintained close connections to the rest of Europe. This development caused fundamental differences between Ukrainian (descendants of Rus) and Russian (ex-Moscovian) populations, traditions, national characters etc. However, official (and to a large extent – invented) history of Russian Empire and modern Russian Federation declares the roots of their statehood and Christian Orthodox religion stemming from Kyiv with implied link to Byzantium and Roman Empire (sic!). Although Ukraine was a part of the Russian Empire and the Soviet Union for more than three centuries, attempts to get rid of imperial rule and oppression (tzarist or communist) had lasted ever. Eventually, it resulted in gaining the independence at the cost of the decay of the USSR in 1991. Unfortunately, Russian imperialistic sentiments and their desire of dominance over ex-colonies, among which Ukraine was one of the most important, inevitably lead to the attempts to re-conquer ‘rebellion provinces’ and re-establish great Russian Empire.

In addition to military, economic and humanitarian aspects of the ongoing war, completely new radiological threats have arisen. The 2022 full scale invasion started by occupation of the Chornobyl exclusion zone with all of its radiologically hazardous facilities inside it - ChNPP and Object “Shelter”/New Safe Confinement over the destroyed reactor #4, radioactive waste storage sites, centralized and local spent fuel facilities, etc. Soon after the beginning of the invasion, the NPP at Zaporizhzhia (the Europe’s largest NPP having six reactors 1 GW electric power each) was occupied and still remains under effective control of Russian military forces and Rosatom administration. That is a new type of terroristic threat towards NPPs that the world did not observe before. A number of industrial facilities that were using radiation sources were partially or completely destroyed (the most known example is Azovstal steel works in Mariupol). In addition,

some hospitals, industrial and research facilities were hit by missile and artillery fire. All those events are associated with the potential risk of radiological incidents or accidents.

The war is far from ending, the situation is changing daily. This talk will present the most recent picture of the associated radiological aspects along with some speculations on potential development and possible threats to public and environment.

Kewords: Ukraine, war, nuclear terrorism, radiolocical, history

Re-establishing the use of nuclear weapons as a scenario in civilian emergency preparedness and response planning

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ABSTRACT

Ever since the development of nuclear weapons in 1945 and their devastating use against the Japanese cities of Hiroshima and Nagasaki the same year, nuclear weapons have been a central part of the global geopolitical situation and everyday life for citizens of most nations of the world. This has also been reflected in civilian emergency preparedness and response planning throughout the cold war. After 1991, both policy makers and academics have considered the risk of use of nuclear weapons and nuclear war in Northern Europe to be decreasing, and contingencies towards use of nuclear weapons have been less emphasized in civilian emergency preparedness and response planning, at least in the Nordic countries. Today, the development in the international security environment, development in nuclear weapon technologies and designs etc. have made several nations again consider the possibility of nuclear weapons being used. In the Nordic countries, many civilian authorities, policy makers and academics are once more considering scenarios with use of nuclear weapons in or in the proximity of Nordic countries. In Norway, we have recently developed such a planning scenario. During the ongoing war in Ukraine, international statements and rhetoric have made the use of tactical nuclear weapons in relation to the war a more foreseeable scenario. Nuclear weapons are weapons of mass destruction, and even the use of weapons in the 1-10 kt range will have devastating consequences. When the use of nuclear weapons are re-established as a planning scenario for civilian emergency preparedness and response, it is important to build a realistic scenario which give added value to the further development of national emergency preparedness and response, and to identify how emergency response capabilities best can be improved. Emergency preparedness synergies between use of nuclear weapons and other nuclear event scenarios should be utilized as much as possible.

Keywords: national emergency preparedness and response, nuclear weapons, scenarios

Network of Modular and Integrated Radiation Detection Systems for Radiological and Nuclear Safety and Threats Response

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ABSTRACT

Increased sensitivity to nuclear safety and security issues has prompted public entities and private institutions to maximize their ability to quickly assess risks and to intervene in the event of an accident or incident. Rapid intervention and response are achieved through nuclear measurements via airborne, ground, and underwater systems that can be effortlessly deployed, remotely controlled, and easily maintained. Current systems often consist of detectors and monitoring devices, never designed to work together. The result is a quantity data arriving from incompatible devices and detectors that need to be integrated and analyzed. This process wastes valuable time that could otherwise be spent on response and mitigation. A network of cohesive, well-integrated and easy deployable detection systems combined with real-time fusion and analysis of critical data is essential to facilitate and enhance decision-making process during these critical times, improving the quality of the management plan. The presented radiation monitoring systems can be integrated in several form factors which depend mainly on operational needs like payload, IP rating and internal battery for autonomous operation. Compact ARM based computers are embedded, which can store large amount of data in their non-volatile memory, run automatic data analysis and trigger alarms in case of exceeding radiation levels. All the systems can communicate with redundant interfaces in failover configuration and upload the acquired environmental information in a central database. The same monitoring systems can alert the emergency response personnel on the field as well, through wireless connection to common tablets or cellphone or SMS, guaranteeing a prompt response in case an illicit transportation of radiological or nuclear material is detected.

Keywords: nuclear accident, nuclear indicent, sensor network.

Advice to health care and medical treatment bodies on consequences of acute radiation/radionuclear incidents

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ABSTRACT

In 2022, the Swedish government instructed the Board of Health and Welfare to further enhance the emergency preparedness. The Russian invasion of Ukraine highlights the issue of health risks due to nuclear accidents and the use of nuclear weapons. The Board of Health and Welfare therefore requested the Swedish Radiation Emergency Medicine Centre to provide a report which could form the basis of a fact sheet with information and advice on preparation for such events to organisations within health care and medical treatment. This was not a trivial task, given the broad range of possible scenarios and the fact that in many scenarios, the demands on health care and medical services would probably be dominated by other strains and stresses than those directly associated with ionising radiation. The fact sheet, issued in December 2022, describes four hypothetical scenarios comprising different levels of medical consequences of exposure to ionising radiation: (1) A radiation incident at a nuclear power plant in Ukraine; (2) Assistance with health care in Sweden for persons exposed to radiation in Ukraine; (3) The 'spectator case' of a nuclear

bomb detonation in, e.g., Ukraine; and (4) A nuclear weapon detonation in Sweden. The characteristics and likely medical consequences of each scenario are described, and a scoring table is provided for initial assessment of patients and suggested level of care. The fact sheet also includes a summary of recommended short- and long-term actions for county councils to take in preparation for a possible nuclear weapons detonation outside Swedish territory. As a scientific basis for our medical advice, we used a Special Issue of the *Journal of Radiological Protection* on 'Medical management after high-dose radiation exposures' which we had initiated, organised, and edited. The overarching theme of the Special Issue is the Acute Radiation Syndrome, but it also discusses the Chronic Radiation Syndrome, the psychological effects, and some aspects of stochastic harm after radiation exposure. We aim to try to persuade the WHO to update on the basis of this Special Issue its advice to national authorities on the management of ARS patients.

Keywords: nuclear installation accidents, nuclear weapons, ARS, emergency preparedness

Establishing an operational preparedness for current nuclear and radiological threats

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ABSTRACT

The two European standard decision support systems, ARGOS and RODOS, are a backbone in Nordic preparedness for managing nuclear power plant accidents. These both contain an elaborate long-term inhabitant dose estmation model, ERMIN, that may be used in planning an optimized recovery strategy. Although the recovery phase as such starts when the incident has been contained and continues until agreed recovery criteria have been met, it is generally highly advantageous to initiate important parts of the recovery work as early as possible. Otherwise, only the expensive, unpopular and less effective options will remain. To avoid this, local planning is necessary in advance of an emergency to enable early action. For example the European Handbook for Assisting in the Management of Contaminated Inhabited Areas in Europe Following a Radiological Emergency describes more than 10 alternative options for reducing the dose contribution from one single type of contaminated surface. So many alternatives are impossible to keep operational, and then nothing will be made operational in advance. Moreover, history has shown that without a monitoring strategy to guide the countermeasure implementation in practice, even the most carefully theoretically optimised countermeasure strategy may result in an irreversible disaster. Expert guidelines for these process are critically needed to secure acceptable results. Also many other updates and planning details are critically needed to make the plans operational and optimised in practice. A complication is that the needs of society for protection change, and with the current situation in Ukraine, a number of scenarios need to be considered, involving for example use of nuclear battlefield weapons and damage of artillery shells or missiles on nuclear power plants. It is discussed with examples how the scenario type would determine key parameters in the decision support systems, and what would be required to run the models for such scenarios.

Keywords: recovery, nuclear, emergency, weapons, decision support, operational preparedness

Visits from nuclear-powered submarines in Northern Norway

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ABSTRACT

The High North is subject to traffic from naval nuclear-powered vessels from several nations. With its increased geopolitical importance, the High North, including the Norwegian Sea and the Arctic Ocean, has seen a considerable increase in the number of vessels operating or being in transit with nuclear propulsion over the last years, both from Russia and from NATO countries. As a NATO member, Norway receives and facilitiates visits from allied nuclear-powered vessels to Norwegian harbours and coastal waters. In Norway, visits from foreign nuclear-powered vessels require a licence according to Norwegian legislation, except for emergency situations. The Norwegian Radiation and Nuclear Safety Authority (DSA) is responsible for giving recommendations on licencing and advice in relation to the visits. In addition, DSA gives advice to and cooperates with local and regional authorities responsible for emergency preparedness. DSA has published a guidance for applications for licences for visits from naval nuclear-powered vessels. DSA is responsible for national nuclear emergency preparedness and heads the national nuclear emergency preparedness organisation. Most of the visits from nuclear-powered vessels to Norway are to coastal waters in the northern part of the country. The only harbour in Norway receiving visits since 2009 has been Haakonsvern Naval Base outside Bergen. In recent years, there has been identified a need for a harbour also in Northern Norway. In 2021, Tromsø industrial harbour Tønsnes (Grøtsund) was pre-approved for receiving visits from naval nuclear-powered submarines. In preparing for the pre-approval, and in connection with each visit, there is a close cooperation between DSA and local and regional civilian emergency preparedness authorities, as well as with the Norwegian Armed Forces. This oral presentation will highlight the requirements and actions taken in order to enable visits from nuclear-powered vessels to the harbour, including environmental monitoring, emergency response plans and preparedness, and communication with the general public.

Keywords: national emergency preparedness and response, nuclear-powered vessels, harbour

Measurement of gross alpha and gross beta activities at low alpha-to-beta activity ratios using LSC - a method for emergency preparedness

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ABSTRACT

A method for the measurement of gross alpha and gross beta activities at low alpha-to-beta activity ratios is presented. Measurement of the gross alpha activity would still be important from an internal dose perspective when the gross beta activity is dominating, since a significant dose contribution may come from alpha emitting radionuclides. The method is intended for screening of drinking water after a radiological emergency when many samples would be valuable to be measured during a short period of time. The work shows that, in contrast to the often used radionuclides ^{241}Am and ^{90}Sr/^{90}Y for calibration, several radionuclides is prominent to use to determine the measurement efficiency and misclassification factors for an unknown sample. Furthermore, the method was adapted to be able to measure low alpha-to-beta activity ratios (0.001-10) with acceptable measurement uncertainties for samples with moderate quench.

Keywords: gross alpha, gross beta, Liquid Scintillation Counting (LSC), misclassification, Pulse Shape Analysis (PSA)

Calibration of medical gamma cameras for estimation of internal contamination in raidiological and nuclear (RN) event emergency preparedness

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ABSTRACT

A radiological or nuclear (RN) event, like the Goiânia accident in Brazil 1987 or the Chernobyl accident 1986, might result in an extensive quantity of internally contaminated members of the public. Following such event, the availability of equipment for estimation of possible internal contamination, and personnel with the expertise to use them, is of great importance. As a result of the ongoing war in Ukraine, there has been an increased concern regarding the risk of an RN event, actualizing the need of increased measurement capability for internal contamination, giving the objective of this study.The aim of this study was to increase the measurement capability in Sweden by calibrating several medical gamma camera units, which are routinely used in the field of nuclear medicine, for the RN event relevant radionuclide ^{137}Cs. A simple water phantom containing ^{137}Cs was constructed, resembling a human body, and transported to numerous hospitals in the south region of Sweden and used for calibration of medical gamma cameras for estimation of internal contamination, based on methods published by the authors. The results show that generic calibration factors, based on the crystal thickness of the gamma camera, can be determined for radiation protection purposes for assessment of internal contamination. These factors can be used on other gamma cameras of similar models to make estimations of internal contamination. However, these calibration factors can only be used for accurate activity estimations if a person is only contaminated with ^{137}Cs, since whole-spectrum analysis is used. Even though the crystal thickness in medical gamma cameras is not optimized for higher energies emitted from e.g. ^{137}Cs, the minimum detactable activities for the whole-spectrum analysis showed that committed effective doses down to a few μSv can be estimated.

Keywords: Gamma camera, RN event, radiological and nuclear event, internal contamination

Comparing decontamination procedures by mapping kerma rate within Monte Carlo simulated suburban areas affected by radioactive fallout

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ABSTRACT

After a radioactive fallout, large, inhabited areas will be contaminated with radionuclides leading to severe radiological consequences. External gamma irradiation is a significant contribution to radiation exposure of the inhabitants over long-term. To evaluate the level of contamination and risk dose estimates, either by measurements in the affected neighborhood, or by modelling, is necessary. For this purpose, we used Geant4, a Monte Carlo simulation tool, to model the transport of the photons resulting from displaced gamma emitters in a Swedish suburban neighborhood. The goal is to register the kerma rate in specific points of interest (referred to as scorers) under different contamination conditions. Planar sources of ^{134}Cs and ^{137}Cs are placed in the surrounding areas of the houses at different depths within the soil and on the roofs. Decontamination scenarios are then simulated to evaluate their effectiveness in terms of dose or surface contamination reduction factor. Due to the modular aspect of the chosen simulation toolkit, a detailed assessment of the external dose contribution of specific contamination surfaces (e.g. roof) to the local scorers is achieved. The presentation will cover details about the used methodology and the obtained results, including future developments and the limitations of the technique.

Keywords: Geant4, Monte Carlo, kerma rate, fallout contamination.

Synergism of X-rays and alpha particles on alternative transcript expression and chromosomal aberrations and implications for mixed exposures

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ABSTRACT

Ionizing radiation exposures often involve particles with different linear energy transfer (LET), as occurs in nature, medical and occupational scenarios, and as predicted for an improvised nuclear device detonation. Beyond low Earth orbit, astronauts primarily encounter galactic cosmic rays and solar particle events, i.e. protons, but also neutrons and photons produced within the spacecraft. The dose relating to the space permissible exposure limit, whereby the risk of exposure-induced death may not exceed 3% as established by NASA, is calculated by multiplying organ-specific absorbed doses by a radiation-type specific quality factor Q derived from Monte Carlo simulations. These do not consider the relative biological effectiveness resulting from the possible interaction of high LET charged particles with low LET photons, increasing the uncertainty of space radiation risk estimates. Here, blood from two healthy male donors, previously shown to differ in their gene expression response to mixed beams of X-rays and alpha particles (1:1), was drawn in triplicate at three different time points. Blood samples were exposed to 0-2 Gy of X-rays, alpha particles or combination (1:1) to investigate the mixed beam effect and the stability of the response on alternative transcripts of radiation responsive genes *FDXR*, *CDKN1A* and *MDM2* by qRT-PCR, and on chromosomal aberration frequency by standard cytogenetic procedure. A synergistic interaction of alpha particles and X-rays was detected in both donors for chromosomal aberrations, although more prominent in one donor, consistent with transcription results of the highest induced *FDXR* variants, where the mixed beam effect was donor- and alternative-transcript-dependent. Both individuals presented similar chromosomal aberration dose responses and overall comparable gene expression responses despite seasonal variability. This data spread tended to be larger interseasonally than intraseasonally and presented a consistent LET-dependency, lowest for alpha particles, followed by mixed beams, and largest for X-rays, contributed by differential expression of *FDXR* transcripts.

Keywords: alternative transcripts, mixed beams, lymphocytes, chromosomal aberrations, interindividual variability.

qPCR analysis of peripheral blood lymphocytes exposed to a combination of gammas and neutrons

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ABSTRACT

A complex mix of high and low linear energy transfer (LET) radiation will emerge in the event of a nuclear weapon detonation. In this scenario, it is of high interest to perform retrospective exposure dose estimates for affected individuals by studying the gene expression response with quantitative Polymerase Chain Reaction (qPCR). Therefore, this study aimed to use qPCR as a complementary technique to the well-established dicentric chromosome assay, as a platform to identify genes, and their radiosensitivity for gamma and/or neutron radiation. The following genes were studied: BBC3, FDXR, MDM2, CDKN1A, GADD45A, and XPC. Blood from three donors was exposed to 0.5 - 1 Gy total dose from two mixed beams exposure setups, where half the total dose was delivered with neutrons first followed by gammas, or vice versa. Samples were also irradiated with only neutrons or gammas. Given the dose range, the study is relevant for triage purposes, whereby those that might require acute medical attention are identified and prioritized following a nuclear incident. The experiment was carried out in collaboration with PTB in Braunschweig, Germany. The results showed varying radiosensitivity in terms of fold change. Despite large standard deviations, statistical significance with respect to the radiation exposure setups was observed at 0.75 Gy for BBC3 and GADD45A. Observations through statistical methods such as the ANOVA and regression tests showed no significance for CDKN1A and MDM2 between 0.5 and 1 Gy. Generally, the fold change with significant regression could be seen in FDXR, BBC3, and XPC with accompanied high-LET neutron radiation. The present work shows the potential of qPCR as a technique to be used for quick assessment of the radiation exposure following a nuclear attack or accident in situations where the dose exposure originates from mixed radiation qualities.

Keywords: qPCR, biodosimetry, LET, neutrons

Radiobiological effects of ^{131}I exposure in the *in vivo* situation

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ABSTRACT

^{131}I laid the foundation for nuclear medicine and has now been used to treat thyroid diseases and cancer for nearly a century. Also, after the Chernobyl accident iodine gained prominence, and was responsible for an increase in pediatric thyroid cancer. The radiobiological mechanisms behind these findings were largely unknown and, consequently, a large effort has been undertaken to understand the induction of thyroid cancer after ^{131}I exposure. A literature review was conducted to examine the current state of knowledge gained from controlled *in vivo* studies regarding the molecular mechanisms triggered by ^{131}I exposure and how associated changes might contribute to cancer development. Focus was laid on gene and protein expression changes, combined with pathway analysis and Gene Ontology (GO) terms. Effects on the expression level were detected both early and late after exposure, but no time-related trend was found. The number of significantly regulated genes/proteins was highest after a low absorbed dose (0.01-0.1 Gy) and decreased with increasing dose. Interestingly, more significantly regulated genes/proteins were found in adult compared to young rats, but young rats demonstrated more affected signaling pathways. Further, several identified genes/proteins were previously associated with thyroid disorders or cancer. GO term analysis revealed an influence on all basic biological functions with metabolism being the most affected. It is important to emphasize that most studies could not confirm previously proposed biomarkers and the results varied widely between studies. Especially, the factors age at exposure, time at exposure, time after exposure, and absorbed dose seem to crucially affect the outcome. The review highlights that although ^{131}I has been in use for a long time, many questions about its radiobiological effects remain open. Further research is needed to provide a solid scientific basis for improved radiation protection and effective treatment of the adverse effects of ^{131}I exposure.

Keywords: biomarker, thyroid cancer, gene expression, protein expression, GO terms

Long term effects on the thyroid proteome after ^{131}I exposure

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ABSTRACT

The radioactive iodine isotope ^{131}I is well known, both for its role in nuclear medicine, and for inducing a rise in paediatric thyroid cancer after the Chornobyl accident in 1986. The detailed radiobiological mechanisms behind thyroid cancer induction, and ^{131}I effects on the thyroid in general, are not well known to date. Hence the precise reason why thyroid cancer was induced in children but not to any detectable extent in adults after the Chornobyl accident, remains unknown. We seek to investigate the matter by studying the biological processes in vivo. In the present study, Mice were injected with 1 kBq or 100 kBq ^{131}I, and sacrificed after 48 hours, three weeks or five months. Corresponding controls received saline solution. Thyroids were excised, and DNA, RNA and proteins extracted. The proteins were analysed using tandem mass spectrometry at Proteomics Core Facility at the University of Gothenburg. For mice exposed to 1 kBq ^{131}I, few proteins were found to be differentially expressed compared with controls at any time point. For mice exposed to 100 kBq ^{131}I, the number of differentially expressed proteins were highest at the last time-point. The proteins are involved in, e.g., DNA DSB repair, p53 signalling, transcription regulation and amino acid metabolism. The most striking result is that the long term response seems to be stronger than the short- and medium term response.

Keywords: ^{131}I, iodine, thyroid, proteomics

Protracted exposure to ^{134}Cs and ^{137}Cs gives substantial contribution to long-term thyroid dose after nuclear power plant accidents

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ABSTRACT

Thyroid dose estimations after nuclear power plant accidents are traditionally based on internal uptake of radioiodine, mainly ^{131}I, either by instrumental measurements of thyroid uptake or by ecological estimations based on geographical dispersion of the radioiodine cloud, demographics and food habits. However, it has been shown that ^{134}Cs and ^{137}Cs in some cases can be the dominant contributors to the thyroid dose over long-term following nuclear power plant accidents.

Based on an ecological model using Swedish specific parameters of the radioactive fallout from the Chernobyl accident in 1986, estimations of the protracted (30 years) thyroid dose were made for the population in northern Sweden (2.2 million inhabitants in 1986). The internal dose contribution was estimated from both the short-lived nuclides, mainly ^{131}I ($T_{½,phys}$ = 8.1 d), and nuclides with longer half-lives, ^{134}Cs ($T_{½,phys}$ = 2.1 y) and ^{137}Cs ($T_{½,phys}$ = 30.0 y). The external radiation dose to the thyroid was based on air-borne measurements of the ground deposition of ^{137}Cs, combined with correction for shielding from residential buildings and snow cover.

The total absorbed thyroid dose from 1986 to 2015 ranged from 0.1 to 15.5 mGy (mean 2.0 mGy) among subjects in the study population. The calculated mean thyroid dose the first year was 0.7 mGy, where radioiodine accounted for approximately 0.3 mGy. The protracted thyroid dose after 30 years was 0.3 mGy (15%) from ^{131}I, and 1.7 mGy (85%) from internal and external ^{134}Cs and ^{137}Cs taken together. Hence, the estimated mean dose contribution from radiocaesium was higher than for radioiodine (^{131}I) both in the first year and in the consecutive 30 years. Furthermore, the 30-y external dose (1.2 mGy) dominates over the internal dose (0.8 mGy) to the thyroid. This finding is of relevance for low-dose epidemiological studies of thyroid cancer which previously have focused solely on radioiodine.

Keywords: caesium, iodine, thyroid dose

Presenting LARCalc: a tool to estimate age and sex-specific Lifetime Attributable Risk after a Nuclear Plant Release

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ABSTRACT

In the event of a nuclear power plant accident that leads to the emission of radionuclides into the environment, planning for the extent of the radiological impact in advance is crucial. We present LARCalc, a newly developed decision support tool to estimate the radiological consequences of nuclear power plant releases. LARCalc utilizes ^{137}Cs ground deposition in combination with fallout-specific nuclide vectors to estimate the cumulative effective dose, the organ-specific absorbed dose, or the lifetime attributable cancer risk. Additionally, it can estimate the residual dose and the averted cumulative lifetime attributable risk from various protective measures, such as evacuation, food restrictions, and decontamination. The LARCalc tool can also estimate collective doses and the increase incidence in the number of cancers in populations. It provides a visualization of the radiological impact of nuclear power plant releases and the effects of different countermeasures. The radiation dose models used by LARCalc are based on previously published works and methods for dose calculation based on ground depositions. These include the pathways groundshine, cloudshine, inhalation, and ingestion of caesium, iodine, and strontium through foodstuffs. LARCalc is intended to be a rapid alternative for the planning of protective measures for an emergency and can clearly show visually how the dose or risk varies with time, age, gender and countermeasures.

Keywords: CED, CUMLAR, NPP release, fallout, countermeasures

Age- and sex-specific cancer risk predictions from some important radionuclides for a Swedish population, using the updated ORNL computation method for chronic exposure

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ABSTRACT
Radiation dosimetry and cancer risk estimations are central to virtually all radiation safety applications, optimization, and research. These estimates relate to various individuals and population groups and to miscellaneous exposure situations including planned, existing, and emergency situations. For internal dose estimates, the International Commission on Radiological Protection (ICRP) has developed a new computational framework. Important components are more detailed and improved anatomical and biokinetic models than before. The ICRP framework is based on the calculation of organ specific absorbed dose for a single intake. To expand this to a chronic exposure over a lifetime or during shorter periods, ORNL has developed a computational framework based on the ICRP primary data but including lifetime population-based radiogenic cancer risk estimations involving age- and gender-specific intake rates and organ specific cancer risk models. For external exposure, cancer risks are calculated for radionuclides in air and water, on ground surface and in soil using published organ absorbed dose coefficients for external exposure and applied in the ORNL computational framework for chronic exposure. In the present study, cancer risk coefficients are calculated for the Swedish population for ^{14}C, ^{137}Cs, ^{90}Sr, ^{131}I, and ^{60}Co, for internal exposure through air, food and water and external exposure from air, water, surface and soil. For intake of ^{14}C, the lifetime attributable risk for a chronic lifetime exposure (from 0-110 years of age) is $2.16*10^{-10}$ for inhalation of unspecifiend forms of radioaresoles (type M) of 1 Bq a day, $2.30*10^{-11}$ for drinking 1 Bq a day through water, and $2.74*10^{-11}$ for ingesting 1 Bq a day through food. For external exposure the lifetime attributable risk for a chronic exposure to ^{14}C from 0-110 years is $5.47*10^{-18}$ per m^3/(Bq-s) for submersion in air, $5.76*10^{-18}$ per m^2/(Bq-s) for exposure to contaminated soil surface, and $8.14*10^{-20}$ per kg/(Bq-s) for exposure to soil contaminated to an infinite depth. An advantage of looking at the age and sex specific parameters during a chronic intake for a whole lifetime for general members of the Swedish population is that the same risk estimate applies to an acute exposure to a whole population. The releases of unwanted artificial radionuclides in the environment could have a big impact on society, both locally and globally, and therefore should these estimations be predicted as best as possible.

Keywords: cancer risk, internal exposure, external exposure, Swedish population

Revisiting external dose rate and ground deposition of Chernobyl fallout in the Gävle region in Sweden: Comparison between estimates from soil sampling vs assessments using a field portable (NaI(Tl)) gamma spectrometer

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ABSTRACT

In 2022, a field survey was conducted with the purpose to revisit the ground deposition of Chernobyl ^{137}Cs and the associated ambient dose rate equivalent at previous measuring locations in the Swedish municipalities of Gävle and Älvkarleby. An additional purpose was to compare the ^{137}Cs deposition values as taken from a field portable gamma spectrometer (NaI(Tl)) with the estimates obtained from gamma spectrometry of soil cores sampled at the different measuring locations. The results for 8 separate locations show that the soil sample data tend to exceed the ^{137}Cs deposition values from the field portable NaI(Tl) gamma spectrometer by, on average, 50%. The difference is mainly attributed to the "hot-spot" effects and the ground surface roughness in the locations giving rise to shielding of scattered and primary ^{137}Cs gamma photons. This shielding will give rise to a smaller field of view of the field gamma spectrometer and a lower estimate of average ground deposition in the area than is measured in soil cores samples within a few meters of the position of the gamma spectrometer. Furthermore, for 2 of the locations, data from this survey indicate that the effective ecological half-time of ^{137}Cs attributed ambient equivalent dose rate in the area may range between 10 to 20 y instead of the 5.5 y obtained from a previous assessment of a continuous time-series of data between 1987 to 2013. This study also confirms results from a previous study that a field portable gamma spectrometer can be used to characterize the long-term time dynamics of ^{137}Cs, even in cases where the ^{137}Cs dose contribution is well below the background levels.

Keywords: field portable gamma spectrometry, ecological half-time, Chernobyl fallout

Modelling redistribution of ^{137}Cs in the Kymijoki watershed, Finland

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ABSTRACT

Radioactive caesium (^{137}Cs) has been ejected into the atmosphere following accidents at nuclear power plants or because of nuclear weapon's testing in the 1950s, '60s, and '70s. It enters the environment either by wet or dry deposition, where the majority of the ^{137}Cs is adsorbed onto clay particles. Very limited movement of ^{137}Cs occurs after fixation, although weathering and erosion may remobilise the radioactive caesium which can then be transported in streams and rivers. Since climate change is projected to lead to increased temperatures and precipitation in northern latitudes, the potential for ^{137}Cs remobilisation increases. In this work, a model of ^{137}Cs erosion and transport will be set up and validated in SWAT+ using historical ^{137}Cs data. SWAT+ is a continuous time model allowing physical processes related to water and sediment transport as well as nutrient cycling and pesticide fate to be modelled. To simulate remobilisation and transport of ^{137}Cs, SWAT+ is modified to include the following ^{137}Cs dynamic processes: solid-liquid distribution, plant uptake, erosion, and transport in the hydrological network. The modelling efforts will be focused on the Kymijoki watershed in southern Finland, where Finland's Radiation and Nuclear Safety Authority have a radionuclide monitoring programme since the early 1960s. To set up the model, ^{137}Cs deposition and soil data will be used, along with ^{137}Cs data from stream water to calibrate and validate the model. The model can then be used to project the fate of ^{137}Cs anomalies in the environment under a changing climate and identify potential downstream areas of contamination, helping to manage the problems of radionuclide pollution and climate change.

Keywords: Radiocaesium, climate change, remobilisation, modelling, SWAT+

Investigating the impact of climate change on radiocesium from moose in Västernorrland and Gävleborg counties, Sweden

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ABSTRACT

Radionuclides, including radiocesium (^{137}Cs), were deposited across large areas of central Sweden after the Chernobyl nuclear power plant accident in 1986. ^{137}Cs is considered highly immobile in the environment due to strong fixation onto fine clay particles. However, due to its long half-life of 30.2 years, it may remain present for several hundred years before reaching negligible levels. Impacts of extreme weather events like floods, erosion or wildfires can disturb the Cs-rich horizon and thus increase the chance of ^{137}Cs remobilisation. With current projections indicating an intensification of climate change in the Northern Hemisphere, the potential risk of ^{137}Cs remobilisation increases. In this study, we hypothesise that moose (*Alces alces*) contamination patterns can be associated with different environmental processes working locally to bury or expose ^{137}Cs. We investigate moose as an environmental tracer of ^{137}Cs anomalies in Sweden between 1986 and 2021. Our case studies focus on Västernorrland and Gävleborg counties, both affected by high initial ^{137}Cs deposition where the surface contamination ranged from 20 to 120 kBq/m^2 in 1986. The activity data of the moose is compared with parameters indicative of climate change, such as temperature and precipitation, as well as the occurrence of erosion and forest fires. Finally, our results show that the decrease of specific activity in moose meat during this period is faster than the decay of ^{137}Cs suggests. We interpret this as a transport of ^{137}Cs in the environmental system. Furthermore, we observe an increase in ^{137}Cs activity in Västernorrland county in 1988, 1993 and 1997, which we link to environmental processes driven by climate change.

Keywords: Sweden, climate change, radioactive cesium, remobilisation

Radiometrical characterization and comparison of vertical profiles in three pit lakes from Southern Sweden

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ABSTRACT

Mining areas are among the potential candidates to be found with enhanced levels of natural radionuclides in the environment. More particulary, opencast mining will generate pit lakes once the mine is closed down. Due to local geology and limnological parameters every pit lake is an unique water body. After a screening process throughout Sweden where more than 45 sites containing pit lakes were covered, 3 pit lakes from Southern Sweden, with enhanced levels of natural radionuclides in its water, have been selected for a deeper study. These three water bodies have 10m, 30m and 60m of maximum depth. In this work, vertical water profiles of physicochemical parameters (T, pH, ORP, OD, Specific Conductivity), elements and activity concentration of natural radionuclides (U, Th, Po isotopes) will be measured and compared among the studied lakes. A bathymetric map of each pit lake will be also generated to find the deeper spot of the lake where to perform the sampling. Multiparametrix and echo probes, ICP-MS/MS and alpha spectrometry will be used for this purpose. The maximum depth was found as the key parameter to let a pit lake the development of stratification layers. Associated to these strata, different behavior were found for the elements and radioisotopes under study.

Keywords: Natural radionuclides, elements, pit lakes, vertical profile.

Naturally occurring radionuclides assessment in the Arctic

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ABSTRACT

Naturally occurring radionuclides (NORs), primarily ^{210}Po, accumulates in seafood, marine, and terrestrial mammals, which are an important part of the traditional Arctic diet. Arctic seafood plays an important role in the worldwide seafood industry. NORs were measured in glaciers from Svalbard, the Arctic Ocean, surface seawater and sediments from Norwegian marine areas, seabirds from Greenland, seafood and marine mammals from the Nordic region, Faroe Islands, Greenland, and Canada, terrestrial mammals from Greenland, and lake sediments in northernmost Finland. Outdoor ^{222}Rn was measured in Finland, Canada, and Norway and atmospheric ^{210}Pb,

^{212}Pb, and ^{7}Be were measured in Norway, Sweden, Finland, Iceland, and Canada. Deposited ^{210}Pb and ^{7}Be were measured in Sweden and Finland. Glaciers and marine sediment results show oil and gas, coal combustion, and ore mining as anthropogenic sources. NORs are long-range transported via atmospheric and oceanic currents in the Arctic. ^{210}Pb has a long atmospheric residence time, especially in winter. ^{228}Ra activities in the Transpolar Drift approximately doubled between 2007 and 2015, indicating that climate-driven changes may be increasing the release of shelf-derived elements to the open Arctic Ocean. Results showed no effect of climate change on ^{210}Pb deposition in sediments in Lake Kevojarvi in northernmost Finland. ^{210}Po is the major contributor to the annual effective dose via seafood and marine and terrestrial mammal consumption in the Arctic population, far exceeding dose contributions from ^{137}Cs, ^{226}Ra, ^{228}Ra, and ^{210}Pb. ^{210}Po absorbed dose rates to studied biota are several orders of magnitude lower than the recommended dose rate screening value of 10 μGy h^{-1}. NORs atmospheric results follow an annual cycle, which is mainly driven by seasonal weather and climate changes. Understanding the sources and associated doses from NORs is necessary to assess risks and public perception of risks, support science-based decision-making, and policy development engaging public and Indigenous peoples.

Keywords: NORs sources, marine, terrestrial, atmospheric, long-range transport, outreach

Final disposal of nuclear waste – status in Sweden

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ABSTRACT

The nuclear waste from the Swedish nuclear programme shall according to the Swedish regulations be disposed of in final repositories to ensure that human health and the environment is protected from the harmful effects of ionising radiation. The Swedish Nuclear Fuel and Waste Management Company (SKB) is tasked by the reactor owners to implement the final disposal in Sweden. The Swedish waste management system includes three final repositories. The final repository for short-lived radioactive waste (SFR) in Forsmark is in operation for disposal of operational waste from the nuclear power plants. The Swedish government approved the extension of the facility in 2021 for handling of decommissioning waste from shut down reactors. The license for the final disposal for spent nuclear fuel, which is also to be sited in Forsmark, was approved by the Swedish government in 2022. There are further steps in relation to licensing before the construction of these two facilities can commence that SKB is currently working with. The third facility is the final repository for long-lived waste (SFL), which is to be constructed for long-lived operational and decommissioning waste, and legacy waste from the early research in the Swedish nuclear program. A safety evaluation has been carried out (SE-SFL) with the objective to give input to future steps in the development of the repository. The coming steps in the Swedish nuclear program are outlined in the research, development and demonstration program that SKB hands in to the government every three years.

Keywords: Nuclear Waste, geological repositories

Hot Cell Decommissioning at the Former Research Center Risø

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ABSTRACT

In Denmark, a few of the nuclear facilities at the Research Center Risø still lacks decommissioning. Among these is the Hot Cell facility, which was in operation through the years 1964 – 1989. Through the years of operation the Hot Cells were used for post irradation experiments on fuels from research reactors, just as radiotherapy sources of mainly Co-60 were prepared within the Hot Cells. All together these activities led to a heavy contamination of the Hot Cells with α-, β- and γ-emitting nuclides, posing severe challenges to the present day decommissioning activities.

Following the end of operation of the Hot Cells in 1989, the cells went through a preliminary decommissioning in the early 1990'es including primarily removal of auxiliary components followed by subsequent sealing of the cell row. In 2007, a second round of decommissioning was started, with the final aim of bringing the Hot Cell to Green Field status. The second round of decommissioning is still in progress, and has recently reached a stage, where focus will shift from remotely controlled cleaning operations within the cells to more manual operations including cell entrance and finally the complete deconstruction of the cell structure.

The present talk will review how radiation levels within the cells have been characterized through the past years by various techniques (TLD, smear tests, gamma camera, Rados survey), and how the information on radiation levels have affected the choice of decommissioning methodologies. The presence of hot spots has been a particular challenge, which will also be addressed. The application of ALARA principles in practice during decommisoning will be discussed, and the future prospect for taking down the cell structure piece-by-piece in a safely manner will be outlined.

Keywords: Hot Cells, Decommissioning, ALARA

Exposure and dose assesssment of future humans and other organisms from the low and intermedial level repository SFR

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ABSTRACT

The final repository for short-lived radioactive waste (SFR) at Forsmark, Sweden, is used for the final disposal of low- and intermediate-level operational waste from Swedish nuclear facilities. The PSAR assessment of post-closure safety is an important part of the construction license application for the extension of SFR. The biosphere assessment is an integrated part of the overall post-closure safety assessment. The biosphere transport and exposure model (BioTEx) is used to describe transport and accumulation of radionuclides in the ecosystems and calculates potential doses to humans and dose rates to non-human biota. The total annual dose throughout the assessment period peaks at 5.6 μSv, occurring around 7000 AD. That is below regulatory risk criterion that corresponds to 14 μSv. Draining and cultivation of a mire is the land-use variant resulting in the highest dose, primarily because radionuclides can accumulate in peat over a long period of time prior to exposure, and because the dose-contributing radionuclides predominantly yield dose through ingestion of food. Mo-93 and C-14 contribute most to the total dose from the time of repository closure up until the time around the dose maximum. Ca-41 dominates in the middle of the assessment period, and Ni-59 is most important at the end. Exposures of non-human biota (NHB) are evaluated will be unaffected by radionuclides released from the repository in the assessed scenarios. Since dose rates are relatively insensitive to the postulated span in climate conditions and object properties this conclusion is robust with respect to uncertainties in the future climate and the development of the landscape. The results are consistent with SKB's general understanding of how climate affects the surface system.. Taken together it is concluded that uncertainties in the landscape development and object properties are unlikely to have any significant influence on the calculated dose and the evaluation of the repository safety.

Keywords: Ecosystem, dose, low level waste

IDAC- BioDose, a complete biokinetic and dosimetric software tool designed for nuclear medicine and built on the ICRP computational framework

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ABSTRACT

Internal dosimetry of radiopharmaceuticals in diagnostic nuclear medicine is based on biokinetic and anatomical models. The biokinetic model describes the uptake, turnover and retention of the radionuclide by the human body and the sites of decay of the nuclide. The anatomical models are computational phantoms used to estimate the energy absorbed in the body from each decay. This means that the regions defining the biokinetic models must also be defined in the computational phantoms. To create more detailed biokinetic models ICRP has, within the charges of its task groups (TG), created a new framework based on compartmental modelling, with a central blood compartment exchanging activity with organs and tissues. To depict more detailed biokinetics for nuclear medicine, ICRP TG-36 has also developed a dynamic urinary bladder and a time dependent gallbladder model. For the dosimetric calculations, anatomical models for the ICRP reference individuals have been created. The ICRP computational framework for dosimetric calculations has been used with IDAC-BioDose as a complete software that integrates compartmental modelling, IDAC-Dose2.2, and ICRP biokinetic modeling, including all features regarding absorbed dose and effective dose calculations. The biokinetic modelling is based on transfer rates often generated by fitting empirical data describing time-dependent and organ-specific behavior of radioactive tracers. The biokinetic component of the IDAC-BioDose software was benchmarked with SAAMII, and the dosimetric part was benchmarked with DCAL. The software is currently further developed and used by the ICRP TG-36 in the revision of biokinetics and dosimetry for ICRP Publ. 128. This includes new absorbed and effective dose coefficients for 60 different radiopharmaceuticals and 6 different patient age groups. This dedicated software tool covering all aspects of the biokinetics and dosimetry, from implementation of measured time dependent organ and patient specific activity to calculation of absorbed and effective dose, will facilitate radiation dose estimations from radiopharmaceuticals within the nuclear medicine community.

Keywords: Software, Biokinetics, Dosimetry, Nuclear medicine, ICRP

A Regulatory Perspective in Practice:

Radiation Safety in Selective Intravascular Radiotherapy

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ABSTRACT

The purpose of the study was to investigate practices related to the selective intravascular radiotherapy (SIRT). This covers the lifespan of the isotope entering the hospital all the way to the waste processing. The aim of the project was to improve the radiation safety of workers and patients. In particular, the aim was to develop a documented inspection method for ensuring radiation-safe operation. The study material consists of instructions from the operators and on-site inspection reports. Operational instructions were collected from all Finnish hospitals holding license for SIRT. Observational studies were performed in several hospitals during SIRT procedures. Based on the study results multi-professional collaboration is a critical factor in radiation safety during SIRT. A documented inspection method for ensuring radiation safety during in SIRT was introduced. Regulatory body for radiation safety can and should inspect SIRTs. The documented inspection method will be suggested for international use. In addition, it is applicable for self-assessments in interventional radiology and isotope units. In complex processes multi-professional collaboration is paramount.

Keywords: nuclear medicine, radiology, selective intravascular radiotherapy, SIRT, radiation safety

From Cobalt-60 to Megavoltage Accelerator Based Calibrations for Radiotherapy Dosimetry

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ABSTRACT

Radioactive sources in the industry and health sectors are increasingly replaced by other sources of ionizing radiation, such as x-ray tubes or electron accelerators. This trend is driven by a combination of factors, including more extensive safety requirements from radiation authorities and increased costs of radioactive sources. For many years, cobalt-60 sources have been used as reference in ionizing radiation metrology, underpinning, for example, external beam radiotherapy dosimetry worldwide. The main radiotherapy dosimetry protocol, TRS-398 from IAEA, however, recommends that hospitals obtain calibrations directly in the relevant megavoltage photon beams, and BIPM, IAEA and primary standards dosimetry laboratories such as, for example, LNHB (France), NPL (UK), and PTB (Germany), have developed calibration services for these beam qualities. The Technical University of Denmark (DTU) has since 2019 provided an ISO-17025 accredited calibration service based directly on accelerator irradiations in five photon beam qualities (4 MV, 6 MV, 10 MV, 15 MV, and 18 MV), and the DTU facility has, for example, been used in an EURAMET research project (RTnorm.eu) to produce revised beam-quality correction factors for ionization chambers for the upcoming revised edition of the TRS-398 protocol. The purpose of this contribution is to communicate the DTU experience with direct megavoltage calibrations relative to cobalt-60 calibrations.

Keywords: Accelerators, Calibration, Cobalt-60, Dosimetry, Metrology, Radiotherapy.

Radiation Protection in interventional radiology; comparison between dose delivered to patients and dose received by performing physician

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ABSTRACT

The main objective of this study was to investigate on the relationship between exposure techniques, the dose delivered to patients and the dose received by performing physican in interventional radiology. Exposure data, procedure code and name of performing phycisian for all interventional procedures within a calendar year performed by 7 interventional radiologists on 3 different angiographic systems were extrapolated from an automatic dose registration system. The total exposure delivered during the procedures in terms of CAK (Central Air Kerma), DAP (Dose Area Product) and TTF (Total Time of Fluoroscopy) were divided according to the registered performing physician and compared to the dose measured with the personal dosimeter readings for each radiologist. The comparison indicated that there is no direct relationship between dose delivered to patients, technique used and dose received by the interventional radiologist. These results shows the importance of the proper use of radiation protection shielding and good radiation hygiene during the procedures.

Keywords: interventional radiology, medical physics

Characterization of optically stimulated luminescence dosimetry using NaCl pellets in breast radiography applications

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ABSTRACT

Dosimetry using NaCl pellets read out with optically stimulated luminescence (OSL) have previously been used in various environmental and medical applications. In this study we characterize the use of NaCl pellets within the field of breast radiography, with energies around 30 kV. The motivation for using NaCl pellets in clinical breast dosimetry is the possibility to conduct multiple point measurements in an affordable and time efficient manner, as well as the over-response of NaCl at low energies. Recently, we reported the pioneering use of NaCl pellets in breast dosimetry. We have used the "standard breast" setup, a rectangular phantom consisting of 45 mm PMMA, with the total breast compression set to 53 mm. Our measurements of the average glandular dose using OSL and NaCl pellets showed 3-5% difference from the measurements using a conventional dosemeter suitable for digital mammography (DM). The corresponding results from measurements using digital breast tomosynthesis (DBT) showed 2-15% difference. In this paper we present results from an ongoing study of repeatability and angular sensitivity of dose measurements with NaCl pellets. The angular dependence is of practical interest in DBT which includes multiple low dose projections in a 15-50 degree range. Our preliminary measurements suggest an overestimation of radiation dose in DBT.

Keywords: Digital breast tomosynthesis, digital mammography, OSL, NaCl pellets, radiation dose measurement

Assessment of radiation dose and image quality for small animal imaging protocols in micro-CT

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ABSTRACT

In preclinical research on small animal, micro-computed tomography (micro-CT) has become one of the more commonly used imaging modalities for studying *in-vivo* animal models of disease. To allow an accurate interpretation of small structures in x-ray based micro-CT images, high spatial resolution is necessary. However, this may also lead to high radiation exposure of the animals. When planning longitudinal micro-CT imaging studies, the radiation dose to the animal should be considered to avoid unintended radiation induced effects to the animal that may influence the study results. It is also of importance for the animal's wellbeing and normal functioning that the radiation dose is monitored and/or calculated before the start of the experiments. In this study the radiation dose has been measured in a custom made PMMA phantom for a specific in-vivo imaging protocol, a so-called retrospective gating protocol, in which the imaging dataset is reconstructed based on the cardiac and/or pulmonary cycle. Measurements were made to test how different parameters i.e. (number of angles, exposure time, filters, tube voltage and current) affect the image quality in relation to dose using a MILABS xUHR-μCT. The dose was measured in a rat-sized PMMA phantom using thermo-luminescent dosimeters (TLDs, MCP-N) and a novel optically stimulated luminescence dosimeters (OSLDs) made from sodium chloride (NaCl) at different depth positions inside the PMMA phantom. The results can be used as a guidance when planning animal experiments in micro-CT imaging by optimizing imaging protocols to reduce potential radiation induced effects while preserving image quality.

Keywords: OSLD, TLD, micro-CT, in-vivo, phantom, image quality

Residual learning-based deep network for nuclide identification in gamma-ray spectroscopy

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ABSTRACT

Automatic identification and quantification of gamma-ray emitting radionuclides is a challenging task in the field of nuclear emergency preparedness and requires expert knowledge in gamma-ray spectroscopy. Most of the literature uses convolutional neural Networks (CNNs) to identify a relatively small number (e.g., 11) of radionuclides in gamma-ray spectra measured using low-energy resolution detectors. This work aims to increase the number of identifiable radionuclides in high-activity samples measured by HPGe detectors using a residual learning-based very deep network with skip connection (ResNet-like architecture). Such a network can help extract more distinctive features than conventional and shallow deep learning networks. Our simulation setup consisted of a point source positioned at 5 mm from an HPGe detector with a crystal diameter of 80 mm and height of 30 mm. The source contained 35 radionuclides with various activities. First, single-nuclide spectra were simulated using the Nucleonica Gamma Spectrum Generator Pro application. Gamma spectra containing different radionuclide mixtures were created: each mixture contained a subset of the 35 nuclides. For each mixture, a set of spectra was generated by linear combinations of single-nuclide spectra, where the combination coefficients were obtained by randomly sampling activities of nuclides in the mixture. Poison noise was applied to each spectrum. In total, 37000 and 5400 spectra were generated for the training and testing data sets, respectively. The neural network was built from scratch and trained using multi-label classification to identify the nuclides in a spectrum. The evaluation of the model resulted in a Hamming loss of 0.029, a precision of 0.915, an F1-score of 0.940, and binary accuracy of 0.971. These promising results show that the network can be a helpful tool for gamma-ray spectroscopists.

Keywords: Gamma-ray, nuclides, residual learning, spectra, deep learning, skip connection.

Internal dose and risk assessment from European Spallation Source releases

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ABSTRACT

Accidental releases from the European Spallation Source (ESS) will include a different set of radionuclides than accidental releases from a nuclear power plant, and therefore the potential internal contamination assessments of on–site workers and members of the public need to be developed and adapted to relevant ESS-specific conditions. Previous research has identified that radionuclides released at various accident scenarios will include alpha, beta and gamma emitting radionuclides. Important dosimetric impact in various accident scenarios will be attributed to ^{148}Gd pure alpha emitter with a half-life of 84±4 y, and ^{187}W, ^{172}Hf, ^{182}Ta and ^{125}I (gamma emitters, with half lives of 23.7 h, 1.87 y, 114.4 d, and 59.49 d, respectively). Following a few days after an accidental release, the main part of the effective dose will result from internal doses from inhalation, and from external dose from the cloud passage and ground deposition. In the long-term period, ingestion of contaminated foodstuffs may also contribute to the effective dose. Therefore, internal contamination of on-site workers and members of the public will be assessed considering inhalation and ingestion routes. The PhD project, financed by Swedish Radiation Safety Authority (SSM), will entail a feasibility study of different radiometric measurements and corresponding time window in order to accurately predict, monitor and follow-up the internal doses accumulated from ESS accident releases. The results of the project will contribute to establishing effective protective measures and monitoring programs in order to ensure the safety of the on-site workers and members of the public. Presented work will outline important previous findings and give an overview of the planned work to be done in this area.

Keywords: ESS, radioactive aerosols, internal dosimetry

Assessment of radiological consequences to biota from radioactive discharges from Ringhals nuclear power plant - A comparison of different approaches

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ABSTRACT

As a step to improve the evaluation of radiological consequences to biota from radioactive liquid discharges, the nuclear power plant Ringhals is comparing different approaches to estimate radioactive exposure to the surrounding environment. The aim is to find a feasible method that can improve the statutory local environmental monitoring program at Ringhals. The initiative is comparing methods to estimate total dos rate from radionuclide produced by, and released from, the nuclear power plant using measured and/or simulated data. Measured activity in samples of marine biota as well as measured discharged in cooling water are used. Simulations and risk assessments are conducted using site-specific dose conversion factors and software tools; PREdiction of Doses from normal releases of radionuclides to the environment (PREDO) and Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA). Simulated and calculated concentration of radionuclides (e.g. C-14) will also be compared with previous published data from analyses of biota taken from the Ringhals surroundings.

Keywords: ERICA, PREDO, radioactive emission, radiation protection, environmental radiology

Early apoptotic response in kidney after ^{177}Lu-octreotate administration with or without potential radioprotector α1-microglobulin

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ABSTRACT

The antioxidant α_1-microglobulin (A1M) has been suggested as kidney protector during ^{177}Lu-octreotate treatment of neuroendocrine tumors, e.g. via protection from radiation induced apoptosis. The aim of this work was to study apoptosis-related transcript expression in kidney cortex and medulla after injection of ^{177}Lu-octreotate and/or A1M. C57BL/6N mice were injected with either ^{177}Lu-octreotate, A1M, or ^{177}Lu-octreotate + A1M, or were sham-treated (controls). Animals were killed after 24 h or 7 d. mRNA was isolated from kidney medulla and cortex. Expression of 84 apoptosis related genes was assessed by q-PCR. Gene expression profiles (compared to controls) in kidney cortex were generally similar in the ^{177}Lu-octreotate and the ^{177}Lu-octreotate + A1M groups. This was also seen in kidney medulla at 24 h, but at 7 d an anti-apoptotic response was observed to A1M. Exposure to ^{177}Lu-octreotate induced a pro-apoptotic response (e.g. *Apaf1, Bax*, and *Tnfrsf10b* genes) in mouse kidney medulla and cortex after 24 h. In conclusion, co-administration of A1M did not inhibit pro-apoptotic response in kidney cortex, in contrast to kidney medulla where A1M initiated pro-survival mechanisms.

Keywords: nephrotoxicity, kidney protection, radionuclide therapy, radiobiology, PCR, mouse

A new method in mobile gamma spectrometry to determine the distance, shielding and activity of a lost source when searching along a road passing the source

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ABSTRACT

One purpose of mobile gamma spectrometry is to locate lost radioactive sources. Searching for a source may take time if the search area is large. When a search unit gets an indication that a source may be present, it is advantageous to also directly get an indication of the source's distance, shielding, and activity. When passing the source, the sequence of pulse height distributions (gamma spectra) may contain helpful information. For an unshielded point source, the change in detector count rate for primary radiation from the source is a specific function of distance, which then can be calculated from a series of measurements along the path. For a shielded source, the Compton interaction in the shield results in pulse registrations in an energy range below the primary photon energy., Provided the shield consists of materials with atomic numbers below 25, the low-energy pulse registrations are relatively simple functions of shield thickness and distance to the source, enabling an assessment of the shielding of the source. If the efficiency of the gamma spectrometer is known, the activity of the source can be calculated from the source distance and shield thickness. Two Excel applications, SODAC (source distance and activity calculation) and SSD (source shielding determination) have been developed for the calculations. Joint experiments (with mobile teams from all Nordic countries) show that in the range of 30 - 90 m, the distance to ^{137}Cs point sources can be determined within ±5 m, provided that the count rate uncertainty of the full energy peak is below ±2%. At 30 m, a shield thickness of up to 330 kg/m^2 can be identified within ±5% uncertainty but with more substantial uncertainties at 90 m. The uncertainty in the activity determination is a combination of uncertainties in the distance and shielding determinations.

Keywords: Mobile gamma spectrometry, orphan source search

Municipality Averaged Uranium Bedrock Concentration Predicts Lung Cancer Incidence in Sweden after Adjustment for Smoking Prevalence

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ABSTRACT

The municipality average value of bedrock U concentration, $U_{Mun,Bedrock}$, was correlated with the cumulative lung cancer and total cancer (excluding lung) incidence rates between 1986 and 2020, respectively in a cohort of 809,939 adult males living in 9 different Swedish counties in 1986 The $U_{Mun,Bedrock}$ was obtained from the Swedish geological Survey (SGU) and ranged between 1.01 to 5.03 ppm in the studied counties. Since lung cancer is strongly correlated with smoking prevalence, a correction for regional difference in tobacco smoking was done using data from surveys conducted by the Public Health Agency of Sweden from 2001 to 2004. In males, a significant positive linear relation was found between the smoking prevalence adjusted lung cancer incidence rate, I_{adj}, and the municipality bedrock U concentration (R^2=0.273). In females, this correlation was weaker, but still significant (R^2=0.121). When instead assessing the total cancer incidence rate (excluding cancer of the lung) with adjustment for smoking prevalence, there appears to be no or little correlation with $U_{Mun,Bedrock}$ (R^2=0.031 for males and R^2=0.021 for females). When the regression was done for county average values of $U_{Bedrock}$ and I_{Adj}, the correlation with smoking prevalence adjusted lung cancer incidence rate became substantially higher; R^2=0.505 for males and R^2=0.404 for females. We hypothesize that the correlation we found is due to a covariance between $U_{Mun,Bedrock}$ and the average indoor radon concentration in residential buildings (as has recently been reported by a Swedish survey). Based on geological survey maps, bedrock uranium concentration can be explored as a proxy for radon induced lung cancer incidence on a population level. Also, this method could be used to estimate what future lung cancer rates can be expected for a population nearing zero smoking prevalence, with and without radon prevention.

Keywords: radon proxy, lung cancer, natural uranium in bedrock, geological maps

Robustness of gene expression signatures as a readout of radiation exposure

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ABSTRACT

Gene expression measurements have been used for the evaluation of healthy tissue responses following, e.g,. accidental radiation exposure or radiotherapy. The technical reproducibility of this method is highly satisfactory. However, large variations in the biological response to treatment can be expected due to e.g. small differences in absorbed dose and dose-rates, different physiological conditions of the irradiated organism and tissue type, etc. The aim of this study was to investigate the reproducibility of the transcriptional response between groups exposed to the same radionuclide exposure, and to evaluate the dependence of radiation type on gene expression changes. To evaluate reproducibility of gene expression responses to internal irradiation, mice were injected with ^{177}Lu-octreotate at an activity resulting in 1 Gy to the kidneys, or saline as control. After 24 h, RNA was extracted from the renal cortex and medulla, and the transcriptional response between mice was analyzed using RNA microarray. The experiment was repeated two more times with other animals which were analyzed separately. To determine the effects of different types of radiation, mice were also injected with $^{177}LuCl_3$ and ^{90}Y-octreotide corresponding to doses of 1 Gy, or exposed to 1 Gy from external irradiation (6 MV photons, either abdominal or whole body exposure) and subjected to the same analyses as above. Some deviations in the transcriptional response were observed both within treatment groups as well as between the different control groups. However, the magnitude and direction of regulation of shared regulated genes was similar when comparing treated animals with controls. Comparison between radiation types showed large deviations in differential gene expression, especially between radionuclide and external irradiation. In conclusion, while RNA microarray is a sensitive tool to detect gene expression changes following radiation exposure, potential confounding parameters such as physiological state and systemic regulation of tissue function need to be considered.

Keywords: radiation biology, transcriptomics, kidney, biomarker

Opportunities and limitations with modern radiobiological methods (radiogenomics) for improvement of radiation protection

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ABSTRACT

There is a continuous rapid development of genetic and molecular techniques to analyse cell and tissue functions. Development of omics methods started with genome (DNA) sequencing (genomics), followed transcriptomics (mRNA) and proteomics (proteins). Metabolomics is aimed for characterising the metabolites. Further, epigenetic effects by factors not influenceing the DNA sequence can modify gene expression (epigenetics). Altogether, omics techiques offer exciting opportunities to improve the radiobiological knowledge both for medical purposes, such as radiation therapy, and for radiation protection and risk assessment. The techniques are very powerful and enable detailed studies on effects also at very low doses and at both early and late time points after irradiation. However, cell signalling and regulation of functions, e.g., inflammatory and immune responses in an organism are very complex, and most of the molecular methods generate very much information, that must be integrated and analysed to be able to interpret. The aim of the presentation is to give an overview of the recent development of molecular methods useful for evaluation of radiation-induced mechanisms in cells and tissues. The potential and limitations of the methods will be discussed. Examples will be selected from our previous and ongoing research and from the literature, and focused on applications valuable for radiation protection.

Keywords: genomics, transcriptomics, proteomics, epigenetics, metabolomics, bioinformatics

Estimating releases of ^{137}Cs and ^{210}Po from boreal forest soil and peat in the event of a wildfire

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ABSTRACT

With a warming climate, Nordic countries will be facing an increased number of wildfires in their boreal environment. If a forest has been exposed to nuclear fallout, wildfires would result in the remobilisation of man-made and natural radionuclides like ^{137}Cs and ^{210}Po in the local environment as aerosols or ashes with potential harmful effects on human health.

The environment of the region of Gävle, Sweden, has been contaminated by radioactive fallouts after the Chernobyl accident in 1986. Samples of forest litter, forest soil, peatbog litter and peat were collected in this contaminated area. The samples were then combusted in a small-scale experimental set-up in laboratory to investigate the fire-induced resuspension of radionuclides. Combustion aerosol were collected on filters using an impactor system and the remaining ashes were also recovered for measurement by gamma spectroscopy. On average, the combusted samples released 29% of their ^{137}Cs in the air while 71% remained in the ashes after the combustion. The influence of the oxygen concentration (flaming and smouldering fire conditions) was also investigated. We estimated that up to 7 TBq of ^{137}Cs could be released by a wildfire in this contaminated area of about 100 km^2. Measurable amounts of ^{210}Po were also observed by direct alpha spectroscopy measurement of filters recovered from the impactor containing the smallest fraction of aerosol (> 0.2 μm) which corresponds to the breathable fraction.

Keywords: forest fire, combustion, cesium, polonium, environmental radioactivity

Uranium aerosol dissolution in simulated phagolysosmal fluid

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ABSTRACT

Nuclear fuel workers are subject to radiation exposure resulting from inhalation of uranium aerosols. The exposure introduces risks of kidney damage and radiation induced cancers, making reliable dose estimates for such workers important. The aerosol particle size distribution is an important factor as it will influence both the deposition and the dissolution in the respiratory tract. Inhaled particles are cleared from the respiratory tract via mechanical processes such as macrophageal and mucociliary transport to the gastrointestinal tract, and by dissolution processes, both in extracellular lung surface fluid and in the intracellular environment inside macrophages. Most studies use simulated extracellular lung fluid to evaluate the dissolution in the respiratory tract. However, as the environment in the extracellular lung fluid differs from the environment inside macrophages, both regarding composition and pH-level (neutral vs acidic), it is important to also evaluate the dissolution of particles engulfed by macrophages. Especially as a significant fraction of particles are engulfed by macrophages within the first 24 h after inhalation. The aims of the planned study is to evaluate the impact of intracellular fluid on the dissolution of uranium aerosols, estimate lung absorption parameters and the dependence on particle size. Aerosol samples are collected using portable cascade impactors from several workshops at a nuclear fuel fabrication plant, where compounds such as UO_2, UF_6, AUC and U_3O_8 are present. A static lung dissolution method with simulated phagolysosomal lung fluid is used, with fluids being collected at regular intervals for up to 30 d. Samples will be radiochemically processed and measured with both alpha spectrometry and inductively coupled plasma mass spectrometry (ICP-MS). Lung absorption parameters will be calculated from the experimental data and the dosimetric impact of using derived lung absorption parameters will be evaluated.

Keywords: internal dose, lung, nuclear fuel cycle uranium

Experimentally determined concentration factors of radionuclides in marine phytoplankton

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ABSTRACT

Small amounts of radioactive elements are released during normal operation of nuclear facilities. This causes a radiation dose to humans which is generally estimated using software which implements ecosystem models. Concentration factors are parameters in these models which relate the concentration of an element in an organism, under equilibrium conditions, to the concentration in the surrounding medium. For modelling of marine ecosystems, phytoplankton concentration factors are crucial for prediction of dose from most radionuclides, since the phytoplankton are primary producers. In the current work, we have identified the phytoplankton concentration factors of Mn, Ni, Zn, Ru, Sb and I as insufficiently well determined. Sensitivity studies were performed using the software PREDO, confirming that the calculated dose caused by radionuclides of each of these elements was indeed strongly dependent on the phytoplankton concentration factors. We then proceeded to determine these phytoplankton concentration factors experimentally. Phytoplankton of the species Phaeodactylum Tricornutum were cultured in the lab with small amounts of radionuclides of these elements (^{54}Mn, ^{63}Ni, ^{65}Zn, ^{106}Ru, ^{125}Sb, ^{131}I) added to the culture medium. The phytoplankton were then separated from the media by filtration, and activities in the filters and media respectively were determined through gamma spectrometry and, in the case of ^{63}Ni, liquid scintillation counting. Triplicate samples were cultured for each element, as well as triple reference samples with no phytoplankton to quantify radionuclide sorption on the filters. Activity concentrations were calculated for the plankton and media respectively, and concentration factors were calculated for each sample and then averaged over the three samples. Conservative estimates of the phytoplankton concentration factors based on our present data are 7200±2600 L/kg for Mn, 1200±300 L/kg for Ni, 9 100±4100 L/kg for Zn, 3600±1400 L/kg for Ru, 34±27 for Sb and 33±13 L/kg for I, all phytoplankton masses referring to fresh weight.

Keywords: Ecosystem models, phytoplankton, radioecology, marine ecosystems, concentration factors.

Can direct alpha spectrometry be used for analysis of radioactive aerosols emitted from the European Spallation Source?

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ABSTRACT

In case of an accident at the European Spallation Source (ESS), radioactive target material may be released into the environment. In the dimensioning event (see the Swedish Radiation Safety Authority's report SSM2018:02) the inhalation dose will be dominating during the first week, and more than 50% of the total effective dose will stem from the pure alpha emitter ^{148}Gd (half-life 84±4 y) in aerosol form. ^{148}Gd aerosols in ambient air thus needs to be quantifiable for correct dose estimates. This work outlines basic requirements for direct alpha spectrometry of ^{148}Gd aerosols expected from the ESS at an accident scenario and during normal operation. Gaussian plume modelling is used to estimate activity concentrations, and the software AASI simulate alpha spectra for various conditions. If short-lived radionuclides are allowed to decay prio to measurement, ^{148}Gd is expected as the predominant ESS-attributed alpha emitter in terms of activity. The AASI simulations predict that the best energy resolution is obtained for thin layers (< 200 μg cm^{-2}), small particles (<<1 μm in diameter) and non-existent penetration into the filter. Simulation results are compared to direct alpha spectrometry of radon daughters in aerosols collected using a high-flow (HiVol) system at a rural background station. Most of the alpha activity on these filters vanishes within days, and ^{210}Po is clearly seen after several months. The HiVol system proved unsuitable for direct alpha spectrometry due to too thick collected layer of aerosols. Since the dosimetry of radioactive aerosols depends on the aerosol size, collection systems that fractionate the aerosols by size (impactor systems) are worth to investigate further. Possible coincidences from other radiation types were not included in the present work. The feasibility of direct alpha spectrometry of air samples thus needs to be further explored to improve the emergency preparedness against accidental ESS releases of ^{148}Gd.

Keywords: ESS, radioactive aerosols, direct alpha spectrometry

Estimation of external exposure from a ^{137}Cs-deposition on the ground: Influence of type of humanlike reference phantoms used and depth distribution of ^{137}Cs in soil

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ABSTRACT

The ICRP has over the years used different reference human phantoms for Monte Carlo simulations of effective dose. For the previous set of effective dose calculations based on the recommendations in Publ. 60 of ICRP, a set of stylized anatomical phantoms were used. These phantoms, often called Cristy-Eckerman or MIRD phantoms, were defined by linear and quadratic equations and based on the anatomical data for the "Reference Man" (ICRP Publ. 23). For the current recommendations (ICRP Publ. 103), ICRP has updated the reference phantoms to sex specific voxel phantoms of six different ages. The voxel phantoms are based on a set of anatomical data given in ICRP Publ. 89. However, as the voxel phantoms, due to the size of the voxels, have a limitation in spatial resolution, ICRP has in its Publ. 145 updated the voxel reference phantoms for adults to mesh-type phantoms. The mesh phantoms have the same anatomical topography as the voxel phantoms, but has no spatial limitation and therefore no limitation in accuracy for Monte Carlo-simulation of small structures and regions e.g. the respiratory tract and the target layer of the skin. In 1986, fallout from the Chornobyl disaster contaminated areas in Sweden with ^{137}Cs, especially in the Gävle region. Soil profiles from a specific site in Gävle were used. The results show that there is a difference in the absorbed dose simulations for the stylized phantoms and the voxel/mesh phantoms, mostly due to their different sets of anatomy. Comparing the voxel phantoms and the mesh phantoms the main differences are observed for small structures such as the lens on the eye and the skin. Based on a uniform activity distribution in soil, both ICRP (Publ. 144 on voxel phantoms) and US EPA (FRG-15 using stylized phantoms) have published dose coefficients for external exposures. This project is based on measured soil profiles and calculates the corresponding dose contributions to the new ICRP mesh phantoms and compare the results with those using the current and previous reference phantoms.

Keywords: External exposure, ^{137}Cs, Chornobyl fallout, ICRP reference phantoms, Monte Carlo

The development of a mobile app to simplify and improve accessibility (for clinical hospital physicists) of ICRP dose data intake of radionuclides in patients, staff and members of the public

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ABSTRACT

The International Commission on Radiological Protection (ICRP), is an independent non-profit organization that acts as an international advisory body on radiation protection. All funding is dependent on donations and gifts as well as sales of ICRP publications. The ICRP is structured with a main commission, a scientific secretariat and four standing committees as well as a series of working groups. In recent years, ICRP has worked more actively than before to make available and disseminate its results and recommendations, which has resulted in all publications being made available free of charge after two years. As part of this work, I have (through a project support from the Swedish Medical Physicist Association, SSFF) developed the ICRP's official "ICRP Dose Viewer" mobile app to easily show the ICRP's current dose coefficients for the intake of radionuclides for the general public, radiation workers and for nuclear medicine patients within diagnostic. The advantage of a digital app is that when the ICRP revises the dosage sheets in new publications, this revision will also take place directly in the app. The idea of the app is to simplify the everyday work of hospital physicists as well as for personnel responsible for assessing the intake of radionuclides for members of the general public and occupationally exposed radiation workers. The app gives direct access to absorbed dose and effective dose for all ICRP-dose coefficients for intake of radionuclides. The app is already available today for download through Google Play and App Store (search "ICRP Dose viewer") or via ICRP's website (https://icrp.org/page.asp?id=637). Currently have all revised dose coefficients for occupational been included in the ICRP Dose viewer and once new or revised dose coefficients are published e.g. for members of the public the app will be updated and replace the current absorbed dose and effective dose coefficients.

Keywords: ICRP, dose coefficient, effective dose, mobile app

Age and sex specific cancer risk estimations for healthy tissues in Swedish patients treated with ^{131}I-iodide for benign thyroid diseases

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ABSTRACT

The effective dose (E) is a radiation protection quantity, intended to create the same detriment as the actual non-uniform irradiation. E is derived from the weighted sum of doses to organs/tissues that are known to be sensitive to radiation. However, if only one or a few organs receive most of the irradiation, absorbed dose to the specific organs is a more appropriate quantity to use than effective dose. In situations when the absorbed dose is so high that cell killing occur (as in trestment of benign thyroid diseases) the risk for later cancer is reduced. After radioiodine intake, ~95% of all decays occur in the thyroid and then effective dose is not an appropriate parameter to use. We have previously studied ^{131}I thyroid uptake in 15 female patients with Graves' disease individually and estimated the absorbed dose to both thyroid and healthy tissues (Andersson and Mattsson, 2021). The patients were on average 50 years old (range 17-90) when orally administered with 170 MBq of ^{131}I. Based on data from 3 ^{131}I uptake measurements of thyroid 3, 4, 48 h and a fourt measurement between 3 and 9 days after administration, the iodide transfer rates in the biokinetic model were adjusted to fit the data points for each patient. This resulted in an estinated mean time-integrated activity coefficient of ^{131}I in the thyroid of 110 (range 67-170) MBq*h/MBq, which corresponds to a mean absorbed dose coefficient for the thyroid of 635 (range 390-980) mGy/MBq. The increased cancer risk for non-thyroid healthy tisse for a 50 years old female is $7.2*10^{-3}$ (or 1 in 140 patients) due to the radioiodine treatment. This corresponds to an increased mortality risk of $4.4*10^{-4}$ (or 1 per 230 patients). An estimate of the mortality risk using effective dose would give an increasd cancer mortality risk of 0.58 mSv/MBq x 170 MBq x 5% per Sv = $5.8*10^{-3}$ or 1 per 200 patients. In this case effective dose highly overestimates the mortality risk compared to tissue specific cancer risk models.

Keywords: ^{131}I, thyroid, patient specific, effective dose, lifetime attributable risk

S-coefficients for steady state distribution of ^{134}Cs and ^{137}Cs in the human body

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ABSTRACT

Following an accidental release of radioactive elements from a nuclear power plant, the internal absorbed dose from protracted intake of radionuclides needs to be estimated. Regarding contribution to long-term exposure, it has been shown that ^{134}Cs and ^{137}Cs are the dominant radionuclides. For this calculation, the internal contamination from consumption of contaminated food has to be considered as a continuous intake, rather than a single intake, where the committed equivalent dose to relevant target tissues is given by a dose coefficient or dose per content function. For modelling of populations doses and lifetime attributable risk of cancer, it is also prefarable to estimate the cumulative absorbed dose derived from the absorbed dose rate at given times after the release event. In this study, we have derived absorbed dose rate coefficients for ^{134}Cs and ^{137}Cs, valid for a steady state distribution in the body, based on specific absorbed fractions published by the International Commission on Radiological Protection (ICRP) and model calculations of equilibrium distribution in the female and male adult reference phantoms. The dose coefficients (S-coefficients; Gy s^{-1} Bq^{-1} or, equivalently, Gy Bqs^{-1}) are given for the complete set of ICRP source regions and target tissues given by ICRP, BEIR VII and National Cancer Institute to facilitate epidemiological studies.

Keywords: internal radiation dose, caesium, fallout

Influence of biological sex on the biodistribution and biokinetics of ^{131}I (iodide) in mice

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ABSTRACT

In general, the biological sex is seldom considered when estimating absorbed dose for radionuclide therapy. There are gender differences, e.g. regarding diseases involving hormones. ^{131}I is widely used for treatment of thyroid diseases and some neuroendocrine tumors types. This study was conducted to investigate the potential differences in biodistribution and dosimetry of ^{131}I between male and female mice. Seventy C57BL/6N mice (35 male and 35 female; n=5/group) were i.v. injected with 170 kBq of ^{131}I, and killed after 1 h to 7 d. Altogether 17 tissue samples were collected, weighed and measured for ^{131}I activity concentration. Mean absorbed dose to the tissues was estimated from the biodistribution data. Differences in ^{131}I biodistribution were found for most organs and tissues, especially for the kidneys and salivary glands. For the thyroid, the maximum uptake was found 18 h after administration for both males and females, but then longer retention was found for females. Females received a higher absorbed dose to all organs, except for the kidneys, where males received almost 4 times higher absorbed dose than females. In summary, there were clear differences in biodistribution and biokinetics of ^{131}I between males and females. The results advocate biological sex to be treated as a variable in dose estimations and risk assessments for patients treated with ^{131}I-containing radiopharmaceuticals.

Keywords: biokinetics, dosimetry, sex difference, thyroid, absorbed dose

Radioactive material in Consumer Products

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ABSTRACT

The Danish Health Authority, Radiation Protection (DHA) has investigated consumer products for their content of radioactive material in concentrations above the exemption levels. The study specifically targeted consumer products advertised as containing negative ions or having properties that might indicate contents of radioactive materials. The study aimed to investigate whether the concentration of radionuclides in this group of products was above the Danish exemption limits and thus illegal. Most of the products investigated were found by searching advertisements on the internet. This was performed by using buzzwords such as Quantum Science, Quantum pendant, Scalar energy, Ion energy and Negative ions.

The study has uncovered a market on the internet where radioactive consumer products are sold as having properties beneficial to ones health. The radioactive material has been found in bracelets of latex and metal, different kinds of pendants, bio-cards and a metal wand. The products have been targeting humans as well as certain pets.

Most of the retailers were unaware of the fact that they were selling radioactive products. Their products had been purchased from abroad, with no warnings about being radioactive, but often with the description of containing negative ions which could be measured with a so-called Ion Tester. What the DHA measured was contents of ^{232}Th and ^{238}U and their daughter nuclides. DHA has reasons to believe that the Ion Tester is in fact a Geiger-Muller-detector.

The discovery led to the DHA requested the retailers for lists of the buyers of the products making it possible to contact them to inform them of the risk and how to dispose of the radioactive products that they had purchased. As a supplement to the written contact, the DHA published on their website, information about the results of the study as well as warning of the radioactive consumer products.

Keywords: Radioactive Consumer Products, Negative ions

Proteomic response in thyroid from mice early after ^{131}I exposure

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ABSTRACT

^{131}I is frequently used in nuclear medicine or may be released from a nuclear accident. ^{131}I as iodide accumulates in the thyroid gland and may cause detrimental effects on thyroid tissue. The aim of the present work was to analyse changes in protein expression in thyroid and plasma from mice exposed to ^{131}I. Balb/c nude mice were i.v. injected with 0 or 490 kBq ^{131}I (iodide), and sacrificed 24 h later (absorbed dose of 32 Gy to thyroid). Thyroid and blood samples were collected. Protein levels were determined by Liquid chromatography tandem-mass spectrometry. Proteins with statistically significant altered concentration between irradiated and control samples were defined. Altogether, 17 and 20 proteins showed altered levels in mouse thyroid gland and plasma, respectively, after ^{131}I exposure. Few of these proteins were among previously proposed radiation related proteins. Functional annotation of identified proteins in thyroid and plasma suggests impact on hematopoiesis, reduced oxygen levels, and reduced thyroid function. Potential biomarkers for ^{131}I exposure in plasma were defined, and should be further studied regarding dose response relationship and usefulness.

Keywords: radiation biology, thyroid gland, mass spectrometry, biomarker

Evaluation of RBP4 as urinary biomarker for kidney injury and A1M as kidney radioprotector after administration of ^{177}Lu-octreotate

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ABSTRACT

Patients may develop radiation-induced kidney toxicity years after systemic treatment with ^{177}Lu-octroetotat. Consequently, the current treatment protocol is strictly limited by the risk of late nephrotoxicity. The therapeutic effect could be increased by using better techniques for increasing kidney protection. Early-responding biomarkers predicting late kidney injury may additionally help to identify patients capable of enduring higher activity of ^{177}Lu-octreotate. The antioxidant alpha-1-microglobulin (A1M) could reduce kidney damage in mice after coadministration with Lu-octreotate, suggesting radioprotective potential. The aim of this study was to evaluate retinol binding protein 4 (RBP4) as a kidney injury biomarker after administration of ^{177}Lu-octreotate and A1M. Mice were given 60 MBq ^{177}Lu-octreotate in the tail vein at day 0, together with none, one or several injections with A1M. After 6-10 w, RBP4 and creatinine concentrations were measured in urine by ELISA. The urinary levels of RBP4 in mice irradiated without A1M were similar to those observed in mice irradiated with A1M. Most groups, however, demonstrated large individual variations. In conclusion, RBP4 may be a valid early-responding biomarker for radiation-induced kidney injury. Further experiments should investigate whether A1M functions as a long-term kidney protector.

Keywords: Radionuclide therapy, nephrotoxicity, kidney protection, biomarker

Degree of intra-, and inter-individual variability for the risk of developing second malignant neoplasms after radiotherapy for cancer

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ABSTRACT

Radiotherapy (RT) is an important treatment method for cancer. Although utilization of ionizing radiation is very effective for cancer treatment, it also significantly induces second malignant neoplasms (SMN). It is known that ionizing radiation-related cancer risk and genetic susceptibility to cancer varies for each individual. Important factors that influence this variability are age, sex, individual life-style, comorbidities, genetic and epigenetic make-up. There is insufficient information to establish the magnitude of these differences or whether biomarkers exist allowing identification of patients with a high genetic susceptibility to SMN. Within the SINFONIA project we are investigating to address these issues by studying the in vitro radiosensitivity of lymphocytes isolated from 200 brain, lymphoma and breast primary cancer patients and 100 SMN patients. Blood samples are being collected before and one or two times after RT. We are utilizing whole chromosome paint fluorescence in situ hybridization (FISH) assay for determination of individual mutation levels; gH2AX focus assay together with cytokinesis block micronucleus assay to evaluate the in vitro individual radiosensitivity and genome wide single nucleotide polymorphism (SNP) markers to assess factors that influence the risk of SMN. We have collected and processed about 170 blood samples from primary cancers and about 20 SMN patients. While analysis of these samples are still undergoing, the outcome of this investigation will give us new knowledge and further understanding of the inter- and intra-individual variability for susceptibility to SMN due to radiotherapy.

This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 945196.

Keywords: Cancer, Radiotherapy, Second malignant neoplasm, Individual radio-sensitivity

Economic aspects of decontamination after a radiological accident

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ABSTRACT

High energy prices recently have moved nuclear power back into the limelight. Nuclear power has been an energy source that over the years has given rise to debates related to its benefits and risks. The biggest risk has been large-scale accidents in nuclear power plants that give rise to ground deposition of long-lived fission products such as ^{137}Cs. Some incidents in the world, notably Chernobyl in 1986 and Fukushima in 2011, have made the risks more obvious. After the two accidents, the governments in the respective countries chose different paths concerning decontamination and return of the evacuees. In Japan, extensive land remediation of affected residential areas was carried out at an estimated direct cost of approximately 60-65 million Euros per decontaminated square kilometer. Estimated indirect costs of the remediation vary between 240 to 470 billion Euro.

We have studied hypothetical scenarios after a potential nuclear accident in Sweden. With a focus on decontamination, to varying degrees, we have taken an economic approach and calculated benefits and costs for society. Our calculations include both direct and indirect costs and benefits related to clean-up and possibly resettlement of evacuees. Direct costs for land remediation of residential areas are estimated to amount to approx. 100 million Euro/km2 at the 2020 price level. The results also show that depending on where in the country the accident occurs and how much socially important infrastructure is affected, the cost-effectiveness of cleanup is different. In some cases, it is reasonable to decontaminate completely, while in others the costs exceed potential benefits and are thus not cost-effective.

Keywords: direct costs of decontamination, indirect costs of decontamination, radiation exposure remediation

Some historical incidents with nuclear submarines along the Norwegian coast

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ABSTRACT

Norwegian Radiation Protection Authority (DSA) is the authority and expert agency for safety regarding radiation and radioactivity in Norway. DSA is a national and international notification centre for all types of radiological and nuclear incidents and has a preparedness system for nuclear purpose actions and accidents. The idea of a nuclear-powered submarine was first proposed to the US Navy by physicist Ross Gunn in 1939. The first nuclear submarine USS Nautilus (SSN-571) was set on water on September 30, 1954. Currently, there are roughly 150 nuclear submarines in operation, of which approximately USA 70, Russia 40, China 12, Great Britain 12, France 10 and India 3. There has been an increase in the activities of naval nuclear-powered vessels in the High North and outside the Norwegian coast. and vessels carrying radioactive waste along the Norwegian coastline, confer *StrålevernRapport* 2018:10 *Endringer i trusselbilde* (*"Changes in nuclear and radiological threats and hazards"*, in Norwegian with a summary in English): https://dsa.no/publikasjoner/stralevernrapport-10-2018-endringer-i-trusselbildet/StralevernRapport_2018-10_Trusselvurderinger.pdf
Previously, there has from time to time been incidents with such vessels in the sea area near Norway, which also require emergency handling from the Norwegian authorities. The poster gives some examples of historical events that have been particularly interesting. The incidents include reactor or cooling system failures, fires, and the actions of crews. The information is taken from the archive of DSA and other public sources.

Keywords: Nuclear-powered submarines, Barents Sea, Kola, coast, Norwegian Sea, accidents

^{137}Cs and isotopic ratios of Pu and U in lichen and moss from Russian Arctic areas sampled in the 1990s

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ABSTRACT

Radioecological situation in Russian Arctic areas was studied retrospectively by determining radionuclide concentrations and isotope ratios from lichen and moss samples, which were collected in the 1990s. The obtained data enables assessment of the past radioactive contamination sources in these regions. The sampling sites included Kola Peninsula, Franz Josef Land, Vaygach Island, Yenisey estuary, Novaya Zemlya, and also Finnish Lapland as a reference site. First, the activity concentration of ^{137}Cs was determined from the lichen and moss samples by gamma spectrometry in 2020. Then Pu and U were separated from the samples by acid digestion, ion exchange and extraction chromatography. Mass ratios ^{240}Pu/^{239}Pu, ^{234}U/^{238}U, ^{235}U/^{238}U, and ^{236}U/^{238}U were determined from the samples by ICP-MS. The activity concentration of ^{137}Cs in lichens and mosses varied from 3.1±1.4 (Inari, Finnish-Russian border) to 303±7 (Kola Peninsula) Bq kg^{-1} (activity corrected to sampling date). The isotope ratios varied from 0.0592±0.0007 to 0.253±0.082 for ^{240}Pu/^{239}Pu, from (4.89±3.91) × 10^{-5} to (6.86±0.04) × 10^{-5} for ^{234}U/^{238}U, from 0.0072104±0.0000021 to 0.007376±0.000041 for ^{235}U/^{238}U, and from < 1 × 10^{-7} to (2.65±0.19) × 10^{-6} for ^{236}U/^{238}U, respectively. Most of the determined isotope ratio values indicate nuclear contamination from atmospheric nuclear weapons testing, Chernobyl accident and undefined local nuclear activities. The obtained results increase awareness of radioecological consequences due to past nuclear events in terrestrial environment of Russian Arctic.

Keywords: uranium, plutonium, isotope ratio, Arctic, nuclear weapon, radioactive contamination

The current NKS program: some new R&D developments

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ABSTRACT

NKS is a common Nordic forum that provides financial support for research activities of relevance to nuclear and radiological safety in the Nordic community. Competence building / maintenance and knowledge sharing are among the most important elements in NKS, which builds on a vast common Nordic cultural heritage. Specifically in relation to nuclear and radiological issues the involved countries (Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands and Greenland) have collaborated since the end of world war two. Throughout the latest few decades, NKS has operated two R&D subprograms: the NKS-R program focusing on reactor safety issues, and the NKS-B program on nuclear and radiological emergency preparedness and management, radioecology and measurements of radioactive materials in any environment. NKS also arranges a seminar every third year in Stockholm bringing Nordic and other experts and interest groups together for a discussion of current and future needs in view of the latest research developments. Compared with for example the European Union's programmes, the funding NKS can provide for research is very limited, but due to an uncomplicated and lean administration procedure, NKS provides room for new and untraditional thinking, efficiently addressing new and emerging problems very rapidly. For example, on the NKS-B side, a series of activities (MUD, AVESOME, SOCHAOTIC) have examined the influences of various parametric uncertainties (e.g., wrt. source term and weather) on airborne contamination prognoses from different release scenarios through series of ensemble runs, which inspired EU to do the same. Already in late 2020, the NUCSEM seminar put focus on scenarios and impact assessments in relation to use of nuclear weapons, and for some years, the Nordic countries have channeled a mutual interest in decommissioning waste out in state-of-the-art NKS projects on measurements of difficult-to-measure radionuclides. The presentation will provide an overview of the latest developments under NKS.

Keywords: radiological, nuclear safety, Nordic, emergencies, radioactive contamination, reactor

Radon Exposure in Swedish Workplaces

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ABSTRACT

After the implementation of the EU BSS Directive 2013/59/Euratom, more focus has been put on radon measurements in European workplaces. From the radon measurement data of Radonova, estimates of possible personal radon exposures (mSv) in Swedish workplaces are made using dose conversion factors from ICRP Publication 137. During 2017-2020, Radonova analyzed long-term radon measurements in more than 3000 Swedish workplaces with 5 or more measurement points in each. In 34 % of these workplaces, radon levels above the Swedish reference level of 200 Bq/m^3 were found. The data are discussed with respect to parameters such as type of workplace and uranium concentration in the soil. In workplaces with time-controlled ventilation, the differences between radon levels during working hours and non-working hours can be large. From short-term follow-up measurements with a continuous radon monitor, a factor between radon during working hours and the total measurement period can be obtained which can be used together with the previous long-term measurement to get a better estimate of the radon concentration during working hours. A preliminary analysis of about 100 follow-up measurement give a factor of 0.26 between radon levels during working hours and the complete measurement period. Results show that radon exposure can be a large part of radiation exposure in Swedish workplaces. Discussions are made about which workplace types have the largest risk for high radon exposures.

Keywords: Radon, Workplaces, Sweden, Exposure

Swedish Society for Radioecology

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ABSTRACT

The Swedish Society for Radioecology – Svensk Förening för Radioekologi (SFREK) – is a non-profit organisation and was founded in April 2001, at the initiative of Klas Rosén and others at the Department of Radioecology at the Swedish University of Agriculture (SLU). Since the start of the society research in radioecology has experienced increasing difficulties to get fundings with a diminishing number of fulltime researchers as a result. This was confirmed by a SFREK survey among its members in 2017. The aim of the society is to promote research within radioecology and related research areas; to work for communication between researchers, decision-makers, media and the public and to draw attention to current issues in radioecology and to disseminate information related to radioecology. For achieving the aims, SFREK uses its website (radioekologi.se), e-mail member list, and organises digital and physical seminars for its members and others. SFREK has also communicated the need for increased attention to the threatened situation of radioecology research in Sweden (in 2015), that SSM partly have improved in recent years. At the annual meetings, SFREK members may nominate a person that have contributed significantly to the aims of the society, for the award “Radioecologist of the year”.

The present board is constituted of seven persons from three universities, industrial and governmental bodies. The number of members is increasing and in spring 2023 there were 77 SFREK members.

Keywords: radioecology, SFREK, society

Swedish academic initiative for radiation sciences and nuclear technology

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ABSTRACT

Swedish academic initiative for radiation sciences and nuclear technology (SAINT) is an academic centre of competence for radiation science. It joins people at Swedish universities that are involved in research and education within fields related to radiation science. The common goal of SAINT is to facilitate a sustainable environment for research and education in Sweden. We aim to reach this goal by a transparent dialog between members of SAINT, by actively stimulating research collaboration and sharing laboratories and infrastructures between members. We also make efforts to attract excellent and committed students to support the national competence development in this field. SAINT started in 2017 as a collaboration between groups at Chalmers and Uppsala University but has since expanded to University of Gothenburg, Academy, Stockholm University and Lund University. In April 2021 the Swedish Radiation Safety Authority became an adjunct member. In addition, the Swedish Centre for Nuclear Technology (SKC) is an appointed an observer. In SAINT, membership fee applies, which currently stand at 50 000 SEK/year/university to cover part time positions for coordinator and director, as well as meeting costs. SAINT is organizationally placed at Chalmers, Department of Chemistry and Chemical Engineering, Energy Area of Advance, but with an ambulatory appointment of coordinator and director (typically for a period of 2 years) between the member institutions. Examples of activities include 2 workshops per year, often with a specific topic, such as the need for joint infrastructure. Most notable activity, however, is the establishment of a formal connection with SSM (Program owner and Manager, POM), aiming to allow SAINT members to more actively apply to European Joint Programs within radiation protection which requires co-funding (to become linked third parties to be able to use in kind contributions).

Keywords: SAINT, competence, collaboration, research and education

The Swedish Radiobiological Society

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ABSTRACT

The Swedish Radiobiological Society was founded in 1965, with the first chair being Arne Forssberg, professor of Radiobiology at the Karolinska Hospital in Stockholm. Forssberg studied, among many other things, the effects of oxygenation and dose rate, and the biochemical interactions during the first seconds after radiation exposure. One of the Society's notable first board members was Åke Gustafsson, professor of Genetics at Lund University, who studied the mutagenic properties of ionising radiation, utilizing the increased genetic variability in selective plant breeding. Another original board member was Börje Larsson, professor of Physical Biology at Uppsala University, who made significant pioneering contributions in many areas including proton radiotherapy and PET-imaging. It was in this multifaceted and multidisciplinary scientific environment that the foundation of the Society was formed. This is also reflected in the statutes. The aim is to promote interest for radiobiological research by connecting people within natural sciences, medicine and technology. Today, the Society has about 80 members representing a broad distribution of both sites and research areas. The main activites include sharing of information about courses, seminars, positions, grants and events, among the members. The society also offers travel grants for active conference particpation, and presents an award in the memory of the renowned professor Lars Ehrenborg. An annual meeting is held in November, often accompanied by a scientific spring meeting. The present board of the Society has representatives from five Swedish universities and one institute.

Keywords: Radiobiological Society, History, Activities, Network

The Royal Swedish Academy of Sciences

National committee for Radiation Protection Research

(NKSSF)

NKSSF

National committee for Radiation Protection Research,

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ABSTRACT

The National committee for Radiation Protection Research (NKSSF) was established by the Royal Swedish Academy of Sciences (Academy) in 1963 upon the request from Rolf Sievert. The main task of the Committee is to meet the needs for a comprehensive discussion on all types of radiation protection problems. The Committee has therefore a very important role as an interdisciplinary forum and a consultative body for many different disciplines.
An important task is also to act as a consultative body on research issues related to both ionising and non-ionising radiation. In this regard, the Committee is unique in its wide, multidisciplinary competence.

The National committee's other aims include:

- promote research and education within its discipline
- promote cooperation with contiguous disciplines
- promote its discipline's influence in society (education, general public and industry)
- give advice to universities and other parts of the educational system
- give advice to the Academy

Many symposia and statements of opinion are produced in cooperation with the Academy's other committees and classes. Committee members include researchers as well as representatives from industry, public administration, education and media.

Keywords: KVA, Rolf Sievert, Radiation Protection, National Committee

SWE-RAYS: Illuminating the Path for Young Radiation Researchers in Sweden

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ABSTRACT

Introduction: Swedish Radiation Research Association for Young Scientists (SWE-RAYS) is an association of PhD students and young scientists engaged in radiation-related research in Sweden. Founded in 2012, the network aims to promote collaboration among Swedish research groups and to encourage young scientists to advance their careers.

Methods: SWE-RAYS supports its members by organizing events and providing opportunities for networking and professional development. A workshop is held every year by SWE-RAYS, usually at the end of summer and the beginning of the fall semester. The workshop is an opportunity for members to present their research and to network with other radiation scientists. A variety of evening activities and invited speakers are also part of the workshops. The network is financially supported by the Centre for Radiation Protection Research (CRPR) at Stockholm University. Any funding will be used to promote PhD students and post-docs.

Results: Since its inception, SWE-RAYS has grown to include members from several research institutions in Sweden. The network has facilitated collaboration among researchers in radiation-related fields and provided valuable opportunities for career development for its members. SWE-RAYS has organized several successful workshops with valuable topics such as presentation techniques, stress management and workload streamlining.

Conclusion: SWE-RAYS is a valuable network for PhD students and junior researchers involved in radiation-related research in Sweden. It is hoped that SWE-RAYS has contributed to bringing together young researchers working in diverse fields of radiation science by providing support and opportunities for collaboration and career advancement.

Keywords: SWE-RAYS, young scientists, radiation research, Sweden, career development, networking, collaboration, PhD students, post-docs, ionizing radiation, non-ionizing radiation, radiobiology, radiation physics, medical physics, nuclear medicine, radiation therapy, radiation safety, radiation dosimetry, environmental radiology

Swedish Society of Radiation Physics (SFfR) – a force for a stimulating exchange of experiences and knowledge in the field of radiation physics

INTRODUCTION

Swedish Society of Radiation Physics – Svensk Förening för Radiofysik (SFfR) – is a non-profit scientific association that is open for all that have a connection to and are interested in radiation physics. The association was founded in 1961.
SFfR is the Swedish Society of Medicine's– Svenska Läkaresällskapets – section for Medical Physics. Together with sister organisations in the neighbouring countries we form the Nordic Association for Clinical Physics (NACP). SFfR is also affiliated with the International Organization for Medical Physics (IOMP) and to the International Union for Physical and Engineering Sciences in Medicine (IUPESM).

PURPOSE

The purpose of the Swedish Society of Radiation Physics is to promote developments in different areas of radiation physics such as research, radiation protection and healthcare, nationally as well as internationally.

WHAT WE DO

The Swedish Society of Radiation Physics organizes scientific meetings, provides support to working groups, offers travel grants, advertises vacancies, and responds to legal referrals. The association administers the Lidén award and the Sköldborn award, to promote quality in radiation physics research, and the Vikterlöf award, to inspire those working in the field. To encourage students, the association each year awards up to three master theses in radiation physics.

CONTACT

Current board members: Åsa Palm, president, Matias Sandström, vice president and course secretary, Lars Ideström, treasurer, Rebecca Titternes, secretary, and Kerstin Lagerstrand, scientific secretary.
For questions, please send an email to radiofysik@radiofysik.org
Information on how to become a member can be found at www.radiofysik.org

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