Norwegian University of Life Sciences

Norwegian Centre of Excellence

CERAD

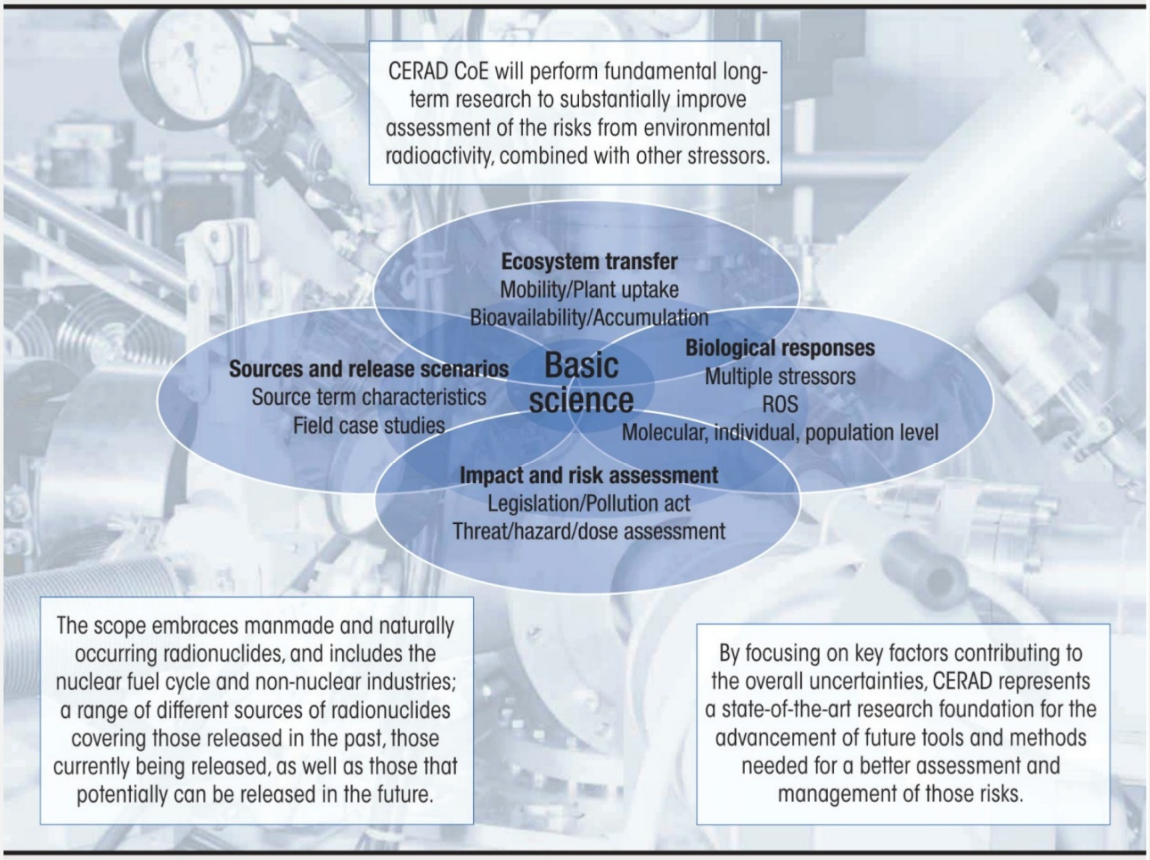
CENTRE FOR ENVIRONMENTAL RADIOACTIVITY

Design & Layout: Signe Dahl, NMBU

Coverpage, outside: Kildin Island, Murmansk Fjord. Expedition 2014. Photo: Hans-Christian Teien, NMBU

Photo coverpage, inside: Signe Dahl, NMBU

The Research Council of Norway has established CERAD Centre for Environmental Radioactivity, to provide new scientific knowledge and tools for better protection of people and the environment from harmful effects of radiation (2013-2023).



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CENTRE FOR ENVIRONMENTAL RADIOACTIVITY

CERAD CoE - In Short 2014

CERAD Partners	
NMBU= UMB+NVH	Norwegian University of Life Science
NRPA	Norwegian Radiation Protection Authority
MET	Norwegian Meteorological Institute
NIPH	Norwegian Institute of Public Health
NIVA	Norwegian Institute for Water Research

Scientific Results	**Number**
Scientific Articles	25
Books/Monograph	0
Technical/Scientific Reports	5
Presentations Internationally	54
Presentations Nationally	12
Popular Science Presentations	2

Funding 2014	**Million NOK**
RCN funding	16.5
In kind, Direct	2.25
In kind, Personnel	19.5
Other research projects (NMBU/Isotope Laboratory)	3.6
Total	41.85

Human Resources - Part time Personnel	
Professors	13
Ass. professors/Scientists	42
Technicians	8
Administration	2
Post Docs	4
PhD	6
MSc	4
Guest Researchers	10
Total	89

Ice sculpture, NMBU
Photo: Signe Dahl

CERAD CoE - In Short 2014

The CERAD CoE, established in 2013, has initiated long term basic research to improve the ability to accurately assess the radiological risks from environmental radioactivity combined with other stressors. By focusing on key factors contributing to the uncertainties, CERAD represents a state-of-the-art research foundation for the advancement of tools and methods to better manage those risks. The scope includes man-made and naturally occurring radionuclides that were released in the past, those presently released, and those that potentially can be released in the future from the nuclear fuel cycle and from non-nuclear industries.

Using an ecosystem based scientific approach, CERAD focuses on different source term and release scenarios, transfer of radionuclides in terrestrial and aquatic ecosystems, biological responses in organisms exposed to radiation combined with other stressors such as metals and UV radiation under varying temperature/climate conditions, to assess overall environmental impact and risks. The assessments will include possible impact not only on man and non-human organisms, but also economic and societal consequences. The strategic research agenda (SRA) developed in 2013-2014 covers a broad scientific field, while most emphasis will be put on eight key Umbrella areas contributing significantly to the overall uncertainties. The program is based on the interdisciplinary effort from scientists representing five Norwegian organisations (NMBU, NRPA, MET, NIPH, NIVA) and a network of international specialists.

CERAD Management Group (MG)

From left: Deputy Director Per Strand, Research Director Deborah H. Oughton, Education Director Lindis Skipperud, Centre Director Brit Salbu.

Photo: Gisle Bjørneby

COMMENTS FROM THE CENTER DIRECTOR BRIT SALBU

Two years of the CERAD´s life has passed, and it has been a pleasure to follow the development of the CERAD team of researchers in initiating a long term basic research program. The Centre has made important progress towards its goal of reducing the overall uncertainties in impact and risk assessments associated with environmental radioactivity, combined with other stressors. The development of the strategic research agenda (SRA) has been a most fruitful process during 2013 and 2014, both with respect to the identification of key research areas and to the integration of a scattered crowd of 40-60 part time scientists representing expertise within different fields of science, different scientific culture and priorities, as well as different institutions. By focusing on common goals, hypotheses and research questions, an ecosystem based long term research program on source terms and release scenarios, ecosystem transfer, biological responses forming the basis for impact and risk assessments has been developed. During 2014, the SRA has been extended and the integration process gone further. At the end of the year, the efforts were gathered under 8 key research topics (Umbrella research areas): Particle sources and effects, Dynamic ecosystem transfer, Radiosensitivity, Combined Toxicity and Cumulative Risk, Transgenerational effects, Ecosystem approach, UV/ ionising radiation and dosimetry, as well as Case studies (Hypothetical nuclear accidents of relevance for Norway).

During 2014, major progress has been obtained locally, nationally and internationally, both administratively and scientifically. From January 1, the Norwegian School of Veterinary Science (NVH) were merged into UMB, forming the new Norwegian University of Life Sciences (NMBU). Thus, CERAD today includes NMBU and 4 partners (NRPA, MET, NIVA, NIPH). At the same time, the new NMBU Prorektor Halvor Hektoen took over as chair for CERAD, and 3 members of the board were replaced. In March 2014, the CERAD conference was organised at the Norwegian Academy of Science with about 80 participants, including representatives from CERAD international network (SAC) and stakeholders (RAC). During the year, several CERAD funded workshops were also organised nationally and internationally. A successful at site full day meeting with the Research Council of Norway was organized in September 2014.

An essential ingredient in CERAD is researcher training and education (MSc, PhD) to provide an internationally attractive research environment, and to produce candidates that are internationally competitive. In 2014, 10 PhD/PostDocs are linked to CERAD, and an additional 4 are expected in 2015. The EU supported NMBU MSc in Radioecology is unique in Europe, and a Research School has been established. The course modules given in English are run intensively to make access possible for students from abroad. Joint MSc in Radioecology has also been initiated with the University Paul Cezanne/Aix-Marseille, France, and with the Moscow State University, Russia, forming a valuable recruitment base for PhD education.

As the CERAD politics includes collaboration and co-financing of the activities with other organisations nationally and internationally, new initiatives were taken in 2014. Thus, 4 new EC funded projects and 2 new nationally funded projects have been accepted, also providing access to internationally facilities and experimental sites. CERAD has also become a member of the ALLIANCE (*www.er-alliance.org*) and NERIS (*www.eu-neris.net/*) platforms, as well as partner in the European Joint Programming CONCERT.

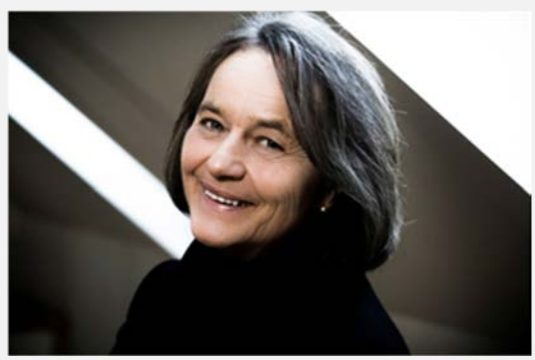
Several expeditions have taken place during 2014; to the Chernobyl 30 km zone, Ukraine, together with IRSN, France, to investigate biodiversity (earthworms); to Poland together with EU COMET partners to investigate NORM contamination associated with mining; to Uzbekistan to investigate

NORM transfer to vegetation; and to the Barents Sea together with Russian scientists to identify if leakages associated with a sunken submarine with fuel could be observed. In 2014, very successful experiments were also performed at the nano beam line at the ESRF synchrotron facility (ID16A) in France.

The International Conference on Radioecology & Environmental Radioactivity (ICRER) was organized in September 2014, Barcelona, Spain, in collaboration with NRPA, a CERAD partner. Per Strand, the deputy chair of CERAD, acted as president of the conference, and CERAD participants contributed with about 20 oral presentations and posters (See ref. list). At the beginning of the ICRER conference, the CERAD director was awarded with the 4th V. I. Vernadsky price.

The scientific programme of CERAD is much more ambitious than anything hitherto attempted within radiation research in Norway. Thus, most field and lab experiments have been performed as an interdisciplinary effort, where exposure (chemistry) is linked to responses (biology), and where dynamic modelling are further developed. Most focus has been put on gamma exposure using the unique low level gamma facility at NMBU or on exposure by depleted uranium and cadmium, individually and in combination with gamma radiation. A series of organisms, also at different life history stages, have been utilized in the experiments; salmon, zebrafish, GMO mice, nematodes (*C. elegans*), earthworm, daphnia and plants using a series of biomarkers related to ecological relevant endpoints. The most comprehensive project focuses on impact and risks (man, environment, economy and society) associated with a hypothetic nuclear accident with deposition in Norway. Emphasis is put on key factors that are contributing significantly to the overall uncertainties when a series of models – from the source to the risks - are coupled. The Research Highlights summarized in the present volume, reflecting the scientific progress, should be of interest to the national and international radioecology community.

It is still a privilege to be head of CERAD, a research organization with highly competent scientists, the well merited international network forming the Scientific Advisory Committee, and motivated stakeholders representing the Relevance Advisory Committee. Therefore, I am looking forward to the progress with respect to scientific and conceptually output, to the further development of a robust scientific organisation, and to an even more important role of CERAD nationally and internationally.



Center Director professor Brit Salbu
Photo: Gisle Bjørneby

COMMENTS FROM HALVOR HEKTOEN, THE CHAIR OF THE CERAD BOARD 2014

Centre for Environmental Radioactivity (CERAD CoE) objective is to provide new scientific knowledge for better protection of people and the environment from harmful effects of radiation by itself or together with other stressors. With a base in science, stakeholders will thereby be able to conduct risk assessments of environmental radioactivity from past or presently released sources, or from sources potentially released in the future.

The host institution, the Norwegian University of Life Sciences, NMBU, together with the Norwegian Institute of Public Health, the Norwegian Meteorological Institute, the Norwegian Radiation Protection Authority and the Norwegian Institute for Water Research represents an exciting and new multidisciplinary collaboration. It is truly in the interface between research areas that interesting and novel questions and hypothesis may arise.

2014 has been an active year for CERAD. While the focus the first year was to bring the participants together, develop the overall Strategy Research Agenda and initiate the research activities, interesting results are now emerging from the research groups. During a two day CERAD seminar in March 2014, we witnessed researchers from a wide spectrum of disciplines present results and share ideas and plans.

More than 50 researcher and 10 PhD students and postdoctoral fellows are now linked to CERAD. In addition, about 15 guest researchers from other institutions and countries have spent time working at the centre the last year. The activity at Figaro, the gamma irradiation installation, is at high speed. The enormous research activity certainly makes administrative challenges. The well-organized Centre administration with Centre Director Professor Brit Salbu and with strong support from the Management Group has shown its necessity. In order to make the centre activities more robust and focused the leadership suggested some organizational adjustments. CERAD is now organized through scientific umbrella areas, which ensures better interdisciplinary approach. On behalf of the board, I will use the opportunity to thank all of you for the great effort during the last year.

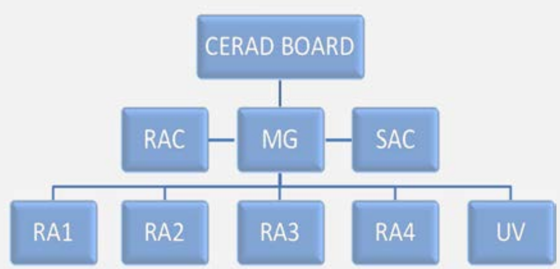
An important part of CERAD is the educational activities, both on master level and PhD-level. NMBU and CERAD have established a masters program in Radioecology which gives the opportunity for students from Europe and other countries to come together. The program uses expert teachers from different institutions in Europe and North America.

In September, we were glad to welcome the Norwegian Research Council at a site visit. The Research Council got a brief presentation of the status and the further development of the Centre. We felt more confident that CERAD was on the right track, and got valuable practical information concerning reporting and preparing for the midterm evaluation.

Finally, I want to congratulate Professor Brit Salbu, on behalf of the board and NMBU, for receiving the 4th IUR V.I. Vernadsky award. She received this award in recognition of her outstanding contribution to the development and dissemination of Radioecology.

The chair of the CERAD board 2014,
Pro-Rektor of NMBU,
Dr Halvor Hektoen

The UV group is referred to as RA5



ORGANISATION OF CERAD

CERAD BOARD MEMBERS

Pro-rector Halvor Hektoen, NMBU, Chair
Director Ole Harbitz, NRPA, Deputy chair
Department Head Jan Vermaat, NMBU/IMV
Division Director Toril Attramadal, NIPH
Deputy Managing Director Tor-Petter Johnsen, NIVA
Research Director Øystein Hov, MET
Scientist Dag Anders Brede, NMBU
Centre Director Brit Salbu, CERAD

CERAD CENTRE MANAGEMENT GROUP MG:

CERAD Director B. Salbu, Professor, NMBU and Head of Isotope Laboratory
Deputy Centre Director: P. Strand, Department of Nuclear Safety and Environmental Radioactivity, NRPA/Professor II, NMBU
Education Director: L. Skipperud, Professor, NMBU
Research Director: D.H. Oughton, Professor, NMBU

EXTENDED MANAGEMENT GROUP

MG + Research Area (RA) Leaders
RA1 O.C. Lind + J. Bartnicki
RA2 J. Brown + H.C. Teien
RA3 A.K. Olsen + P. Aleström
RA4 A. Liland + K.E. Tollefsen
RA5 T. Christensen + J. Olsen

RAC – RELEVANCE ADVISORY COMMITTEE:

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The Ministry of Trade, Industry and Fisheries, Lars Føyn
Ministry of Climate and Environment, Ingvild Swensen
The Ministry of Foreign Affairs, Johnny Almestad
Norwegian Radiation Protection Authority, Kristin Frogg

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Glenn Seaborg Institute, LLNL, USA

Dr Valery Kashparov,
National University of Life and Environmental Sciences of Ukraine, Ukrainian Institute of Agricultural Radiology, Ukraine

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University of Antwerp, Belgium

Professor Peter Stegnar,
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Professor Carmel Mothersill,
McMaster University, Canada

Professor Colin Seymour,
McMaster University, Canada

Dr Tom Hinton, IRSN, France

Dr Clare Bradshaw,
Stockholm University, Sweden

Dr. Marcel Jansen,
University College Corc, Ireland

Forskningsrådet

Summary of marks

Criterion	Mark
Scientific merit	7
The project manager and project group	7
Feasibility	A
International cooperation	A
National cooperation	A
Value added generated by establishment of the centre	7
Dissemination and communication of results	A
Overall mark	7

Andedammen and Cirkus, NMBU
Photo: Signe Dahl

CERAD Strategic Research Agenda

INTRODUCTION AND BACKGROUND

The CERAD Strategic Research Agenda (SRA) presents the five CERAD research areas (RA) and their main research questions, hypothesis and approaches to testing those hypotheses. In addition to focusing on the key challenges within individual research areas, the SRA also identifies integrated research areas, and forms the basis for decisions about needs and priorities for personnel, experiments, and equipment within CERAD. Following brain storming sessions and several workshops, the first outline of the SRA was completed in April 2013, with the involvement of over 40 scientists from all partner organisations, in addition to consultations with CERAD international partners. The second draft was produced in January 2014.

DESCRIPTION AND EVOLUTION OF THE RESEARCH AREAS

The CERAD CoE was founded around five overarching Research Areas: RA1 Source Term and Release Scenarios; RA2 Ecosystem Transfer, RA3 Biological Effects; RA4 Risk Assessment and RA5 UV exposure. From 2015 these will be reorganised into 8 cross-cutting umbrealla projects (see final section).

PRIORITISATION OF RESEARCH ACTIVITIES

The SRA formed the basis for selection of research priorities and projects for 2013 and 2014 (see page 14 and 15). The main priority was given to projects providing opportunities for collaboration between partners in order to stimulate integration across research areas (see below). For 2014, two additional criterias were: Funding of new positions (PhD, PostDocs) and Availability of co-funding from CERAD partners.

OTHER FUNDING CRITERIA INCLUDED:

- Relevance: Radiation ecology, risk evaluation, novelty, basic science, multidisciplinary, reduce overall uncertainties, relevance with respect to sources/threats of concern to Norway.
- Potential impact: Increased protection of man and the environment, accordance with societal needs, applicability to radiation protection, change in paradigm, education/ training/recruitment.
- Feasibility: Availability of expertise, access to relevant sites, samples, facilities infrastructures, experimental models.

INTEGRATION ACROSS RESEARCH AREAS

Collaboration across different research areas is an important mechanism for integration and collaboration, both scientifically and to build human competence and capacities.

Hence a number of joint projects were included within the SRA. Briefly, the case study scenarios acted as a focus point for all RAs, impacting on the knowledge needed for fieldwork and laboratory model studies. Sensitivity analysis should highlight the factors, variables and processes contributing to the overall uncertainties in risk assessment. Collaboration between release scenarios and ecosystem transfer is particularly important with respect to the source-term, speciation and particle weathering impacts on transfer, including UV impacts on transfer. Ecosystem transfer is linked to biological response with respect to the exposure of organisms, bioavailability and uptake, depuration and retention of radionuclides as well as stressors such as metals or deficiency of antioxidants like selenium. Impact and risk assessment is linked to all other RAs, which uses results to improve the analysis of risk, impact and benefit-cost.

OBJECTIVES AND KEY RESEARCH QUESTIONS

A brief summary of some of the overarching objectives and key research questions within the RAs is given below together with a table of projects from 2013 and 2014. More detailed information on the ongoing projects and approaches to answering these questions can be found in the Research Highlights Section.

RA1 Source terms and release scenarios:

To characterize radionuclides released from different sources under different release scenarios with respect to physico-chemical forms, and to use such information to better determine the potential implication for air/water dispersal and further environmental transfer through development of integrated models.

Key research questions:

- How do release scenarios impact the release (source term); radionuclide and multiple stressor composition and speciation, in particular the nano- and micrometer sized particle characteristics,
- What is the relevance of particle releases to air/water transport, deposition and exposure models?
- What is the relevance of uneven particle exposure to dose estimates?

RA2 Ecosystem transfer:

To specify how speciation, co-contaminants, climate conditions and biological factors influence radionuclide transfer through ecosystems in a Nordic context, and to replace equilibrium transfer constants with time and temperature dependent functions.

Key research questions:

- What are the key factors that influence, under boreal and sub-arctic climatic conditions, the mobility and speciation of radionuclides in soil, sediments and water?
- Which abiotic factors influence food chain transfer in Nordic environments?
- Which physiological parameters influence accumulation in different organisms?
- How do ecological factors, such as trophic interactions, influence the bioaccumulation of radionuclides?

RA3 Biological responses:

To identify responses induced in biota exposed to medium to low radiation doses/dose rates, in combination with other stressors such as UV radiation, metals and antioxidant deficiency under varying temperature/climate conditions.

Key research questions:

- Are effects at high doses/dose rates relevant for low doses/dose rates? If yes – does this apply to both humans and non-human biota?
- Which biomarkers are most relevant for field investigations and chronic exposures?
- What are the implications of chronic multi-generational exposures for reproduction, hereditary and epigenetic effects?
- To what extent are the effects of ionising radiation (gamma, alpha) on living organisms modulated by exposure to other chemical stressors?
- Why are some species, tissues and life history stages more sensitive to ionising radiation than others?

RA4 Impact and risk assessments:

To evaluate and improve impact, risk and benefit-cost assessments for establishing a scientifically based set of decision criteria for handling radiation and multi-stressors within an environmental and societal perspective.

- Can harmonization and integration of risk assessment approaches improve the existing models?
- Can the risk of multiple stressors be predicted on basis of in-depth knowledge of the exposure and effect of single stressors to identify ecological relevant risk scenarios?

- How can benefit-cost analysis be used to illustrate the trade-off between environmental and public health risk and net benefits of mitigating measures and regulatory actions in a societal perspective?
- How can we reduce the overall uncertainties in impact and risk assessments?

RA5 UV GROUP

To evaluate how UV and ionizing radiation interact in biological systems and the effects of tertiary stressors (e.g. biological processes, metals,) and climate change (e.g. temperature and acidification) on transfer and effects.

- To what degree do the damage and regulatory effects induced by UV in terrestrial and aquatic organisms depend on life cycle stages and environmental conditions?
- How does the production and composition of ROS species induced by UV, ionizing radiation and other stressors differ?
- Can the protective mechanisms induced by one stressor protect against effects of other stressors?

NMBU
Photo: Signe Dahl

REORGANISATION INTO UMBRELLA RESEARCH AREAS

By the end of 2014, CERAD had supported 48 sub-projects with budgets ranging from 50-650 k NOK. These ranged from small pilot studies to large projects involving all partners. In order to better stimulate cross-partner activities, at the beginning of 2015 the five research areas were reorganised into eight large umbrellas.

These are:

- UMB1: Particle sources and effects
- UMB2: Dynamic transfer
- UMB3: Radiosensitivity
- UMB4: Combined Toxicity and Cumulative Risk
- UMB5: Transgenerational effects
- UMB6: Ecosystem approach
- UMB7: UV-/ionising radiation and dosimetry
- UMB8: Case Studies
  - 8A - Western Norway Scenario
  - 8B - Arctic

Highlights from many of the 2013 and 2014 projects have been included in this report. Some of the projects will continue under the new umbrellas.

CERAD
CENTRE FOR ENVIRONMENTAL RADIOACTIVITY

Reasearch Activities

Research Projects 2013	Collaboration	NMBU IS	NVH	NRPA	NIVA	NIPH	MET
Projects:	Project leader:			CERAD Participants			
Research Area 1							
U1-1 Virtuelt scenario	NMBU IS; OCL	x		x	x	x	x
U1-2 Source term, K-27	MET; JB	x		x			x
U12-1 TRAP	NRPA; JB	x		x			
Field work/samples available							
U12-2 KOMI NORM	NMBU IS; DO	x					
U12-3 Chernobyl	NMBU IS; LS	x		x			
U12-4 Fukushima	NMBU IS; DHO	x					
U12-5 Kara Sea	NMBU IS; OCL	x		x			
Research Area 2							
U2-1 Modell particle, Water-soil	NMBU IS; OCL	x		x			
U2-2 Modell particle, C-elegans	NMBU IS; DB	x					
U2-3 Modell exp, salmon + U	NMBU IS; HCT	x		x	x		
U2-4 Modell exp, algae + U	NIVA; ARU	x		x	x		
U4-1 ERICA Dynamics	NRPA; JB	x		x			
Research Area 3							
U3-1 Zebrafish + gamma	NVH ; JL	x	x	x			
U3-2 Se Mice + Gamma genotox	NIPH; AKO	x				x	
U3-3 Se Mice + Gamma riRNA	NIPH; AKO	x				x	
U3-4 C elegans mix tox	NMBU IS; DB	x					
U3-5 RBE-Zebrafish	NVH; JL	x	x	x			
Research Area 4							
U4-2 Sensitivity Analysis	NRPA; AJ	x	x	x	x		x
U4-3 Workshops	NIVA; KET	x	x	x	x	x	
Research Area 5							
U5-1 UV + zebrafish	NVH ; JL	x	x	x			
U5-2 UV + plants	IPM; JEO	x				x	
U5-3 Testing cell culture	NIVA; KPE			x	x		
U5-4 UV-antioxidant	NRPA; TC		x	x	x		
Equipment 2013	NMBU IS; OCL						
ICP-QQQ-MS		x					
U5-6 FIGARO upgrade		x					
U5-7 FFF auto sampler		x					
U5-8 UV installation		x		x			
U5-9 Exposure incubators					x		
U5-10 FIGARO control shielding		x					

Research Projects 2014	Collaboration	NMBU IS	NMBU VET	NRPA	NIVA	NIPH	MET
Projects:	Project leader:		CERAD Participants				
Research Area 1							
U1-1 Virtuelt scenario	NMBU IS; OCL	x		x	x	x	x
U1-2 Source term, K-27	MET; JB	x		x			x
U1-3 Atm Model development	MET: JB	x		x			x
U1-4 Marine Model develop	MET: JB	x		x			x
U1-5 Model RN Irish Sea	MET: JB	x		x			x
U1-6 Micro/nano CT	NMBU IS; OCL	x					
U12-4/5 AMS	NMBU IS; CWW	x		x			
U1-7 TOF SIMS	NMBU IS; OCL						
U1-8 Logging Vikedal	NIVA; YL	x		x	x		
Research Area 2							
U2-3 Modell salmon geneotox	NMBU IS; HCT	x			x		
U2-5 Modell salmon Cd/U	NMBU IS; HCT	x		x	x		
U2-6 UV and U FFF	NMBU IS; HCT	x					
U2-7 NORM Mobility	NMBU IS; LS	x		x			
U2-8 NORM E-18	NMBU IS; LS	x		x			
U12-1 TRAP/SNAP	NRPA; HT	x		x			
U2-10 Tilapia	NMBU IS; HCT	x					
U2-11 Key factors transfer	NRPA; JB			x			
Research Area 3							
U3-5 Zebrafish transgeneration	NMBU-VET; JL	x	x	x			
U3-6 Mice Transgeneration	NIPH; AKO	x				x	
U3-4 C elegans mix tox	NMBU IS; DB	x					
U3-7 Adverse Outcome Pathways	NIVA; KP	x		x	x		
U12-2 KOMI Barcoding	NMBU IS; EL	x					
Research Area 4							
U4-4 Knowledge gaps	NRPA; AL	x	x	x	x	x	
U4-5 Health Damage	HH: SN	x		x			
U4-6 Predictive Risk	NIVA; KB				x		
U4-7 Stakeholder Dialogue	NMBU IS; YT	x		x			
U4-8 Risk Communication	NMBU IS; YT	x					

Research Area 5								
U5-1 UV/IR	NRPA; TC		x		x			
U5-2 HT analysis	NRPA; AJ		x		x		x	
U5-2 Plant reproduction	IPM; JEO	x						
U5-2 UV Map	NRPA; BJ				x			
U5-3 Sperm quality	NMBU-VET; IM		x					
U5-4 UV+neurotox	NMBU-VET; IM		x		x			

NMBU
Photo: Signe Dahl

Research Highlights

THE WESTERN NORWAY PROJECT

Ole Christian Lind, NMBU and Astrid Liland NRPA/NMBU

The Western Norway (WN) sub-project is an integrating project involving all the CERAD research groups and covering all aspects of risk assessment from sources via transfer, exposure and biological effects of radionuclides to consequences on health, environment, society, economy and ethics. The overall goal is to reduce the uncertainties in the risk assessment work. Simulations of two different hypothetical nuclear accidents in the UK are used to identify knowledge gaps and perform sensitivity analyses using real-time meteorological data for atmospheric transport of radionuclides to the west coast of Norway, and subsequent deposition. Results from various work related to the Western Norway project are to be found in several of the CERAD annual report highlights.

The CERAD modelling group has proven that the different environmental models can be coupled to run in a sequence. The resolution of the SNAP atmospheric dispersion model has been increased (10x10 km grids) to produce a detailed fallout map for ^{137}Cs in Rogaland County and the North Sea. Based on this deposition, the following was modelled:

- Outdoor radiation doses to humans, (ARGOS).
- Concentrations in agricultural food products (AgriCP) and in wild foodstuffs, (STRATOS).
- Concentrations in water and sediments in the Vikedal river and lakes from deposition and catchment area runoff, (INCA-RAD).
- Concentrations in freshwater organisms and corresponding doserates, (ERICA Tool).
- Freshwater input of ^{137}Cs to the marine environment from the Vikedal river as well as from all other rivers in Norway based on upscaling from River Vikedal, (INCA-RAD).
- Marine dispersion, concentrations and doserates from 137Cs to marine organisms using the ROMS and NRPA box model based on ocean deposition, (SNAP) and river runoff, (INCA-RAD).

An essential task during the process of coupling the models was to identify the parameters associated with the largest uncertainties and to quantify the uncertainty factors they may introduce. The results of this senstiivty analysis will serve as input to ongoing and upcoming focused research aiming to reduce the uncertainties. In 2015, the aim is to reduce uncertainties by employing dynamic modelling and obtaining and implementing site-specific data in the models. Site-specific data will be obtained by involving local stakeholders and performing fieldwork in Vikedal/Rogaland.

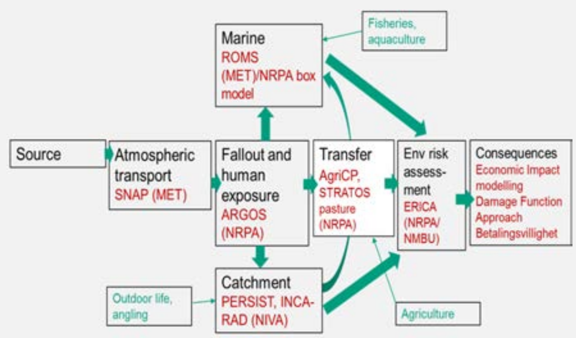


Figure 1. Coupling of models used in the WN project

References: NRPA, StrålevernRapport 2009:6 and StrålevernRapport 2010:13.

Participants: J. Bartnicki P.E. Isachsen, H. Klein, M. Simonsen, Ø. Sætra (MET), R.M. Couture, Ø. Kaste, Y. Lin. J. Moe, K.E. Tollefsen (NIVA), J. Brown, J.E. Dyve, A Hosseini, M. Iospe, H. Thørring, M.A. Ytre-Eide (NRPA), O. Bergland, E. Romstad, S. Navrud, D.H. Oughton, B.O. Rosseland, B. Salbu, Y. Tomkiv (NMBU).

Other Information: Magne Simonsen and Astrid Liland hold CERAD PhD fellowships.

STAKEHOLDER DIALOGUES

Yevgeniya Tomki, NMBU and Astrid Liland, NRPA

Stakeholder dialogues are internationally recognized as an important part of the emergency preparedness. They bring a range of stakeholders together, building a wider, more comprehensive perception of the issues than would be achieved if emergency planners and recovery managers developed their plans in isolation. Two stakeholder dialogue meetings will be organized within the Western Norway project in early 2015 to address social, economic, environmental, ethical and risk communication aspects of the Sellafield-scenario. The meetings will be held in Rogaland County as this area is expected to receive radioactive fallout if a nuclear accident in UK was to occur. The outputs from the Western Norway project and the Sellafield scenario will be used for demonstration of an accidental situation. Potential impacts in Rogaland, regionally and locally will be discussed with the stakeholders. The meetings are organised together with the Section for emergency preparedness and response at NRPA and the County Governor of Rogaland.

A wide range of participants have agreed to take part in the dialogues. These include representatives of Rogaland County Governor, municipalities, Directorates for Civil Protection and Fisheries, fish farming industry, national and regional authorities (Food Safety Authority, Radiation Protection Authority), agricultural sector, health sector, drinking water providers and others.

Typical emergency preparedness seminars are based on one-way communication. One objective of the present project is to show the value of cross-sectorial, cross-topical discussions on the consequences of a radiological accident for research and emergency preparedness. It will also assess the way stakeholder dialogues can contribute to improved knowledge and engagement at the local level, and aid in finding solutions to problems. The project should also be beneficial for participants. It aims to increase their knowledge about nuclear emergency preparedness and management, including consequences and countermeasures, which will have to be implemented on the local level. The long-term aim of the project is to strengthen emergency preparedness and management on the regional/local level and contribute to reduction of the uncertainty in scientific prognoses.

Participants: O. Bergland, D.H. Oughton, S. Navrud, E. Romstad, O.C. Lind, B. Salbu (NMBU), M. Dobbertin, I.M. Eikelmann, Ø. Selnæs, L. Skuterud, P. Strand, Ø. Aas-Hansen (NRPA).

Other information: Astrid Liland holds a CERAD PhD fellowship.

Figure 1. Sellafield nuclear reprocessing facility. Photo: J. E. Dyve

WORST CASE SCENARIO FOR NORWAY IN CASE OF A HYPOTHETICAL ACCIDENT IN THE RUSSIAN SUBMARINE K-27

Jerzy Bartnicki, MET

The Russian nuclear submarine K-27 suffered a loss of coolant accident in 1968 and with nuclear fuel in both reactors it was scuttled in 1981 in the outer part of Stepovogo Bay located on the eastern coast of Novaya Zemlya. The inventory of spent nuclear fuel on board the submarine is of concern because it represents a potential source of radioactive contamination of the Kara Sea and a criticality accident with potential for long-range atmospheric transport of radioactive particles cannot be ruled out if a slavage operation is initiated.

To address these concerns and to provide a better basis for evaluating possible radiological impacts of potential releases in case a salvage operation is initiated, we assessed the atmospheric transport of radionuclides and deposition in Norway from a hypothetical criticality accident on board the K-27 at three different locations: 1) initial location, 2) on the way to final destination and 3) at the final destiation at Gremikha Bay.

To achieve this, a long term (33 years) meteorological database has been prepared and used for selection of the worst case meteorological scenarios for each of three selected locations of the potential accident. This task was completed in the first phase of the study in 2013.

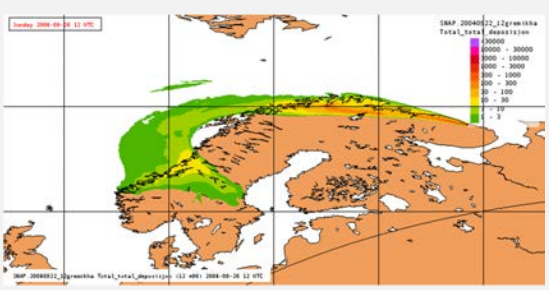
In the seceond phase (2014), the source term for the worst-case accident scenario in K-27 has been developed. Then, the dispersion model SNAP was run with this source term for selected meteorological scenarios.

The results showed that predictions were very sensitive to the estimation of the source term for the worst-case accident and especially to the sizes and densities of released radioactive particles. Depositions were also very sensitive to the magnitude of the source term used.

The results indicated that a large area of Norway could be affected, and that the deposition in Northern Norway would be considerably higher than in other areas of the country.

Concerning radiological risk, the simulations showed that deposition from the worst-case scenario of a hypothetical K-27 accident would be at least two orders of magnitude lower than the deposition observed in Norway following the Chernobyl accident.

Participants: I. Amundsen, J. Brown, A. Hosseini, M. A. Ytre-Eide (NRPA), H. Haakenstad, Ø. Hov., H. Klein (MET), O.C. Lind, B. Salbu, C.C.S. Wendel (NMBU).



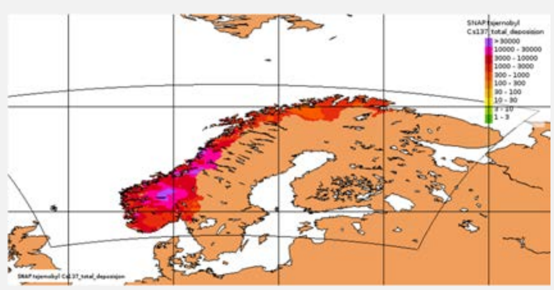


Figure 1. Comparison of total deposition map from the worst case K-27 scenario (top) with total deposition map from the Chernobyl accident (bottom). The same scale is used on both maps.normalized.

MARINE TRANSPORT MODELLING

Magne Simonsen, MET/NMBU

An accidental release from a near-coastal nuclear installation will most likely give significant fallout on the ocean surface or direct release to the ocean. Ocean transport modelling is therefore highly relevant to estimate the fate of the radionuclides on both short and long term. During 2014, most focus has been spent on numerical simulations of Cs-137 releases from a hypothetical accident scenario at Sellafield Nuclear Reprocessing Plant. The main numerical tool for simulations has been the ocean circulation model ROMS. Radionuclides have been assumed to be non-reactive, conservative dissolved radionuclides that are transported by ocean currents and diffusion. Processes such as adsorption to particles or bottom sediments are not considered at this stage. Dispersion of Cs-137 is computed with the internal routines in ROMS, simultaneously with the hydrodynamics. The initial conditions are the accumulated deposition from the atmosphere the first days after the hypothetical release, computed with the SNAP dispersion model at Norwegian Meteorological Institute. The simulations have been performed with different configurations; one setup at relatively coarse spatial resolution (20 km), and one setup with eddy-permitting resolution (4 km). Both model configurations have a vertical grid consisting of 35 terrain-following layers. To show the importance of increased resolution on transport times and distribution of the radionuclides, time series of Cs-137 concentration in the ocean from the two model configurations have been compared (Fig. 1). To investigate the sensibility to unresolved non-linearities due to uncertainty in the initial conditions, a small ensemble was created, originating from slightly different initial conditions. Outer forcing such as boundary conditions, wind stress, rivers and tides were identical in all realizations.

Participants: P.E. Isachsen, Ø. Sætra (MET), O.C Lind, B. Salbu (NMBU).

Other Information: Magne Simonsen holds a CERAD PhD fellowship.

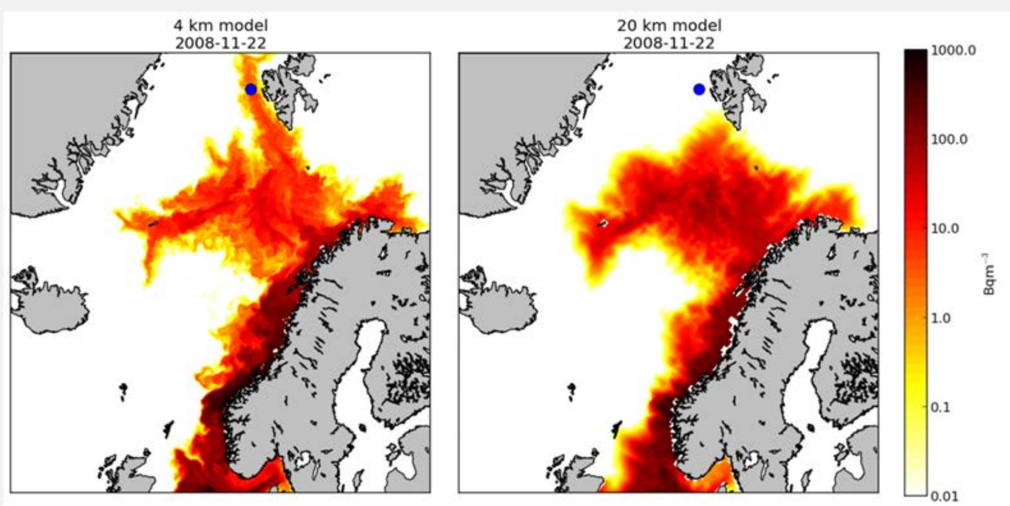


Figure 1. Distribution maps of surface Cs-137 concentration one month after a hypothetical accident scenario. Right figure shows results from the relatively coarse model, while left figure shows results from the eddy-permitting model.

PLUTONIUM IN KARA SEA SAMPLES

Cato Christian Szacinski Wendel, NMBU

The Stepovogo fjord, on the east coast of Novaya Zemlya served as a dumping place for radioactive waste for the Soviet Union. In addition to 2000 containers with solid radioactive waste, a nuclear submarine with intact reactors was dumped in the fjord. Joint Norwegian Russian research expeditions were conducted in 1993, 1994 and 2013 sampling seawater, sediment and biota within the fjord.

Plutonium (Pu) atom ratios and concentrations in seawater, sediment and biota from the Stepovogo Fjord were determined by AMS (Australia). Radioactive particles were searched for with digital autoradiography.

Sediment

Activity concentrations of $^{239+240}$Pu were found to range within 21 and 77 Bq·m^{-2} in all reaches of the Stepovogo fjord. Activity concentrations were higher in the inner parts of the fjord than in the outer parts. Similarly, sediments samples collected on the deck of the K-27 dumped submarine and close to one of the dumped containers did not show appreciable deviations from the remaining samples. Atom ratios of ^{240}Pu/^{239}Pu were found to range within 0.11 and 0.2, and mostly within the range of northern hemisphere global fallout (0.182±0.005). The atom ratios in four samples were found to deviate significantly from global fallout, namely St1 9-10 cm depth (0.148±0.004), St 3 3-4 cm depth (0.152±0.006), St12 2-3 cm depth (0.14±0.006) and St18 2-3 cm depth (0.11±0.02). The lower atom ratios found in these layers may indicate influence from sources different from global fallout, e.g. local fallout from nuclear weapon testing at Novaya Zemlya before, dumped radioactive waste within the Stepovogo fjord or long transported waste from European reprocessing plants.

Seawater

The concentrations of $^{239+240}$Pu (2.2-2.4 mBq·m^{-3}) in surface waters of the Stepovogo fjord were found to be similar to surface waters in the Pechora sea, while bottom water, varying within 2.4 and 2.8 mBq·m^{-3}, showed an increasing trend from the entrance (2.4±0.7 mBq·m^{-3}), the outer part (3.2±0.7 mBq·m^{-3}) and the inner part of the fjord (4.8±0.8 mBq·m^{-3}). Atom ratios of ^{240}Pu/^{239}Pu ranged within 0.15±0.02 and 0.23±0.09, but were not significantly different from global fallout values (0.182±0.005) as defined by Kelley *et al*. (1999).

Radioactive particles

The dried soft tissues of two mussels were coarsely ground using an agate mortar. The ground material was then mounted on adhesive film, covered with clingfilm and subjected to digital autoradiography with an exposure time of 7 days. Hotspots indicating the presence of radioactive heterogeneities were observed in the material, as shown below.

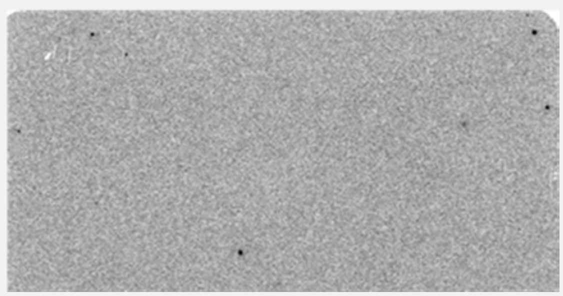


Figure 1. Autoradiographs of dried and coarsely ground soft tissue of mussel showing radioactive heterogeneities.

Participants: J.P. Gwynn (NRPA), O.C. Lind, B. Salbu, H.C. Teien (NMBU), A.L. Rudjord (NRPA).

PLUTONIUM CONCENTRATIONS AND ATOM RATIOS IN SEDIMENTS NEAR FUKUSHIMA, JAPAN

Cato Christian Szacinski Wendel, NMBU

Radionuclides released from the damaged Fukushima Nuclear Power Plant (FNPP) reactors have caused widespread radioactive contamination in the environment. Volatile radionuclides have been detected at large distances from the accident site (e.g. Masson *et al.* (2011)), while more severe radioactive contamination has been limited to the local scale (e.g. Steinhauser *et al.* (2014)). It has been indicated that a small proportion of the plutonium (Pu) present in the reactors and spent fuel storage ponds in the FNPP was released during the accident. The $^{240}Pu/^{239}Pu$ atom ratios in this material were relatively high (0.320-0.456) and easily distinguishable from global fallout (0.182±0.014). Debris collected in the terrestrial environment within 30 km of the FNPP has shown $^{240}Pu/^{239}Pu$ atom ratios (0.303-0.330) clearly deviating from global fallout levels, indicating that Pu has been released as well (Zheng *et al.,* 2012).

In collaboration with Woods Hole Oceanographic Institue, USA, sediment sample cores were taken in May 2012, June and July 2012 and May and September 2013 during cruise campaigns by Japanese research vessels. Concentrations and atom ratios of Pu were examined in selected cores by advanced techniques (AMS). Plutonium atom ratios serves as indicators of origin for nuclear materials, as the $^{240}Pu/^{239}Pu$ ratio varies with reactor type, fuel utilisation and irradiation intensity.

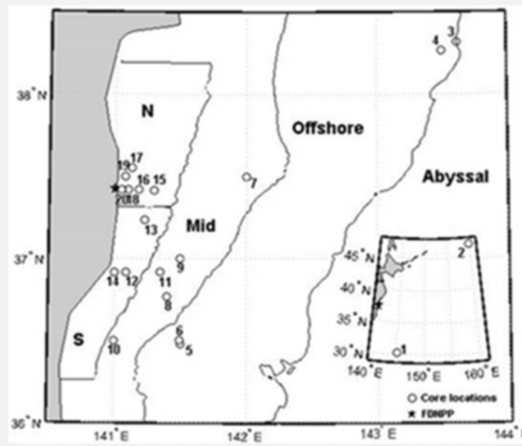


Figure 1. Locations of sediment core sites off the coast of Japan.

Pu concentrations in sediments

The activity concentrations of $^{239+240}Pu$ were found to range within 0.3 and 10.6 Bq·kg-1, with the highest concentrations found in cores 12 and 14, 55 km south of the damaged reactor (fig.). $^{240}Pu/^{239}Pu$ atom ratios were found to range within 0.21 and 0.28, with the highest atom ratios found in deep layers core 20 taken close to the reactor (5 km east of the damaged reactors). These atom ratios are significantly higher than global fallout in Japan, however, are not thought to originate from the reactor. Seawater and sediments close to Japan and in the north pacific region are elevated due to long transported debris from nuclear weapon detonations at the pacific proving grounds (PPG).

Participants: D.H. Oughton, B. Salbu, O.C. Lind (NMBU), K. Buesseler, E. Black (WHOI), K. Fifield, S.G. Tims (ANU, Canberra, Australia).

NATURALLY OCCURRING RADIONUCLIDE TRANSFER STUDIES

Lindis Skipperud, NMBU

All organisms are inevitably exposed to radionuclides that are naturally present in the environment. Primordial radionuclides such as ^{238}U, ^{235}U and ^{232}Th have been present in rocks and minerals of the earth's crust since its formation. These radionuclides are of particular interest as they are the "mothers" of radioactive decay chains, followed by important radioactive decay products such as ^{228}Th, ^{226}Ra, ^{228}Ra, ^{210}Pb and ^{210}Po. Various anthropogenic activities such as mining, oil and gas production, phosphate industry, etc. use or disturbe ores that contain naturally occurring radionuclides (NOR) resulting in elevated levels of NOR in certain (by)products and wastes. Besides enhanced NOR levels, these wastes are complex mixtures of different chemical compounds, minerals and elements, including heavy metals.

In 2011, the Norwegian Pollution Control Act was amended to include naturally occurring radioactive materials (NORM) as contaminants, in addition to trace metals and organic compounds (Lovdata, 2004). This amendment implicated that radioactive waste regulations were no longer exclusive to the nuclear industry, but also applied natural radioactive material derived from non-nuclear industries. CERAD in collaboration with the NORWAT project, funded by the Norwegian Public Road Administration, have been focusing on alum shale leaching from the road- and tunnel construction site in the Gran municipality on Highway Rv4 in Norway. The bedrock is rich in U-bearing minerals, giving a high potential for environmental contamination.

Fieldwork and laboratory experiments, including leaching, have been performed. Concentrations of U, Al, Cd, Cu, Mn, Mo and Ni and other metals in water in contact with different types of alum shale and lime stone have been measured over a period of up to 7 weeks. Uranium concentrations in the leachiate water at the end of the experiment varied from 17 to 602 µg/L, due to the different types of minerals, and the leaching of uranium and metals were still increasing, still not reaching steady state.

As a comparison, WHO's uranium drinking water guideline is 30 µg/L (WHO 2011), and drinking water limits are often too high to provide sufficient protection of aquatic organisms. Further, these elements, U and other metals, could be taken up in organisms. Concentration ratios (CR) for some elements in fish collected from Vigga lake, Gran, before tunnel construction started, are given in the table, showing varying values according to organs.

Table 1: CRs of NORM and some elements in fish organs from Vigga, Gran, sampled prior tunnel construction.

CR	As	Cd	Pb	Th	U
Liver	171	17294	2564	103	2
Kidney	3279	10000	17648	1248	100
Gills	569	7706	13750	163	31

The studies shows that leaching from U-bearing minerals is of importance for all types of industry (construction, mining), and there is a demand for specially designed waste rock deposits or other countermeasures to hold back possible leaching to aquatic environments.

Focus of future work will be to obtain a parameterized model to predict time dependent NOR mobility and uptake by terrestrial plants and aquatic organisms based on soil and water characteristics in order to reduce uncertainties related to environmental risk assessment (linked to CERAD umbrella project 2, Dynamic Transfer).

Participants: H.C. Teien, O.C. Lind, B. Salbu, T. Helmers (NMBU).

Other information: Several MSc students have done, and still do, their project work within this NORM project.

BIOLOGICAL KEY FACTORS-TRANSFER- PHYLOGENY

Justin Brown, NRPA

In this phylogenetic analysis, we will pose the questions of whether bioaccumulation characteristics differ between plant and animal taxa and whether the degree of difference increases with their period of evolutionary divergence. Statistical models, such as the residual maximum likelihood method can be used to test whether predictions of radionuclide activity concentrations in unknown (plant or animal) species can be derived from data for species sampled at a given site.

So why might phylogeny be important? The answer lies in the practical application of ICRP's framework based around Reference animals and plants (RAPs). In most real impact assessments one will be interested in particular representative organisms that may or may not be related (with respect to transfer, dosimetric considerations etc.) to RAPs. In cases where there is little or no relationship, a systematic method of relating the transfer of a radionuclide for a given biota species to those of a particular RAP would be of benefit. So, by example, if one were to determine transfer for a given plant type at a site one might also be able to then say something about transfer to the RAP wild grass (if a phylogenetic relationship in transfer for that element has been established) at the same site and through this have access to all the other reference information (including effects data, derived consideration reference levels and the like) that is coupled to the RAP. Basically the approach provides us with one tool for extrapolating from entities we have information for (e.g. RAPs) to those where we have little information. It might thus form an integral part of developing risk assessment systems.

A pilot study was conducted in 2014 on the application of this methodology to a marine organism dataset taken from IAEA's wildlife database. The work is at a stage where organisms have been classified in terms of their taxonomy – splitting into species, family, order etc. and the sites from which samples were taken from has been specified. Further work is now required in relation to coding up the dataset in relation to phylogeny – numerical coding based upon degree of evolutionary divergence.

Participants: T. Hevrøy, R. Gjelsvik (NRPA).

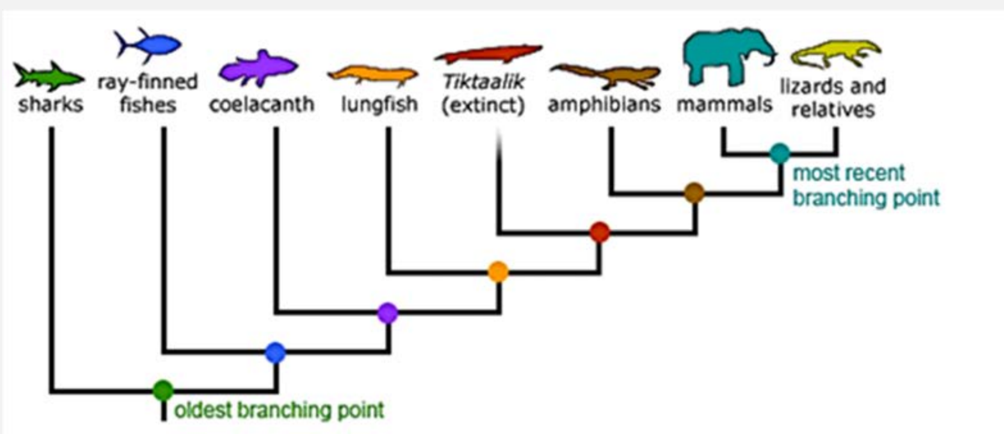


Figure 1. Example of phylogenetic classification for selected vertebrates http://evolution.berkeley.edu/ evolibrary/images/ miscon_fig7.gif

ERICA TOOL DYNAMIC MODULE

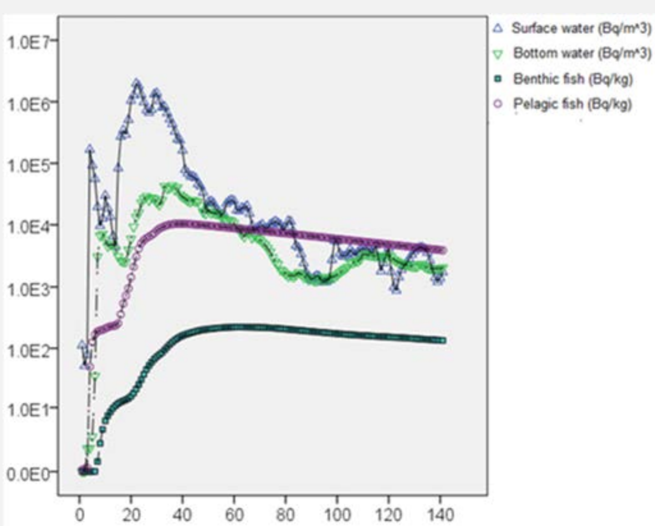
Justin Brown, NRPA

Currently, the ERICA Tool (Brown *et al.*, 2008) has been implemented for routine discharge conditions where the assumption of steady state between radionuclides within environmental compartments is reasonable. In such cases the implementation of simple transfer ratios is justifiable but for cases where discharges are changing rapidly such an approach becomes untenable. Further developmental work has been conducted on a marine kinetic model, by considering uptake via food and water for aquatic organisms. Similar models have also been developed for terrestrial systems accounting for processes such as interception of contamination by vegetation, weathering loss and dilution of radionuclides by plant growth. The time-dependent transfer of radionuclides within the food chains can then be described by simple, first-order differential equations, one for each trophic level. Furthermore, parameters such as depuration rates have been taken from data in the published literature. The marine model has been tested within IAEA's MODARIA working programme through comparison with other models of this type. The terrestrial model has formed an important part of dynamic prognoses for activity concentrations in plants and animals following the Fukushima Daiichi accident (Fig. 1) and conducted under the auspices of the United Nations Scientific Committee on the Effects of Atomic Radiation.

Participants: A. Hosseini (NRPA), J. Vives I Batlle (SCK-CEN),

Reference: J.E. Brown, B. Alfonso, R. Avila, N.A. Beresford, D. Copplestone, G. Pröhl, A. Ulanovsky (2008). The ERICA Tool. Journal of Environmental Radioactivity 99, Issue 9, pp.1371-1383.

Other Information: This work has formed part of the IAEA's MODARIA programme and UNSCEAR's Fukushima assessment and was conducted as part of the ongoing maintenance and support of the ERICA Tool funded by the NRPA.



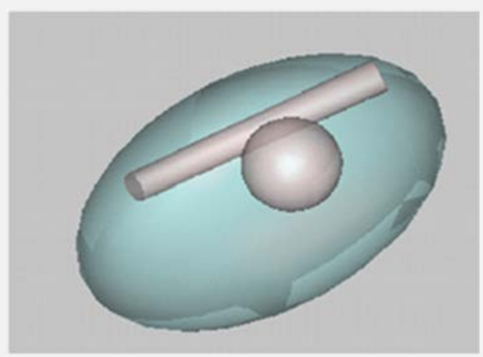


Figure 1. Predicted activity concentrations of Cs-137 in Benthic fish and Pelagic fish versus time (days) derived from modelled seawater concentrations in the Fukushima Daiichi North Channel in the initial period following the accident. The figure to the right shows the dosimetric depiction of marine biota.

TRAP

Håvard Thørring, NRPA

The International Commission on Radiological Protection (ICRP) has developed a system based on Reference animals and plants (RAP) – for the purpose of estimating doses and effects of ionising radiation in the environment. An important part of this system is to identify smaller reference areas in different countries. For this purpose the *Tjøtta Reference Animals and Plants* project was initiated in 2011, with a continuation within CERAD from 2013. More than 400 samples have been gathered – comprising of various tissues of relevant plant and animal species (Fig. 1), and samples of soil, freshwater and sea water. Different RAP life stages were also considered e.g. for frogs (eggs, tadpoles, adults). Quantitative analyses of ~60 stable elements using ICP-MS were finalised in 2014, and a report covering all data is under preparation. Further publication will be due in 2015. Project data will also be compared with similar data sets from Reference areas in UK, Ukraine and Spain within the EC-project COMET.

Participants: J.E. Brown (NRPA), L. Aanesen (Bioforsk), D.H. Oughton (NMBU).

RAP	Sampled species	Part(s)
Poaceae	Wavy hair grass	Whole
Pinaceae	Scots pine / sitka spruce	Annual shoot
Lumbricidae	Various earth worms	Whole
Apideae	Honey bee	Whole
Muridae	House mouse	Muscle, bone, liver, gonads
Cervidae	Moose	Muscle, bone, liver, gonads
Anatidae	Various ducks	Muscle, bone, liver, gonads
Ranidae	Common frog	Muscle, bone, liver, gonads
Salmonidae	Trout	Muscle, bone, liver, gonads
Pleuronectidae	Plaice	Muscle, bone, liver, gonads
Cancridae	Edible crab	Soft tissues, shell
Fucaceae	Bladder wrack	Whole

Figure 1. Scenery, sites and sample information. Photo: Bioforsk

RETENTION OF RADIOACTIVE PARTICLES AND ASSOCIATED EFFECTS IN THE FILTER-FEEDING MARINE MOLLUSC *MYTILUS EDULIS*

Ole Christian Lind, NMBU

Radioactive particles are aggregates of radioactive atoms that may contain significant activity concentrations. They have been released into the environment from nuclear weapons tests, and from accidents and effluents associated with the nuclear fuel cycle.

Aquatic filter-feeders can capture and potentially retain radioactive particles, which could then provide concentrated doses to nearby tissues. This study experimentally investigated the retention and effects of radioactive particles in the blue mussel, *Mytilus edulis*. Spent fuel particles originating from the Dounreay nuclear establishment, and collected in the field, comprised of a U and Al alloy containing fission products such as ^{137}Cs and $^{90}Sr/^{90}Y$. Particles were introduced into mussels in suspension with plankton-food or through implantation in the extrapallial cavity. Of the particles introduced with food, 37 % were retained for 70 h, and were found on the siphon or gills, with the notable exception of one particle that was ingested and found in the stomach. Particles not retained seemed to have been actively rejected and expelled by the mussels. The largest and most radioactive particle (estimated dose rate 3 $Gy.h^{-1}$) induced a significant increase in Comet tail-DNA %. In one case this particle caused a large white mark (suggesting necrosis) in the mantle tissue with a simultaneous increase in micronucleus frequency observed in the haemolymph collected from the muscle, implying that non-targeted effects of radiation were induced by radiation from the retained particle (Fig. 1). White marks found in the tissue were attributed to ionising radiation and physical irritation (skin burn).

The results indicate that current methods used for risk assessment, based upon the absorbed dose equivalent limit and estimating the "no-effect dose" are inadequate for radioactive particle exposures. Knowledge is lacking about the ecological implications of radioactive particles released into the environment, for example potential recycling within a population, or trophic transfer in the food chain.

Participants: B. Jaeschke, C. Bradshaw (Stockholm University), B. Salbu (NMBU).

Figure 1. Light microscopy of (left) the Dounreay spent nuclear fuel fragment used in exposure experiments and (right) a large white mark (suggesting necrosis) observed in the mantle tissue at the location where the fragment had been retained.
Photo: Ben Jaeschke

LONG-TERM CONSEQUENCES OF CHRONIC EXPOSURE TO RADIONUCLIDES AND CHEMICAL STRESSORS: FIELD STUDIES IN KOMI, RUSSIA

Emmanuel Lapied, NMBU

Industrial areas in the Vodny settlement in the Komi Republic, Russia, have been contaminated by uranium mill tailings and radium production wastes due to activities in the 1950s. The sites have high activity concentrations of both naturally occurring radionuclides (NOR), heavy metals, and rare-earth elements, and constitute a valuable field laboratory. Joint Russian-Norwegian Fieldwork has been carried out in 2012 and 2013. Full soil macrofauna analysis has been completed on four sites: two control and two contaminated by production wastes, covering earthworms, insects (Coleoptera Diptera), ants, molluscs (snails, slugs), arachnids and myriapods Air dose rates range from 10-100 μGy/hr at the contaminated sites, with calculated internal doses to soil fauna up to ten times higher. Sites also showed high concentrations of heavy metals (Pb, Cu, Cd, As, Hg).

Data showed a significant reduction in earthworm density and diversity at the contaminated sites compared to control sites. DNA bar-coding to assess the species diversity of soil invertebrates is ongoing, and a variety of other endpoint measurements: (e.g., DNA damage, DNA methylation) should give insight into possible causes of the changes

Other information:

This project is co-financed by the Norwegian Research Council as a part of EANOR, ERANET EU-project and CERAD.

Figure 1. Abandoned radium production equipment at the Vodny site Komi. Field work 2013
Photo: Deborah Oughton

Participants:

Y. Tomkiv, T. Hertel-Aas, D.H. Oughton (NMBU), V. Zainullin, E. Belykh, A. Kaneva, I. Velegzhaninov, T. Evseeva (The Institute of Biology Komi Scientific Center of UB RAS).

APOPTOTIC RESPONSE IN EARTHWORMS EXPOSED TO GAMMA IRRADIATION

Emmanuel Lapied, NMBU

Earthworms are one of the most radiosensitive components of the soil fauna, and decreases in populations have been observed following nuclear accidents. However, little is known about the mechanisms of radiation impacts on earthworms. Since apoptosis is known to be a central mechanism in the biological response to irradiation, a study has been carried out to investigate the impact of gamma irradiation of apoptopic response in *Esenia fetida* Three different apoptosis methods (TUNEL, Apostain and caspase 3 staining) were tested on five different tissues: cuticule, circular and longitudinal musculatures, intestinal epithelium and chloragogenous matrix.

The results showed for the first time the apoptotic process in earthworms and, the conservation of caspase 3 proteins. Doses of 10 mGy/hr gave significant increase in apoptic response after 7 days exposure (Fig. 1 and 2). These dose rates have been linked to decreases in reproductive capacity following longer exposure times. Hence the biomarker could be valuable as an early warning of radiation exposure and effects.

Further studies are investigating the potential links between apoptosis and tissue and earthworm species radiosensitivity.

Participants:

D.H. Oughton, O.C. Lind, B. Salbu (NMBU), J.M. Exbrayat, E. Moudilou (University of Lyon, France).

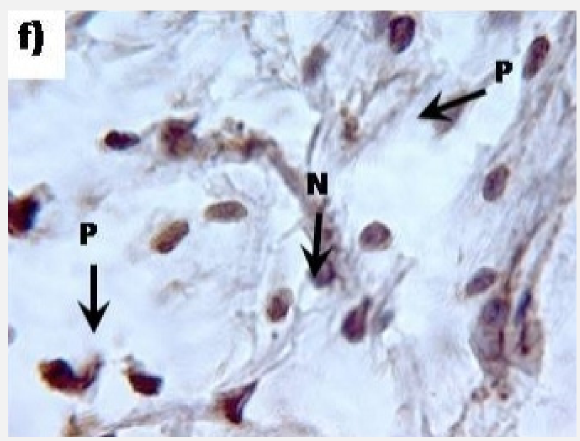


Figure 2. Apopstain of chloragogenous tissues, E. fetida.
Photo: Emmauel Lapied

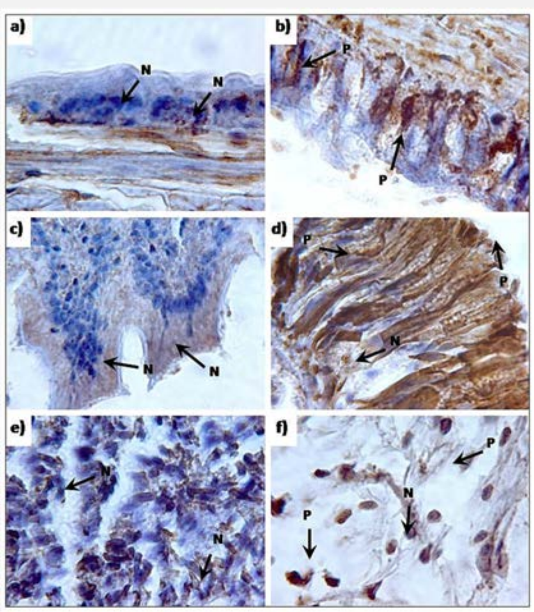


*Figure 1. Light microscopy images from Apostain stained tissues (945x magnification) of Eisenia fetida exposed to 0 mGy.h^{-1} (control: plates **a, c** and **e**) or 10 mGy.h^{-1} (plates **b**, **d** and **f**) at 20 °C, distinguishing cuticule (**a, b**), intestinal epithelium (**c, d**) and chloragogenous tissues (**e, f**). Arrows indicate negative (N) and positive (P) apoptotic response in stained cells.*

MODELL EXPERIMENTS URANIUM AND ATLANTIC SALMON (*SALMO SALAR*)

Hans-Christian Teien, NMBU

A goal of the EU STAR project was to develop a biotic ligand model (BLM) that incorporates speciation of uranium (U) and the protective effects of competing cations to describe the bioavailability and toxicity in Atlantic salmon (*Salmo salar*). Knowledge about the bioavailability and toxicity of U towards aquatic organisms is rather limited and controlled exposure experiments were therefore performed. Atlantic Salmon juveniles (in total about 1200 fish) were exposure to commercially available depleted uranium (DU) separately or in combination with a second stressor cadmium (Cd) in accordance with the OECD guidelines for acute toxicity tests. Speciation, gill and liver accumulation and induced toxicity of U in fish as a function of varying water concentrations of H^+, Ca^{2+}, Mg^{2+}, Na^+ and K^+ as well as U and Cd were studied.

The observed dose-response demonstrated that varying concentrations of K^+, Na^+ or Mg^{2+} had no apparent effect on the U induced toxicity in terms of 96 h LC_{50}-values. U toxicity was, however, strongly dependent on pH. Reducing pH from about 6.7 to 6.0 or 5.5 reduced the LC_{50}-value from 3.1 to 1.4 mg U/l. However, by increasing pH to 7.9, LC_{50}-values increased to 25 mg/L (Fig. 1).

Ultrafiltration of the exposure waters, demonstrated that U was present as dissolved species less than 10 kDa in size. Using FFF-ICP-MS results demonstrated that a small fraction of U is present as colloids mainly in size 1-1.5 kDa in U concentration causing mortality, and that this fraction was lowered when the pH increased.

Analyses of gills and liver samples demonstrate U accumulation, dependent upon U speciation in water, as the concentration in gills and liver decreased with increasing water pH. U accumulation at >50 µg U/g dry weight gill was correlated with ion regulation problems and stress response in fish, reflected by reduced plasma Cl concentration and increased blood glucose, and mortality was observed at concentration levels >200 µg/g gill dry weight (Fig. 2). Thus, toxic effects in fish were correlated to U concentration in gills, and the concentration of U in gills was highly dependent upon pH in water and the U speciation.

U did not only absorb to the external boundary of the fish gills, but it was also taken up and was present in the core of the gill filament. This was visualized by utilizing µ-XRF/µ-XRD two-dimensional scanning and µ-XRF/µ-XRD tomography at the microprobe end-station of the PETRA III P06 beamline.

Correlation between U in water and U in liver demonstrated uptake of U. Collection of tissues at different exposure times, demonstrated steady state of U-gill at 96 hrs while not in liver, still increasing 120 hrs after start of exposure. Transfer to non U-contaminated wate demonstrated slight decrease in U- gill concentration after 96 hrs but no change in liver concentration. Following up experiments with increased time of depuration are needed to estimate halvlife of U in fish.

Analyses of Cd in tissues of combined exposed fish demonstrated antagonistic effects and reduced uptake (e.g. body burden) of Cd in presence of U in liver of the fish. These findings highlight the importance of understand underlying toxicokinetic processes (uptake) affecting the body burden and the toxic MOA in mixture studies, resulting in reduced toxicity of Cd when co-exposed to U and thereby demonstrating antagonistic effects.

The work is co-funded by EU STAR project.

Participants: Y.A. Kassaye, D.A. Brede, S. Nehete, O.C. Lind, B. Nkwell Sone, M. Kleiven, D.H. Oughton, M.N. Pettersen, T. Loftaas, B. Salbu, L. Skipperud, Y. Song, Y. Tomkiv, L. Valle (NMBU); L.K. Jensen, G. Rudolfsen, H. Thørring (NRPA); S. Lofts (NERC, UK), and includes several MSC students.

*Figure 1. **A)** Experimental setup **B)** Dissection of fish and **C)** LC50 values at different water pH.*

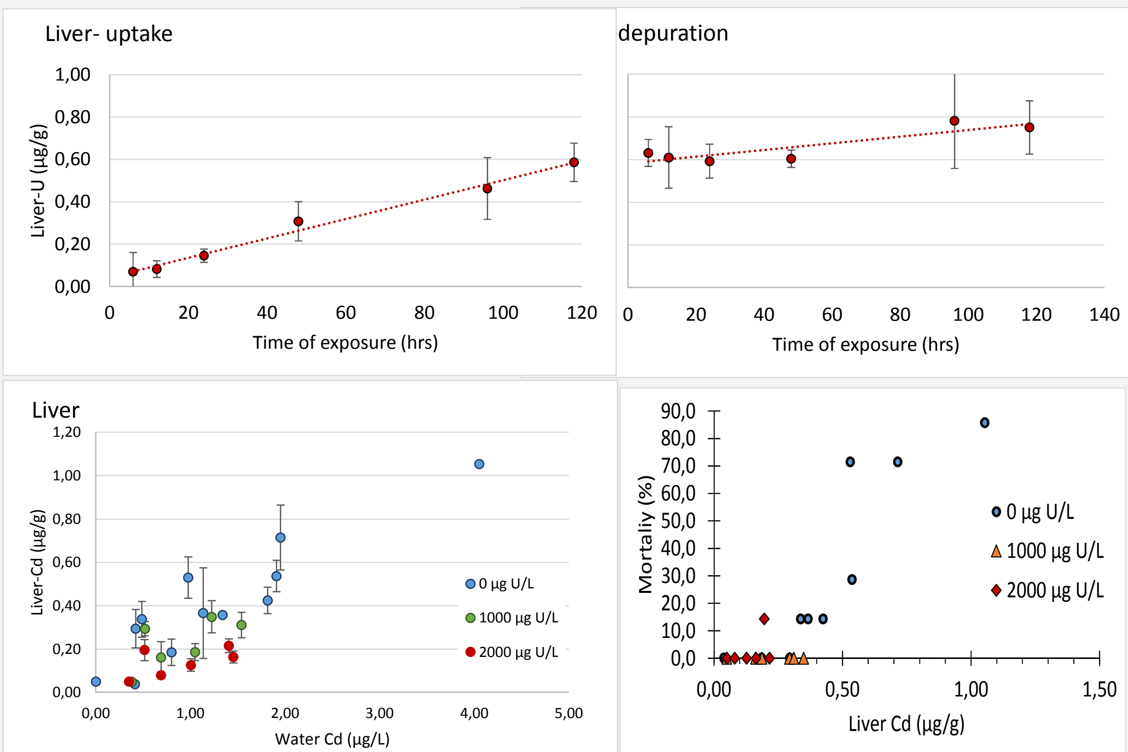


*Figure 2. **A)** Uptake of Uranium in Atlantic Salmon Juviniles, **B)** Changes in U-liver concentration after transfer of fish to control water for depuration, **C)** Uptake of Cd in liver of fish co exposed to Uranium. **D)** Correlation between Cd in liver and mortality at diferent U concetrations.*

INVESTIGATING TOXICITY UPTAKE AND FATE OF NANOPARTICLES IN *CAENORHABIDITIS ELEGANS* USING STATE-OF-THE-ART X-RAY NANOIMAGING TECHNIQUES AT ID16A, EUROPEAN SYNCHROTRON RADIATION FACILITY (ESRF)

Dag Anders Brede and Ole Christian Lind, NMBU

Within radioecology and environmental chemistry there is a need to determine the solid state speciation of radionuclides and stable elements in complex systems, such as within organisms. The nematode *C. elegans* is a widely used model organism in the fields of eco-toxicology, neurology, molecular biology and (epi)-genetics. In Cerad, *C. elegans* is used to study toxicological effects of nanoparticles and radionuclides, but also to investigate uptake in live animals using state of the art X-ray nano-imaging. In this study we have employed a combination of synchrotron radiation (SR) based coherent X-ray imaging techniques and X-ray fluorescence (XRF) microscopy as well as laboratory based X-ray absorption nano-tomography (nano-CT) to visualize the potential uptake of engineered cobalt nanoparticles (Co NP) in nematodes following 96 h toxicological exposure tests. Dynamic light scattering showed that the nanoparticles (4 nanometer (nm) in diameter) formed aggregates (~180 nm) in the aqueous exposure solutions. No acute lethal effects were observed for *C. elegans*. However, at high concentration Co NP exposure negatively affected growth, development and reproduction, which in an ecological perspective could seriously affect sustainability of a population. Due to the small size (1 mm) of *C. elegans* it is possible to perform non-invasive nano-imaging of entire animals using X-ray tomography. This allowed us to investigate the interaction between *C. elegans* and the NPs in intact animals and reconstruct 3D data of the cobalt distribution subsequent to exposure.

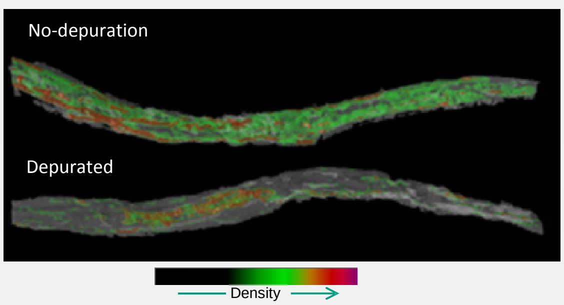


Figure 1. Nano-CT x-ray absorption tomography images of C. elegans after exposure (top) to Co-NP, and subsequent depuration on agar (bottom).

Nano CT performed at the Technical University of Warsaw, showed that the body surface of the nematodes was covered by the Co NP during the exposure and Co NP was retained within the animals after depuration on agar (Fig 1).

Detailed information on the accumulation of NPs in specific organs or tissues of *C. elegans* was obtained in highly sophisticated experiments using SR based high resolution X-ray absorption phase-contrast tomography and nano-XRF mapping at beamline ID16A, ESRF (Fig. 2). The results showed that Co NPs were mostly retained within the GI tract, but that some Co clusters were observed outside the GI tract and specifically in the vicinity of embryos. **Participants:** S. Cagno, D.H. Oughton, B. Salbu (NMBU), K. Janssens, F. Vanmeert, G. Nuyts (Univ. Antwerpen), J. Jaroszewicz (Techn. Univ. Warsaw), R.T. Tachoueres, P. Cloetens, A. Pacureanu (ESRF).

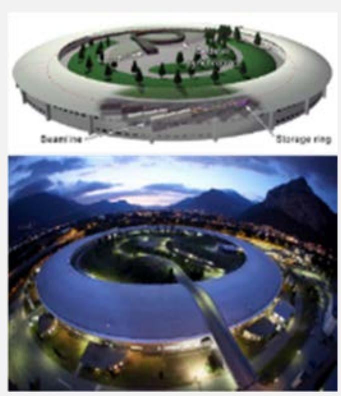


Figure 2. Outline (top; ESRF. EU) and photo (bottom, P. Ginter, ESRF) of the storage ring of ESRF, one of the most powerful synchrotrons in the world.
The ID16NI beamline used in the present work has state-of-the-art nanoprobes.

IONISING RADIATION AND A CHEMICAL INHIBITOR OF ANTIOXIDANT ACTION AFFECT THE UV-SENSITIVITY OF ZEBRAFISH EMBRYOS

Terje Christensen, NRPA and Selma Hurem, NMBU

The zebrafish embryo test (FET, OECD-test 236) was applied to score toxic effects of UVA and UVB alone and in combination with Hydroxyethylmethacrylate (HEMA; plastic monomer). Embryos were treated in the early embryo period including mid-blastula stage, i.e. until 5 hours post fertilization (hpf). HEMA was shown to decrease the amount of glutathione in zebrafish embryos (Fig. 1) and thereby reduce the antioxidant capacity of the embryos. The addition of HEMA also increased the sensitivity of fish embryos to ultraviolet radiation (UVA as well as UVB) scored as surviving embryos at day 2 post fertilisation. This finding may indicate that synergistic effects may be induced if UV-radiation and chemical pollutants interact in the environment.

Zebrafish embryos were exposed to gamma irradiation at the Figaro facility for 3 h, intermitted at 2 h by a brief exposure for 6 to 24 s of UVB. Preliminary analyses showed that both gamma alone and in combination with UVB affected, hatching time differentlially from controls. It was concluded that irradiation influenced on the time the embryos escaped from the egg shell (Fig. 2). However, further studies are needed to elucidate the effect of co-exposures.

Participants: P. Aleström, D.A. Brede, O.C. Lind, J.L. Lyche (NMBU), E. Bruzell (NIOM, Nordic Institute of Dental Materials), T.B. Aleksandersen (NRPA).

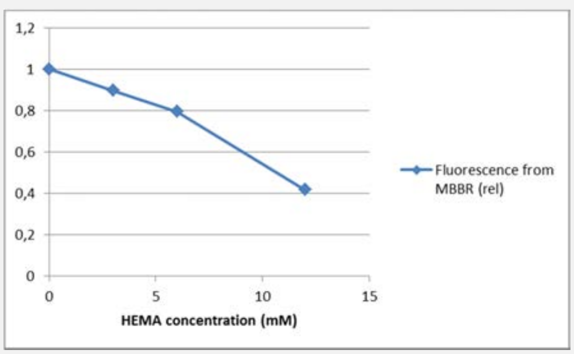


Figure 1. Fluorescence from an indicator (MBBR) of glutathione decreases as a function of the concentration of HEMA added to zebrafish embryos. Decreased amount of glutathione was shown to increase the sensitivity to ultraviolet radiation.

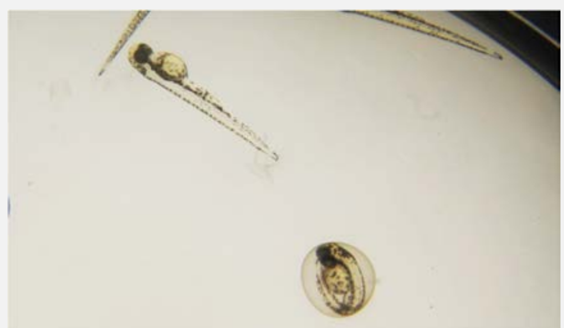


Figure 2. The zebrafish embryos hatch between 48 and 72 hpf. Preliminary studies indicate that UVB and gamma radiation delay the onset of hatching and that combined exposures delays the process even more.

COMBINED EFFECTS OF ULTRAVIOLET AND IONISING RADIATION ON ZEBRAFISH AND HUMAN CELL CULTURE MODELS

Alicja Jaworska and Terje Christensen, NRPA

Ionising radiation usually exerts its effect on living organisms in combination with other physical and chemical factors or contaminants. In almost all living organisms, UV radiation is a common physical stressor. Both ionizing and UV radiation produce, during their action, free radicals. It has also been proved that as much as 60 – 80 % of biological effects caused by gamma and x-rays are mediated by reactive oxygen species (ROS).

The aim of this study is to reveal similarities and differences in chosen cellular and subcellular response mechanisms to the treatment of UV and ionizing radiation alone and in combination with each other in cell culture systems. Special emphasis in the study was put on ROS and mitochondrial function. The goal is to use results of this project as a supporting action to further design and development of studies on combined treatment of UV and ionizing radiation at different wavelengths and dose rates on the organism and population organisation level.

In late spring 2014 NRPA in collaboration with NIPH launched the study on combined effect of acute exposure to broad band UVB radiation and x-rays on cellular systems from two species; TK6 humane lymphoblastic cells and ZF4 zebra fish embryonic cells. The levels of UV and ionising radiation was chosen taking into consideration similar level of cell survival. Fluorescence probes are used to study the cell survival measured as metabolic activity of the cells, production of ROS is measured by estimation of the level of hydroperoxides, and mitochondrial condition is measured by estimation of the mitochondrial membrane potential. The ROS production is being tested during and after exposure to X-ray and UV, both alone and in combination of these two exposures, while the survival of cells and mitochondrial status are being tested three days after the same exposure combinations. After the treatments DNA samples were taken for future studies of mitochondrial DNA and possibly status of methylation of nuclear DNA.

Preliminary results of the project indicate that both treatments (i.e. UV and X-ray) produce ROS, but the production of ROS seems to be higher for X-rays at similar level of cell survival. Combination of both treatments seems to be additive in terms of cell survival, ROS and mitochondrial membrane potential for human cells. But for zebra fish cells it seems not to be the case, as judged from the preliminary results.

Further studies are planned to confirm the responses in zebra fish cell line. Attempts to study abundance and morphology of mitochondria in both cell lines will be made, by estimating the amount of mitochondrial DNA, and by microscopic studies of fluorescent stained mitochondria.

Participants: N. Asare, E.L. Hansen (NRPA), G. Brunborg, A.K. Olsen, N. Duale (NIPH).

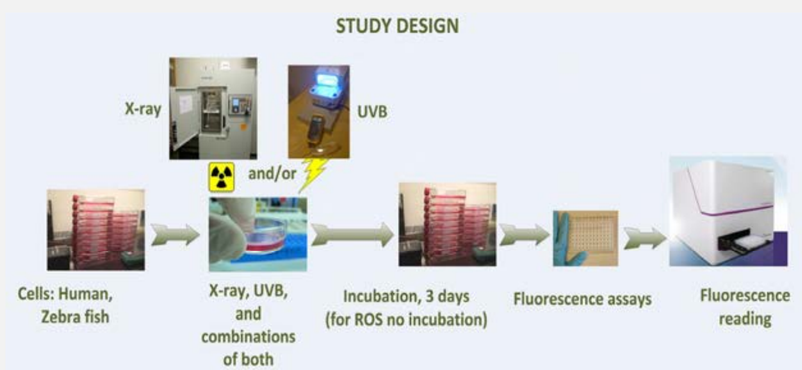


Figure 1. Outline of the study design
Drawing A. Jaworska

ZEBRAFISH MODEL: DOSE RESPONSE RELATIONSHIP OF GAMMA IRRADIATION ON GENE EXPRESSION DURING EARLY LIFESTAGES AND EPIGENETIC EFFECTS ON SOMATIC TISSUES IN ADULT FISH.

Leonardo Martin, Jorke Kamstra, NMBU

In order to assess gene expression changes following irradiation, (2013; U3-1) zebrafish (*Danio rerio*) blastula stage embryos were exposed to gamma (Co-60) at Figaro for 3.5 hrs at 0.5, 1, 5 and 10 mGy/h. RNA was extracted from the four exposure groups plus an IR shielded control and submitted for RNA sequencing (RNA-seq; BGI, Hongkong, China). A LINUX server dedicated for bioinformatics was installed and a bioinformatics pipeline for genome-wide gene expression analysis established. The results revealed differentially expressed (DE) genes showing a positive dose-response (Fig. 1), of which 68 genes in the 5 and 10 mGy/h exposure groups overlap. Analyses using Ingenuity Pathway Analysis (IPA) is ongoing to categorize functions and roles in networks of the DE genes.

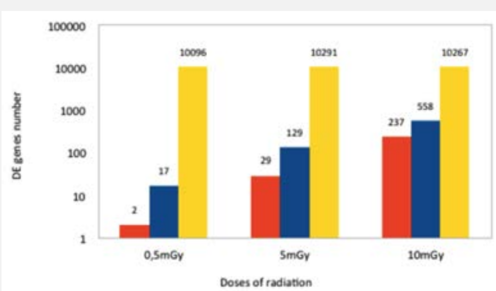


Figure 1. Numbers of DE genes exposed to 0.5, 5 and 10 mGy/h. Down-regulated genes (red), up-regulated genes (blue), total no. of genes (yellow) (Martin unpublished).

A second zebrafish IR experiment studied the impact of radiation quality on the biological response (RBE) in adult fish exposed to five different dose rates (0.005, 0.01, 0.1, 1, 10 mGy/h) of gamma irradiation for 26 days, as compared to internal exposure to Am-241. Blood samples were collected for micronuclei analysis, which is an indication of DNA damage. Samples were also collected for histology/morphology and tissue samples (brain, liver, intestine, testis, muscle) for RNA and DNA extraction. Gene expression analyses by RNA-seq and RT-qPCR is ongoing.

To address epigenetic changes as an effect of low dose IR, a HPLC-MS method for global DNA methylation and hydroxymethylation (5mC and 5hmC) has been set-up (Kamstra *et al.* 2015). In samples from fish exposed to 10 mGy/h, 26 days, testis shows an increase in global 5hmC whereas the other tissues remain at same level. For global 5mC there is no effect from the exposure (Fig. 2).

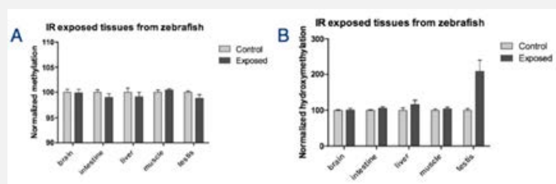


Figure 2. Effects on adult zebrafish exposed to IR for 26 days (total dose = 6 Gy; n=5 for all but testis samples with n=4). Panel A: global levels of 5mC and panel B global levels of 5hmC (Kamstra, unpublished).

Publications: Kamstra *et al*. 2015. Dynamics of DNA Hydroxymethylation in Zebrafish. Zebrafish, published on-line. doi:10.1089/zeb.2014.1033.

Participants: J.L. Lyche, S. Hurem, V. Berg, D.A. Brede, H.C. Teien, D.H. Oughton, B. Salbu, P. Aleström (NMBU).

Håvard Aanes is acknowledged for training of LM in bioinformatics of RNA-seq data.

Other Information: S. Hurum and L. Martin are PhD students, LMM is co-financed by FishmiR (RCN No. 213825) and CERAD. J. Kamstra present address is Juliette Legler Lab, VU University, Amsterdam. The RBE experiment is a collaboration between CERAD-IRSN (C. Adam-Guillermin), France, and co-funded by EU STAR.

A MULTIGENERATIONAL STUDY OF SUBCHRONIC GAMMA IRRADIATION EFFECTS IN THE ZEBRAFISH MODEL

Selma Hurem, Jan Ludvig Lyche, NMBU

The aim of this study was to assess potential adverse effects of external exposure to gamma radiation during two subsequent generations and to establish a gametogenesis, embryogenesis and a gametogenesis and embryogenesis gamma irradiated line of zebrafish for a transgenerational study(Fig. 1).

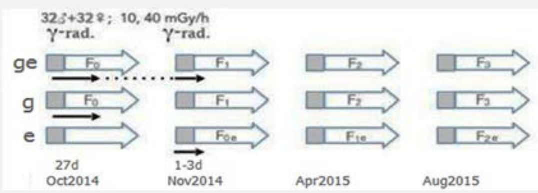


Figure 1. Transgenerational study.

For the gametogenesis line, two groups of 32 male and 32 female adult zebrafish (F0) from the AB wild type strain were exposed to ^{60}Co gamma radiation at nominal[1] dose rates of 10 mGy/h and 40 mGy/h for a period of 27 days. Crossing exposed males and exposed females produced a lower number of embryos compared to non-exposed controls (Fig.2).

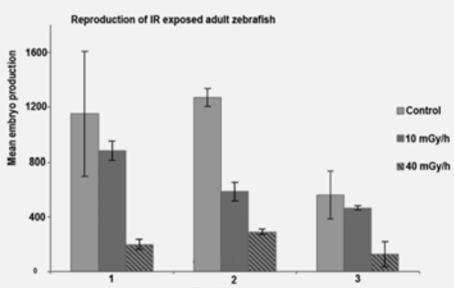


Figure 2. Reproduction of zebrafish exposed to ^{60}Co gamma-radiation in nominal 10 and 40 mGy/h for 27 days compared to controls (n=24 breeding pairs/week) (S. Hurem unpublished).

F1 embryos from F0 irradiated at nominal 10 and 40 mGy/h showed 20 % and 100 %, respectively. The mortality at 40 mGy/h occurred during the gastrulation stage corresponding to 8 hours post fertilization (hpf).

Figure 3. Coagulation of a zebrafish embryo (6-8 hpf), offspring of fish irradiated at nominal 40mGy/h. (Cyt3 Imaging; kynetic brightfield/freq=30min).

Demographic scoring in F1 conducted at 28, 48, 54, 60 and 72 hpf showed that the exposed groups hatched earlier than the non-exposed controls. Furthermore, significantly higher numbers of deformities were found in exposed embryos compared to controls at 75 hpf. Most observed malformations were mild to severe retardation in development, delayed or complete absence of hatching and lack of pigmentation. Further analyses include global gene expression and epigenetic changes analyses such as histone methylation/acetylation and DNA methylation in the offspring.

Participants: P. Aleström, V. Berg, D.A. Brede, O.C. Lind, Y.A. Kassaye, I. Mayer, D.H. Oughton, B. Salbu, H.C. Teien (NMBU), E. Lindbo-Hansen (NRPA).

[1] Actual measured ranges for the absorbed dose rate to water from the deepest to the most shallow areas accessible to zebrafish were [4.5 - 8.9 mGy/h] and [35 - 69 mGy/h].

GENOTOXIC AND REPRODUCTIVE EFFECTS OF CONTINOUS CHRONIC LOW DOSE RATE GAMMA IRRADIATION OF SELENIUM DEFICIENT MALE MICE.

Ann-Karin Olsen, NIPH and Brit Salbu, NMBU

Information on biological effects of low dose rate/low dose ionising radiation and the antioxidant status is scarce. Selenium (Se) is an essential element, incorporated in important antioxidant enzymes. Exposure to ionising radiation will produce free radicals and ROS, inducing oxidative stress and DNA damage. Free radicals and ROS can be scavenged by antioxidant enzymes such as Se-proteins. Thus, radiation effects may increase if the Se status is poor. Investigation of Se-deficiency and associated effects is particularly relevant as the blood Se levels are declining in the Norwegian population. Based on RCN funded Se-projects, Se rich wheat has been produced at MBU, and feed with variable Se-concentrations are used in animal experiments. In the present project, two mouse lines were used, one with defective repair of certain oxidative DNA lesions (Ogg1-KO). Mice (F0) bred from parents (P) given low-Se feed, (i.e., generations of mice were given low Se feed to maintain the Se-deficient situation through two generations). Male F0 mice given low-Se (0.01 mg Se/kg) or normal-Se (0.23 mg Se/kg) feed were exposed to continous low dose rate (1.41 mGy/h) gamma radiation for 45 days followed by a 45 day recovery period. Se-deficiency clearly led to adverse reproductive effects with reduced fertility in F0 mice and sterility for F1 males. Other reproduction related endpoints supported the fertility findings. Exposure to gamma radiation aggravated these effects. Genotoxicity and mutagenicity were investigated by measuring levels of DNA damage: single-strand breaks and oxidised base lesions and mutagenicity (micronuclei MN; chromosomal mutations; Fig. 1) and the Pig-a assay (point mutations). Results showed that Se-deficiency led to increased DNA damage levels in testis and lung, but not in blood cells. Se-deficient mice exposed to gamma showed higher DNA damage levels and more pronounced pathological changes in the testis.

Conclusion Gamma radiation – even at low dose rates – is genotoxic and mutagenic, and impairs reproduction. Se-deficiency adversely affects male reproduction and leads to increased DNA damage levels in male germ cells, with potential implications for future generations. An interaction between Se-deficiency and low dose rate gamma irradiation was observed in testis, but not in blood.

Participants: A. Graupner, C. Instanes, J. Andersen, D. Eide, H. Rasmussen, G. Brunborg (NIPH), D.A. Brede, A. Brandt-Kjelsen, O.C. Lind, D.H. Oughton (NMBU), H. Bjerke (NRPA).

Publications: PhD thesis delivered October 2014; Graupner *et al.*, Mutation Research/Genetic Toxicology and Environmental Mutagenesis 772, (2014) 34-41; Graupner *et al.,* Mutagenesis. 2015 Mar;30(2):217-25.

Other Information: Anne Graupner is a PhD student partly financed by CERAD. The work has been co-funded by NFR and the EU DoReMi project.

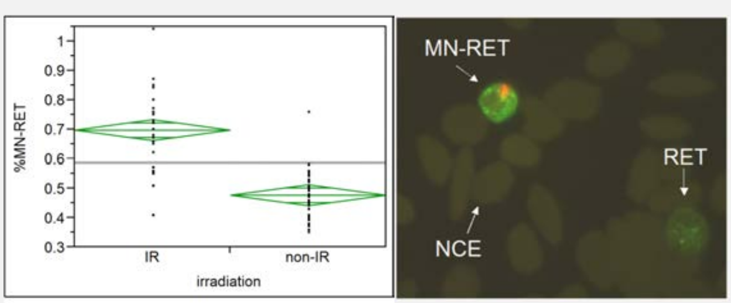


Figure 1. Flow cytometry based micronucleus assay in erythrocytes.

TRANSGENERATIONAL BIOLOGICAL EFFECTS OF PATERNAL EXPOSURE TO LOW DOSE RATE IONIZING RADIATION

Hildegunn Dahl and Ann-Karin Olsen, NIPH

This project aims to provide new knowledge regarding the concerns of long-term biological effects (through generations) associated with chronic exposure to low dose rate ionising radiation. The gained knowledge will contribute with valuable novel data regarding potential transgenerational effects in the ongoing discussion of risk assessment of humans and to a better understanding of harmful effects associated with chronic low dose rate radiation.

The main aim is to identify biological changes resulting from paternal pre-conceptional chronic low dose rate ionising radiation in the individual itself, and on subsequent generations.

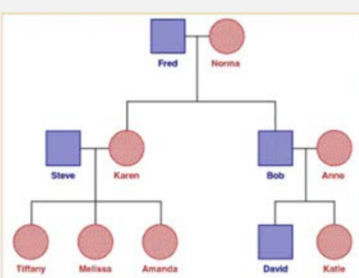
In a previous project male mice (F0) were continuously exposed to low dose rate gamma irradiation for 45 days, in order to mimic a chronic situation and to expose all stages of spermatogenesis. The exposed mice were bred with naïve unexposed females at days 34-48 after irradiation, at a time when all mature spermatozoa originate from exposed testicular stem cells, to give rise to the F1-generations. The breeding was reiterated with the F1-males to give rise to F2-offspring.

The first subgoal is to assess genomic instability in F1 and F2 generations of exposed F0-fathers. This has been accomplished by measuring formation of micronuclei (MN) in reticulocytes (RETs) from F1 offspring, male and female, descended from irradiated- and non-irradiated fathers using a flow cytometry based MN-method. F1-mice (88) have been sacrificed and tissues harvested. The second sub-goal is to assess whether F2-offspring of exposed grandfathers (F0) have acquired a altered susceptibility to genotoxic insult. F2 offspring from irradiated F0 males will be acutely exposed to whole body X-ray irradiation to investigate their genetic susceptibility to genotoxic insult. These experiments will be conducted during April 2015 using 200 F2-mice. Pilot experiments have been performed during 2014. Blood samples are collected at different time points and are used for determining DNA damage levels (comet assay, γH2AX) and MN-formation. The γH2AX assay for measuring double strand breaks has been established. Tissues and blood have been collected from 500 F2 animals. Testis pathology has been performed for all generations. The third sub goal is to determine whether epigenetic mechanisms like microRNA and DNA methylation is a likely mode of action for transgenerational biological effect. Blood plasma has been isolated for miRNA analysis. Training in LC-MS/MS based method for global DNA methylation has been performed. Results will be available in 2015.

Participants: C. Instanes, N. Duale, G. Brunborg (NIPH), D.A. Brede, D.H. Oughton, B. Salbu (NMBU).

Dissemination: A paper will be presented at the 15th International Congress of Radiation Research (ICRR 2015) in Kyoto, Japan.

Other Information: Hildegunn Dahl holds a CERAD PhD fellowship.



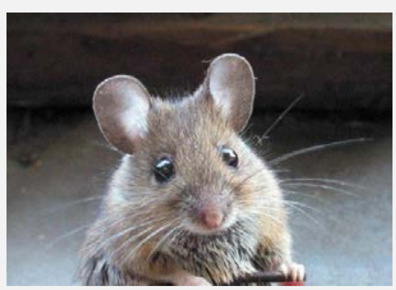


Figure 1. Mice are test organisms to study trans - generational effects of radiation

ACCELERATION OF PARKINSON PATHOGENESIS BY CHRONIC LOW-DOSE RATE GAMMA EXPOSURE (OSTINATO)

Dag Marcus Eide and Ann-Karin Olsen, Norwegian Institute of Public Health (NIPH)

Ionising radiation has an impact on the risk for neurodegenerative diseases. High-dose radiation from radiotherapy to children has been connected to increased risk of premature dementia (Kempf *et al.* 2012). The evidence for such a link in low-dose exposed cohorts is less clear. There is a possibility that low dose radiation to the brain early in life may cause an accelerated development of Parkinson Disease (PD). A known risk-factor for neurodegenerative disease is oxidative stress to the neuronal tissues, and this is the most likely mode of damage from chronic low-dose rate ionising radiation.

In collaboration with the HMGU Institute for Radiation Biology in Munich a sensitive mouse model was exposed to low dose rate ionising radiation in utero and in early postnatal life. The PD mouse model Pitx-mutant exhibits an impaired formation of dopaminergic (da) neurons in the substantia nigra (SN) and ventral segmental area due to a Pitx3 point mutation called EYL. These mice show PD-symptoms and the progression of motor impairments in these mice with increasing age. The DNA repair protein OGG1 is the main enzyme to remove 8-oxoGuanine residues, one of the prevalent DNA adducts after oxidative stress and ionizing radiation. The mitochondrial form of OGG1 is expressed in mesencephalic cells (SNc) and found to be upregulated in the midbrain of PD patient brain, suggesting a function in the disease pathology. This study was initiated by crossing the two mouse-models, a procedure lasting 7 months involving 320 breeding mice.

Pregnant mice were exposed to 1 Gy and 0.2 Gy at Figaro together with their new born pups until they were three weeks old. The 1 Gy is a dose that is most relevant in radiation oncology for areas of the brain that lie outside of an irradiated tumor target. The 0.2 Gy dose is similar to the X-ray exposure to children in multiple CT-scans. The 500 exposed young mice with different genotypes and dosages have been transferred to HMGU for behavioural testing for the development of PD symptoms (disordered walking patterns, limb shaking) and impairment of other behavioural traits (explorative activity) and detailed neurological tests (Catwalk, Rotarod, orientation in maze, memory test in swimming pool). Detailed histomorphological evaluation of the substantia nigra compacta (SNc) will be performed. Biological materials for endpoint analyses will be harvested at sacrifice, including male reproductive organs and brain. Blood has been taken to measure DNA damage levels and to establish plasma miRNA expression profiles. RNA will be extracted from brain for miRNA profiling at NIPH, and tissues will be analysed for oxidised DNA lesions at NIPH. Exposed P fathers have been sacrificed and biological materials have been preserved.

The results of this project will have a major impact on our understanding of radiation exposure to humans by low doses onto the development of late neurodegenerative diseases. It therefore opens a new field in our understanding of the general health impact of ionizing irradiation. The data gained from the study would enable us to draw a concise picture of both acute LD irradiation on the adult brain (Cerebrad) and of a chronic low-dose rate exposure during development (Ostinato) for their impact onto neurodegeneration. The project will therefore have direct implications for the long-term risk of extensive CT diagnostics early in childhood.

Participants:, N. Duale, G. Brunborg (NIPH), D.A. Brede, O.C. Lind, D.H. Oughton, B. Salbu (NMBU) E.L. Hansen (NRPA).

Other Information: The work is co-funded by CERAD and EU DoReMi project Ostinato.

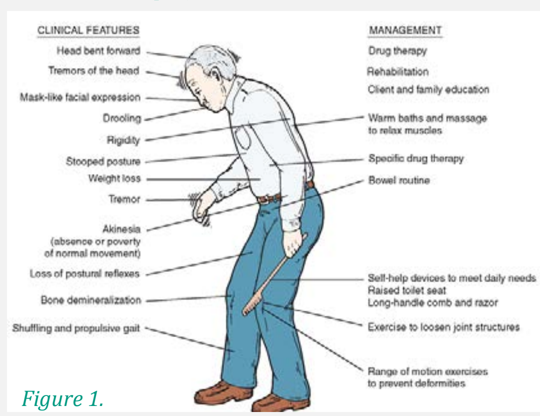


Figure 1.
Concept outline.

TESTING PLANT SENSITIVITY TO RADIATION BY ANALYSIS OF DNA DAMAGE (CERAD GRANT AND IN KIND PHD-PROJECT)

Jorunn E. Olsen, NMBU

Different types of DNA damage are serious adverse effects of UV and ionizing radiation in living organisms. Most plants in natural ecosystems are tolerant to ambient UV levels due to presence of UV-protecting compounds. In this respect, flavonoids play important roles as UV-screening compounds and antioxidants. However, at least certain food plants are more susceptible due to breeding for low levels of such compounds. Although information on UV-signalling associated with UV-induced production of antioxidants and UV-modulation of plant morphology is currently emerging in the rosette plant *Arabidopsis thaliana*, in other species with elongated internodes such information is virtually non-existing.

For elucidating the UV-signalling in pea (*Pisum sativum*), pea plants mutated in anticipated UV-B signalling compounds were studied. To evaluate UV-sensitivity, immunological methodology for analysis of UV-related DNA damage, i.e. cyclobutane pyrimidine dimers (CPDs) and 6-4-photoproducts (6-4-PPs) in plants was established in the plant cell laboratory at NMBU. Higher and lower levels of CPDs in different pea genotypes correlated with lower and higher levels of flavonoids, respectively. The UV-B signalling in pea was shown to be partly similar to that of *A. thaliana*, but an important difference was also discovered, in that a central signalling component apparently acts opposite in the two species. Furthermore, our studies have indicated that pea plants are more sensitive to UV-B under lowered temperature and under high compared to low relative air humidity (RH). This demonstrates that UV-effects in plants are modified by other environmental factors. In collaboration with NIPH, the plant group has also worked with adapting the COMET assay for DNA strand breaks in plants. This work will be continued in the near future. The methods for analysis of DNA damage will be important tools in further CERAD work on radio-sensitivity and interactive effects of ionising radiation and UV in plants and lichens.

Participants: A. Gobena Roro, T. Melby, L. Arve, YK. Lee, L. Nybakken, K.A. Solhaug, S. Torre (NMBU), G. Brunborg (NIPH), G. Koppen, I. Zaharia, S. Abrams (National Research Council Lab, Saskatoon, Canada).

EFECTS OF IONIZNG RADIATION ON PLANT GROWTH AND REPRODUCTIVE DEVELOPMENT

Jorunn E. Olsen, NMBU

Within CERAD an important aim is to investigate radiosensitivity of different species, as well as to study interactive effects of gamma and UV-radiation. Aiming at evaluating radiosensitivity with respect to vegetative and reproductive development in *Arabidopsis thaliana*, young seedlings (wild type and UV-B *hy5* signaling mutant with low levels of flavonoids (antioxidants)) were exposed to different total doses of ionizing radiation ranging up to 90 Gy at the gamma source, NMBU (Fig. 1). After-effects of the ionizing radiation were then evaluated under controlled environmental conditions where vegetative and reproductive growth and development were recorded during a period of several weeks. Furthermore, photosystem II efficiency (Fv/Fm) was assessed, and sampling was done for analysis of flavonoids and expression of genes involved in DNA repair and flavonoid production (flavonoid and gene expression analyses still ongoing). Whereas the leaf formation rate was not affected by the gamma doses provided, there seemed to be small, significant effects of the highest gamma doses on leaf size parameters, length of the bolting stem and time to visible flower buds. Photosystem II efficiency appeared to be slightly affected in the *hy5* mutant only and not in the wild type. The small effects, given the high gamma doses provided, support that *A. thaliana* is not very sensitive to gamma radiation. In 2015, additional experiments will be performed, with exposure of *A. thaliana* to still higher doses of ionizing radiation as well as exposure of additional plant species.

Figure 1. Set-up for exposure of small seedlings of Arabidopsis thaliana in petri dishes to ionizing radiation. Photosynthetically active light was mounted above the plants, including control plants shielded from radiation.
Photo: J.E. Olsen

Participants: D. Blagojevic, D.A. Brede, O.C. Lind, Y.A. Kassaye, B. Salbu, YK. Lee, T. Melby, M. Siira, L. Ripel, K.A. Solhaug, L. Nybakken (NMBU).

EFFECTS OF UV-B AND TEMPERATURE ON PHENOLOGY IN TREES (IN KIND PHD PROJECT)

Christian Bianchi Strømme, NMBU

To survive the winter, trees must cease their growth and attain dormancy and cold hardiness in time before the winter. Widely distributed woody species include latitudinal and altitudinal ecotypes adapted to the local climate at their site of origin. In this respect, photoperiod and light quality are primary signals, whereas the temperature appears to modulate the responses. However, information about effects of UV-B on phenology in trees is scarce although UV levels vary with time of the year and day as well as latitude and altitude. The aim of this PhD project is to shed light on effects of UV on phenology in the dioecious woody species European aspen (*Populus tremula*). In a field study where increased UV-B, corresponding to 30 % decrease in the ozone layer, was achieved using UV-B lamps, we observed accelerated winter bud formation in male clones. A 2°C temperature increase (using infrared heating devices), counteracted this to a certain extent. Also, increased UV-B and temperature during the growth season resulted in earlier bud burst the subsequent spring, indicating more shallow dormancy. Such a phenological shift may affect the growth potential and survival since early bud burst makes plants more susceptible to damage from spring frost. Aiming at evaluating also effects of natural UV-B levels at different altitudes, a field study using UV-attenuation filters was established in 2014 at three field sites at different altitudes in Gudbrandsdalen, Central Norway. Preliminary results show that lowered UV-B delays bud set in autumn in both sexes, with more pronounced effect at higher altitudes. Aiming at shedding light on the basis of the observed phenological shifts, plant materials have so far been sampled for analyses of hormone levels, secondary components (antioxidants), and macronutrients. The experiment will continue in 2015. To obtain more detailed mechanistic information, effects of UV-B are currently also studied in growth chamber experiments. The obtained results provide basis for investigating interactive effects of ionizing radiation, UV and temperature on phenology (climatic adaptation) in ecologically and economically important trees.

Figure 1. Aspen growing under UV-B-attenuation filter.
Photo: C. Bianchi Strømme

Participants: R. Julkunen-Tiitto (Univ. of Eastern Finland), J.E. Olsen, L. Nybakken (NMBU).

DEVELOPMENT OF ADVERSE OUTCOME PATHWAY (AOP) FOR IONIZING RADIATION

Tânia Gomes, NIVA

This project combines exposure studies and effect assessment in the algae *Chlamydomonas reinhardtii* and the crustacean *Daphnia magna* for single and mutliple stressors. Work in 2014 has primarily been focussed on assembling and generating data to develop an Adverse Outcome Pathway (AOP) for ionizing radiation on basis of Mode Of Action (MOA) and adverse effect information. Several bioassay endpoints ranging from exposure markers (e.g. ROS formation, depletion of GSH), to early gene and functional responses (gene expression, antioxidant defense, DNA damage and repair) and adverse effects (growth, reproduction, survival) are being addressed. Exposures to metals and organics were used as a starting point to develop and evaluate the toolbox prior to more extensive use in experiments with ionizing radiation and other relevant stressors.

The toolbox is currently operative for most endpoints and finalisation of the toolbox development is expected by summer 2015. Pilot studies with *D. magna* exposed to low dose rates of gamma radiation have been conducted using a selection of the endpoints developed (Fig. 1 and 2). Experiences from these studies are currently being used to optimise large-scale studies with ionizing radiation and depleted uranium as single and multiple stressor scenarios. Experimental and theoretical data gathered will then be used to develop an AOP for ionizing radiation.

Participants: Y. Song, K. Petersen, K.E. Tollefsen (NIVA), D.A. Brede, O.C. Lind, B. Salbu, H.C. Teien (NMBU), K.B. Gutzkow (NIPH), E.L. Hansen (NRPA).

Other information: Tânia Gomes holds a CERAD PostDoc fellowship.

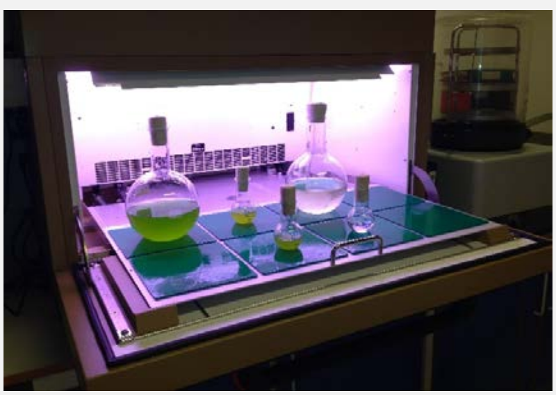


Figure 1. Algae test to determine the ROS formation after exposure to Cu.
Photos: Tânia Gomes and You Song

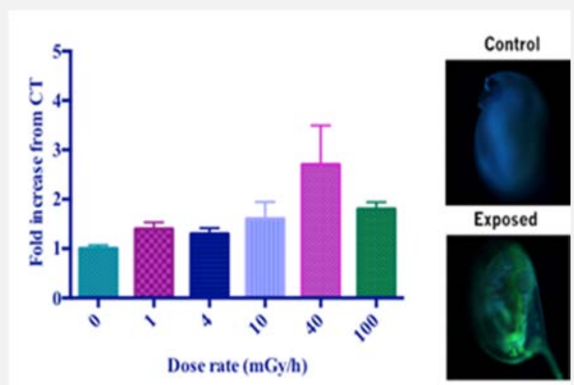


Figure 2. ROS formation after 24h exposure of D. magna to gamma radiation and the redox-cycler paraquat.

MODELLING TIME SERIES OF GEOGRAPHIC DISTRIBUTION OF SOLAR UV RADIATION IN NORWAY

Bjørn Johnsen, Martin A. Ytre-Eide, Terje Christensen, and Lill Tove Nilsen, NRPA

There are indications that UV radiation may influence health and environmental risks induced by nuclear accidents. Since nuclear fallout may occur anytime and anywhere, there is a strong need for correct information on UV exposure in real time under current weather conditions and for reconstruction of past UV data.

In this project we use the libRadTran software package for radiative transfer calculations in the atmosphere *(http://www.libradtran.org)* to model time series of geographic distribution of UV. Clear sky data are based on digital elevation maps from Kartverket, ozone maps from NASA satellite observations and surface albedo based on snow data from the Norwegian Water Resources and Energy Directorate (NVE). Clear sky UV maps will be validated against data from the Norwegian UV monitoring network. The different input data allows reconstruction of UV maps back to the early 1990'ies, with a resolution of a few square km.

At the current stage, we are focusing on implementing surface albedo data (Fig. 1). The location of the network sites for validation of UV maps is shown in Fig. 2. A library of UV maps of different data products will be established (eg. UVB, UVA and UV weighted according to different biological action spectra).

Participants: J. Andersen (NVE).

Publications: Bernhard G, Fioletov V, Heikkilä A, Johnsen B, Koskela T, Lakkala K, Svendby T, and Dahlback A. UV Radiation, pp. 121-123 in Blunden, J., and D. S. Arndt, Eds., 2014: State of the Climate in 2013. Bull. Amer. Meteor. Soc., 95 (7), S1-S238.

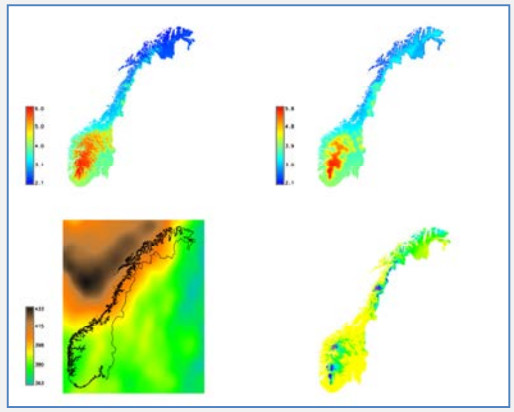


*Figure 1. Clear sky UV index on 14 May 2014 (upper panel), based on two different surface albedo assumptions, **Left**: based on an assumption of a linear increase from grassland conditions to snow conditions above a seasonally variable snow line and **Right**: based on snow maps from NVE, to account for the heterogeneous distribution of snow depth in neighboring pixels **Lower left**: Ozone data based on the OMI ozone monitoring instrument. **Lower right**: Snow depth map from NVE.*

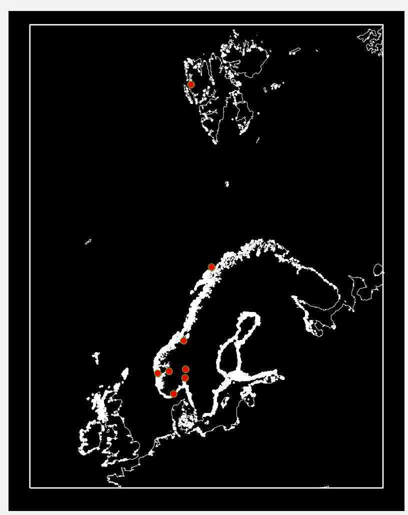


Figure 2. Location of the UV monitoring stations, whose data will be used to adjust the UV maps.

IONIZING RADIATION DOSIMETRY FOR WILDLIFE AND IN THE LAB

Elisabeth Lindbo Hansen, NRPA/CERAD

Dosimetry is the study of how physical interactions between radiation and matter transfer energy to matter (Fig. 1). For most types of environmentally relevant ionizing radiation, with the exception of cosmic rays, the energy is transferred via electromagnetic interactions to electrons. In a short time span these electrons collide with other electrons so that the initially transferred energy distributes across the system in trails of energy deposits. If states that are chemically reactive or that inhibit normal biochemical function are populated, event chains initiated from these states may carry biological consequences that over long timescales propagate up in complexity to affect the whole system. Dose-effect studies seek to investigate how biological endpoints depend on the initially deposited energy, normally through the average quantity known as the absorbed dose [1]. The absorbed dose can however be measured only in certain locations and typically with detectors that are not themselves the systems that are actually of interest. The absorbed dose to living organisms must therefore normally be calculated from measured radiometric or dosimetric quantities or deduced through simulations. The current project is focused on developing Geant4 Monte Carlo radiation transport applications for exposure facilities, species and ecosystems of relevance to CERAD, and on introducing standards-traceable measurements [2] as a prerequisite for good dosimetry.

Participants: See references

References:

[1] K. Stark, J.M. Gomés-Ros, J. Vives i Batlle, E. Lindbo Hansen, L. Kapustka, K. Beaugelin-Seiller, M. Wood, C. Bradshaw, and A. Real, *Ionizing radiation dosimetry for wildlife: State of the art and perspectives*. To be submitted (*2015*).

[2] E.L. Hansen, I.H.R. Hauge, P.O. Hetland, and H. Bjerke, *Absorbed doses to water for x-ray dosimetry on a PXI X-RAD 225, Part I - Measurements*. NRPA Technical Document Series. To be submitted (*2015*).

Other Information: This work is co-funded by CERAD and EU STAR project.

Elisabeth Lindbo Hansen holds a CERAD PostDoc fellowship.

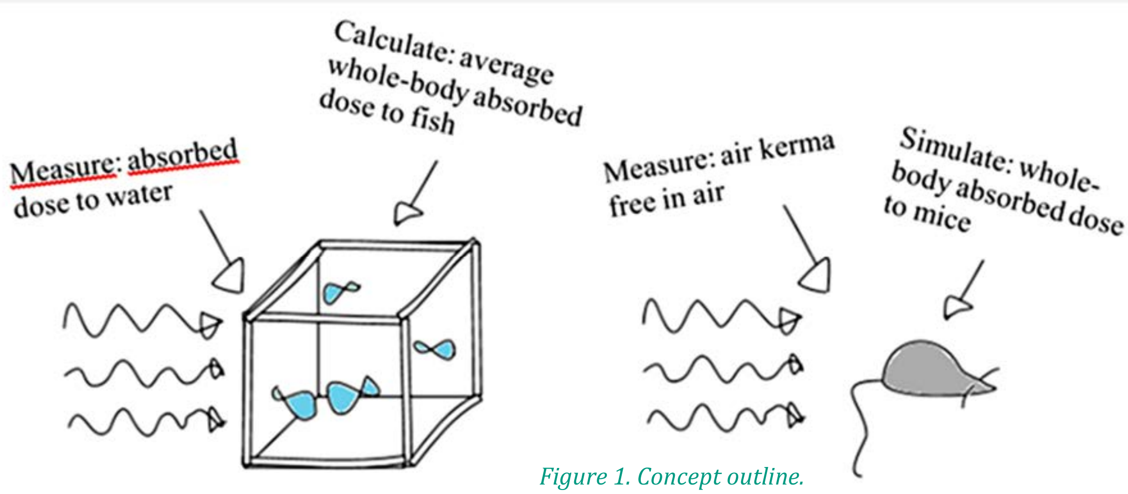


Figure 1. Concept outline.

PREDICTIVE RISK ASSESSMENT OF MULTIPLE STRESSORS

Karina Petersen, NIVA

The potential environmental risk of multiple stressors under realistic exposure scenarios is poorly understood, and there is a need to develop a usable and realistic framework for environmental risk assessment (ERA) of multiple stressors (e.g. chemicals and ionizing radiation). This project has combined existing frameworks for ERA of chemical mixtures and ionizing radiation (ERICA tool) to obtain an initial framework for the ERA of multiple stressors. The ERA for multiple stressors was evaluated with use of ecologically-realistic exposure data for metals, organics and naturally occurring radioactive materials (NORMs) in effluents released to Vatsfjorden (Norway). The ERA of multiple stressors was performed in a two-tiered approach where the conservative first step was summation of the ratios between the predicted exposure concentration (PEC) and the predicted no effect concentration (PNECs) for all stressors. In cases where the sum of PEC/PNEC ratios was indicative of a potential environmental risk (value ≥ 1), the second tier was initiated to identify species group (taxa)-specific sum of toxic units (STU) and subsequent taxa-specific risk quotients. A predicted environmental risk was identified in cases where the taxa-specific risk quotient was larger than 1. The highest sum of TU was observed for crustaceans, followed by fish and then algae for the chosen exposure scenario. The metals were the main toxicity (risk) driver for crustaceans, organics and metals were the main toxicity drivers in fish (Fig. 1), and metals and NORMs were the main toxicity drivers in algae. An approach for reducing uncertainty in the environmental risk assessment of multiple stressors has also been developed as a basis for assisting future data inquiries, experimental effort to generate effect data and need for more accurate monitoring data. There is still a need for further development of this concept, especially in light of uncertainties associated with the bioavailability of the measured stressors and other factors that can influence the uncertainty of the ERA.

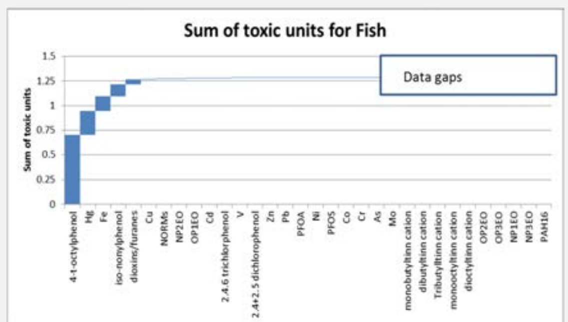


Figure 1. Contribution to the sum of toxic units (=1.3) by the different stressors based on toxicity data for fish.

The developed framework for ERA of multiple stressors was used to: 1) identify the total predicted risk of multiple stressors in a real case scenario, 2) form a basis for prioritization of stressors according to their individual TU and/or risk-contribution, 3) identify the most sensitive taxa and 4) identify uncertainty related to knowledge gaps.

Participants: K.E. Tollefsen (NIVA), J. Brown (NRPA).

REVIEW ON TRANSGENERATIONAL EFFECTS AND EPIGENETIC MECHANISM IN A RISK ASSESSMENT PERSPECTIVE

Christine Instanes, NIPH

Aim of the review: The aim of this project is to review and evaluate the available literature on transgenerational effects of ionizing radiation (IR) and other stressors in the content of risk assessment and summarize it into a review paper. The paper will include transgenerational effects and the possible mechanisms for these effects in humans, animals and plants. An important issue is to highlight how these effects can be examined in the traditional risk assessment for humans and biota.

There is a lack of data on effects of low dose radiation exposures and long term consequences such as cardiovascular dysfunction, neurological alterations, lens opacities and transgenerational effects in humans. Hereditary or transgenerational effects are highlighted as an area of concern in the Strategic Research Agenda (SRA) of MELODI (Multidisciplinary European Low dose Initiative) and in the SRA of CERAD. In RA3 several projects focus on transgenerational endpoints of IR, alone or in combination with UV or other stressors in both animals and plants. These experiments will be conducted on several species and at different life stages. To be able to plan RA3 work well an overview of the literature is required. Previous risk assessment of IR has been based on cancer effects at higher doses with extrapolation to lower doses. For RA4 it will be very important to address adverse low dose effects for reducing the uncertainties in the risk assessment. Transgenerational effects is an important low dose no-cancer effect that needs to be evaluated as an endpoint for both the ecotoxicological and human risk assessment in RA4. In the light of todays knowledge gap we find it very important to address these issues.

Progress: The working group is in the process of reviewing the relevant literature. This is a more extensive process than planned, since the search strategy needs to be documented. The work is divided into four working groups (coordinator); plants (Jorunn Olsen), ecological model organisms (Christine Instanes) and human studies/ human models (Selma Hurem) and mechanisms (Nur Duale). In our next meeting we will present the most relevant studies for each area and suggested titles for the chapters. The next meeting is planned to be held in March-April.

First draft will be ready for reviewing by the working group end of May 2015.

Participants: J.L. Lyche, P. Aleström, Jan .E. Paulsen, S. Hurem, J. Thaulow, J.E. Olsen, L. Nybakken, D.A. Brede (NMBU), T. Christensen (NRPA), G. Brunborg, A.K. Olsen, H. Dahl, N. Duale (NIPH).

HEALTH DAMAGE COSTS FROM RADON EXPOSURE

Ståle Navrud; NMBU

The aim of this project was to illustrate how the Damage Function Approach (DFA; Fig. 1) can be used to integrate knowledge from natural, health and social sciences to provide economic estimates of commercial, environmental and public health impacts from radioactive radiation.

Although indoor air radon concentration causes a number of premature deaths due to increased risk of lung cancer risk, very few studies have been conducted to document the health damage costs; and thus the social benefits of measures to reduce indoor air radon concentrations. In the absence of any such studies in Norway, a Contingent Valuation (CV) survey of 750 households was conducted in the spring of 2014 in order to elicit Norwegian households' willingness-to-pay (WTP) for reductions in radon induced lung cancer risk. In addition to estimating mean WTP, we sought to determine what factors affected households' WTP, whether people are willing to pay more for larger lung cancer risk reductions (i.e. a scope test), and what measures people had conducted to measure and reduce indoor air radon concentrations. In the survey, respondents were asked their WTP for two CV scenarios: i) scenario A reducing radon induced lung cancer risk by 0.19 percent, and ii) scenario B with an even bigger reduction of 0.23 percent.. When excluding "don't know" answers and "protest zeroes" from the sample, mean WTP/household as a one-time payment were 9.700 and 10.200 NOK for scenarios A and B respectively. The estimates were found to be significantly different, and thus in accordance with economic theory predicting higher WTP for the higher risk reduction. The econometric analysis found increased household income and knowledge of the radon issue as well has having positive attitudes towards saving money increased stated WTP. Furthermore, the analysis suggests that both increased age and having a job decrease the probability of passing the scope test, while having bright prospects for future income and positive attitudes towards saving money increase the probability of scope. Among factors explaining why they had conducted radon measurements in their dwelling; knowledge of the radon issue, the feeling of being exposed to radon, and having received sensors from local authorities were the most significant factors; all having a significant positive effect on WTP.

The project has shown that DFA and CV can be successfully applied to impacts of radioactive radiation; and produce reliable economic estimates of the health impacts of radon induced lung cancer, and thus adds to the scarce international valuation literature in this area.

Participants: C. Hassfjell (NRPA), A. Myrseth (NMBU-HH).

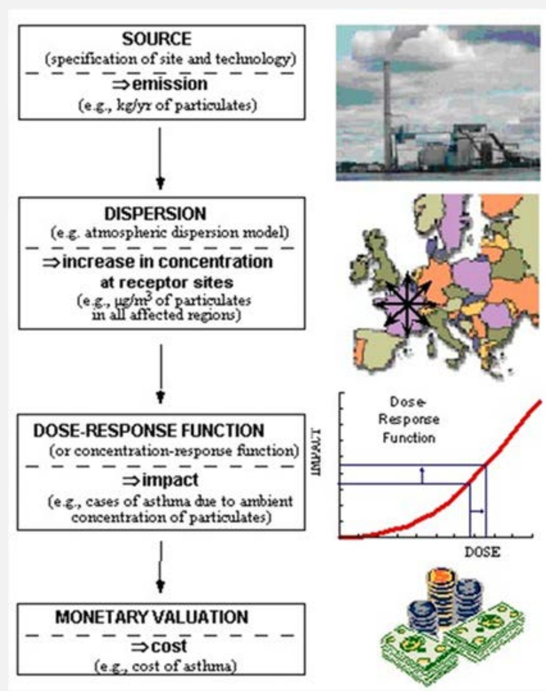


Figure 1. Damage Function Approach (DFA).

MEDIA ANALYSIS

HOW DID NEWSPAPERS COVER THE FUKUSHIMA ACCIDENT?

Yevgeniya Tomkiv, NMBU

Media is a major source of information to public and works as a bridge between experts and general population. It plays an important role in the risk communication and in amplifying controversies over risks. The accident on the Fukushima nuclear power plant in 2011 has induced enormous coverage in the media worldwide. The aim of this research was to study how media reports on the nuclear emergency, to identify the differences in reporting on the similar radiological emergency in different countries and to identify factors, which influence such differences.

The content of 1340 newspaper articles reporting about the Fukushima nuclear accident in Belgium ("*Le Soir*" and "*De Standaard"*), Italy ("*Corriere della Sera*" and "*La Repubblica*"), Norway ("*Aftenposten*" and "*Dagsavisen*"), Russia ("*Komsomolskaya Pravda*" and "*Izvestiya*"), Slovenia ("*Delo" and "Večer"*) and Spain ("*El País*" and "*El Mundo)* was analysed. All articles were coded by two coders and one master coder in each language, in accordance with the methodology for content analysis.

The results showed that the accident on the Fukushima nuclear power plant has received a great deal of attention in the European press, despite great geographical distance to the epicentre of the events. Newspapers focused not only on radiological, psychological and socio-political consequences of the accident, but also linked it to the domestic and international implications for the countries where articles were published. The future of nuclear energy and emergency management in general were among other topics, which received attention in the media. This shows that the variety of discussions will appear in the society in connection to the nuclear accident. The analysis of the data collected is still ongoing.

Participants: D.H. Oughton (NMBU), T. Perko (SCK-CEN, Belgium).

Other information: The data used in this study were collected as part of a larger research in the context of the European Commission FP7 project PREPARE.

Figure 1. The newspapers used in the media study.

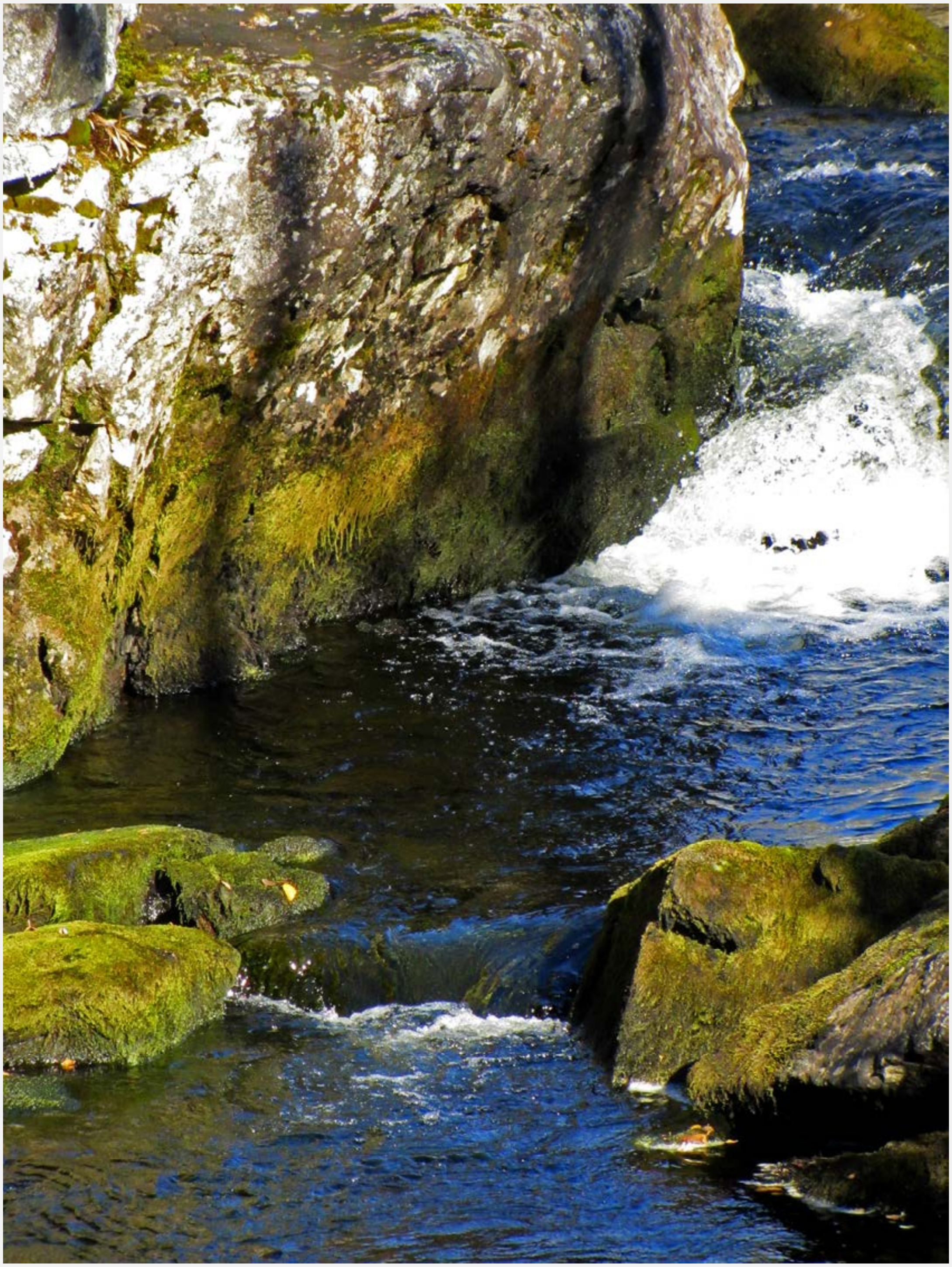


Photo: Signe Dahl

NATIONAL, BILATERAL AND INTERNATIONAL COLLABORATION

National collaboration has been extended in 2014, as the CERAD partners NMBU and MET have become partners in the Fram Center in Trømsø where NRPA and NIVA already are members. National collaboration on NORM, especially related to road construction work in alum shale areas has been strenghtened.

Norwegian-Russian collaboration remains an important focus for several CERAD partners. The NRPA administers the subsidy funds for the Nuclear Action Plan where initiatives for nuclear safety have helped to reduce the risk of nuclear accidents and radioactive contamination in Northwest Russia. Bilateral collaboration extends to regulatory support and to research based projects in the Mayak Production Association in the Urals covering themes as diverse as internal human dosimtery and radiological impacts on freshwater ecosystem. A fruitful working arrangement continues as evidenced by recent achievements. In 2014, Norwegian experts, including partners from CERAD, completed a successful expedition in collaboration with Russian partners to the sunken submarine K-159 in the Barents Sea.

International collaboration in 2014 includes the CERAD international network (SAC), participation within EU projects and platforms, and collaboration/representation in inter-national bodies such as IAEA, NATO SfP, ICRP and the International Union of Radioecology (IUR).

CERAD features prominently in Europe with connections to the European Radioecology Alliance (*www.er-alliance.org*) that have been established between the radiation protection organisations in Europe to pool knowledge and research efforts and train new experts in the field of radioecology. Within radioecology, CERAD is partner in the EU STAR, COMET and COMET/RATE projects. Indeed, NMBU now runs the only European MSc in radioecology and collaboration with universities in France and Russia are initiated (MoU). CERAD is also a partner in projects associated with radiochemistry (CHINCH-II), radiobiology (DoReMi) and emergency preparedness (Prepare). CERAD members also collaborate on the Open Project for the European Radiation Research Area (OPERRA), are members of the NERIS European Platform on Peparedness for Nuclear and Radiological Emergency Response and Recovery (*www.eu-neris.net*), and are partners in the European Joint Programming CONCERT.

CERAD has been involved in UNSCEAR, in the assesment of the consequences of the accident on the environment, where development of the ERICA tool by incorporating kinetic modelling has allowed for a more dynamic appraisal of the effects from the Fukushima-Daiichi nuclear power plant accident. CERAD MG is also represented on two ICRP committees, and the research director chairs the task group on ethics. CERAD members have also participated in seven ICRP co-expertise dialogues in Fukushima. Furthermore, CERAD works together with the IUR in the development of an Ecosystem Based Approach in radioecological assessment.

CERAD is also heavily involved in the new IAEA Coordinated Research Project on Environmental Behaviour and Potential Biological Impact of Radioactive Particles (2013-2016), where the director of CERAD acts as chair. CERAD members are also involved in other IAEA activities; revision of technical safety guides, and co-ordinating work on the societal consequences of Fukushima for the IAEA Comprehensive Report.

Finally NRPA has been elected president of the European organisation against skin cancer (EUROSKIN). NMBU has been involved in NATO Science for Peace and Security programs for many years. As a follow up, CERAD is currently involved in projects related to Central Asia.

ACCESS TO EXPERIMENTAL FACILITIES AND TOOLS

A CLEAR VISION FOR THE SCIENTIFIC OUTPUT FROM CERAD COE IS TO PROVIDE:

- Novelties: major progress at the interface between disciplines
- New concepts: integrated concept for man and the environment, integrated concept for contaminants, integrated concept ionizing and UV radiation, and explore an effect unit non-human organisms
- Cutting edge: combination of advanced tools from other disciplines
- Dynamic models: time and climate depended variables

To meet these scientific outputs, CERAD CoE has the possibility to perform cutting edge research due to access to unique experimental facilities and tools, both within CERAD and partner institutions and also internationally. A brief description of the experimental facilities and tools is given below.

THE NMBU LOW DOSE GAMMA RADIATION EXPOSURE FACILITY (FIGARO)

The 8 Ci Co-60 gamma irradiation source at CERAD/NMBU is the only one of its kind and provides a continuous dose rate field from 2.5 Gy/hr (at source) down to 300 μGy/hr and allows simultaneous, chronic exposure of samples over the whole dose-rate field. The facility was opened in 2003, and upgraded in 2012. The national animal research authority has given approval for research on a number of organisms, including rodents, fish, aquatic and terrestrial invertebrates, as well as genetically modified organism (GMO) vertebrates.

The facility is also authorised for radionuclide internal exposure (including alpha emitters), as well as other chemical stressors (e.g., metals, organics, nanoparticles) and UV exposure, thus permitting multiple stressor experiments. A temperature and pH controlled flow–through system is available for aquatic organism exposures.

The climate control specifications for the experimental hall are:

The Figaro 8 Ci Co-60 gamma source.
Photo: Gisle Bjørneby

- Temperature: 4-37 ^{o}C (+/- 1 ^{o}C)
- Light : ca. 50 - 300 lux with automatic dimmer
- Humidity: 45 – 65 % (ScanClime)
- Ventilation: 300 m^3/h (HEAPA filtered)

Additional climate control for rodent experiments is provided by the ScanClime/ScanTainer system (www.scanbur-technology.com). Custom made climate, light and UV controlled exposure chambers are being produced at NMBU and will be delivered September 2015.

The facility has been used for *in vivo* irradiation of fish, earthworms, plants, rodents (GMO mice), and cell cultures, for up to three months exposure times. The facility is utilized for a series of chronic exposure experiments (including combined gamma/alpha and multiple stressor studies).

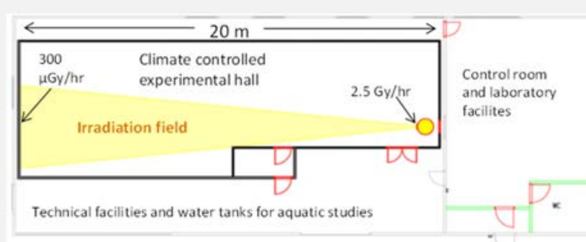


Figure 1. Outline of the FIGARO facility.

In Situ Gamma and UV Measurement Stations

NRPA in cooperation with the Norwegian Environment Agency/NILU is responsible for nine monitoring stations in Norway. Monitoring data of both gamma radiation and UV is available on-line, real time. Based on almost 20 years of such monitoring data and a widely used radiative transfer model, NRPA in cooperation with met.no are currently exploring the possibilities of predicting surface UV for locations of interest for CERAD. Variables like snow-cover, altitude, time of day, thickness of the ozone layer etc. will be used as input variables in the mode

UV-A and UV-B Exposure

UV-A and UV-B are examined separately and in combination at the NRPA UV lab, NMBU/NVH and in the phytotron at NMBU/UMB. UV-A/UV-B sources will also be installed in the NMBU gamma facility to explore effects of both gamma and UV radiation. Furthermore, optical radiometers for the monitoring of source stability and total exposure are available at NRPA and at NMBU. These can be used in laboratory experiments. Other monitoring setup for field use will be explored.

Synchrotron X-Ray Radiation Facilities

NMBU Isotope Laboratory also have access to SEM/TEM, TOF-SIMS, Synchrotron radiation based X-ray nano-/microscopic techniques (PETRA/Germany and ESRF/France): 3D element distribution: tomography, structure: µ-XRF, µ-XRD/nano-XRD, oxidation states: µ-XANES/nano-XANES i.e. methods developed by NMBU and Univ. Antwerp. The Imaging Centre Campus Ås aiming at a state-of-the-art status within microscopy (SEM/TEM, confocal laser SEM, light microscopy, live cell imaging and spectroscopy (x-ray, RAMAN micro imaging) etc. was established in 2012, in which CERAD should act as a future key node (stereo microscope with micromanipulation, micro-XRF, micro-XRD).

Radionuclide and Element Determination

At NMBU Isotope Laboratory and NRPA instrumentations and methods for determination of both gamma- beta- and alpha emitting radionuclides are available. NMBU/UMB also has two Agilent 8800 Triple Quadrupole ICP-MS (ICP-QQQ-MS) for determination of long-lived radionuclides and a large range of elements, including isotope ratios. Cooperation with Australian National University gives access to Accelerator Mass Spectrometry for determination of low level elements and long-lived radionuclides and isotope ratios.

Speciation and Particle Characterization Techniques

In situ fractionation systems, hollow fibres, are available at NMBU Isotope Laboratory, and these are used in fieldworks all over the world where CERAD/NMBU is involved in projects. At NMBU a FFF-ICP-MS system is also in use for further spesiation work together with a HPLC-ICP-MS system.

Sampling of soil profile samples autumn 2014, Uzbekistan. Photo: Lindis Skipperud

Ecotoxicology – Biomarkers and Biological Response

CERAD includes a series of advanced biomarkers to identify the induction of biological responses, such as ROS, DNA damage and DNA repair incl. germ cell mutagenesis and transgenerational effects, bystander effects and genomic instability, biomarkers and advanced toxicogenomics (genomics, proteomics, metabolomics, transcriptomics and epigenomics) to uncover novel and interrelated effects. Expertise is provided by a combination of national partners and CERADs international network.

NIVA has a well-equipped ecotoxicological laboratory with availability of a suite of marine and freshwater plants, algae and crustaceans. The lab is accredited to GLP (Good Laboratory Practice) and may accommodate regulatory testing according to international standardization criteria when required.

Fish Experimental Facilities - Transfer and Effects Experiments on Fish - both Freshwater and Marine Fish Species

At NMBU, the Fish Laboratory includes a specifically designed laboratory for using radionuclides in experiments with aquatic organisms including fish. The laboratory includes a temperature controlled room with logging system for water variables; pH, temperature and oxygen. The facility are so far limited to batch/flow through experiments, but with large flexibility to use different fish species, life stages and different types of freshwaters (both naturally and synthetic). Facilities to perform experiments of different life stages of fish are available, e.g., the early life stages releated to the period from fertilisation of egg until hatching and swim up stage, start feeding, juvenile and adult fish. In addition, canulated fish could be used to follow uptake from water into blood over time *in vivo* in fish. Experimental facilities and availability of a large range of marine species to perform exposure studies with radionuclides are available at NIVA Solbergstrand marine research station.

Thus, the combination of experiments on different fish species, at different life stages in different types of water with use of advanced analytical techniques will allow different controlled test to obtain information on the bioavailability, uptake and toxic effects of different radionuclides and evaluate the sensitivity of different fish species, and the sensitivity of different life stages.

Zebrafish Platform – Transfer and Effect Studies on Zebrafish

The Norwegian Zebrafish Platform (http://zebrafish.no) was established at NMBU/NVH in October 2007 as a FUGE Technology Platform (RCN #183344) and consists of a medium size zebrafish facility (AZLab) with a capacity of 10,000 fish, having a high operational quality standard with accreditation from AAALAC. The Platform coordinates the Zebrafish Network Norway (ZNN) and has organized an annual international ZNN Conference combined with a PhD course. The AZLab has participated for several years in a research program focused on microgravity effects on biological functions. The Zebrafish Platform will organize the European Zebrafish Meeting 2015 with about 800 participants (www.zebrafish2015.org).

Mouse Platform –Transfer and Effect Studies on Mice

The Division of Environmental Medicine at NIPH comprises an animal facility which is extensively used by The Department of Chemicals and Radiation (MIKS, partner in CERAD) for *in vivo* investigations of responses to chemicals and X-ray radiation in mice and other rodents for many years. NIPH thus exhibit the expertise to conduct comprehensive rodent experiments. The conjunction of the animal facility at NIPH with the low dose gamma radiation facility at CERAD/NMBU enables studies of biological effects of low dose rate/low doses of gamma radiation, alone, or in combination with other stressors. Mice from the NIPH-facility, transported the low dose gamma radiation facility for exposure, after which mice have been terminated. Biological material have been prepared for endpoint analyses at the CERAD/NMBU low dose gamma facility, or the mice have returned to NIPH for endpoint analyses.

Greenhouses/Plant Uptake and Effect Experiments (Phytotron)

At the Centre for Plant Research in Controlled Climate (SKP) at NMBU, greenhouse compartments including isotope laboratory and growth chambers are available on a rental basis. This enables plant experiments under controlled conditions. Specific CERAD-funded prototype climate and growth chamber with UV and visible/infrared sources is under construction, to be used for single and multiple stressor experiments at the gamma facility.

Transfer and Effect Studies on Earthworms

NMBU has facilities to study transfer and effects of both radionuclides and metals on earthworms. Transfer studies are often combined with effect studies (growth, maturation, reproduction, mortality and other sub-lethal endpoints). These include studies at the gamma source which allow combination of internal and external exposure, as well as sampling and dissection for a whole range of targeted immunohistochemical and histology studies in specific organs.

Available Test Organisms

Aquatic organisms: Zebrafish, salmonids and a suite of crustaceans, algae and plants to perform multigenerational studies.

Plants: e.g., Arabidopsis thaliana, Norwegian spruce/pine, pea.

Terrestrial: Earthworm (*E. fetida*), *C. Elegans*. Mouse lines relevant as experimental models for effects of radiation on humans, with deficiencies in DNA repair pathways and/or carrying reporter genes for mutation assessments are available at NIPH.

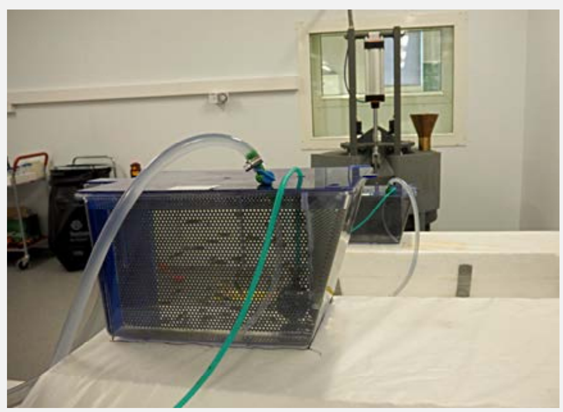
Most of the test organisms are included in the ICRP reference animals and plants list, and, thus, relevant to radiation research.

Models

Advanced air/marine transport models and real time/historic/future prognostic meteorological data are available at MET and NRPA.

Ecosystem transport models (NIVA, NRPA), advanced models on dosimetry (NRPA), models for impact and risk assessment including the ERICA assessment tool (NRPA, NMBU) and contemporary economic models (NMBU) are available. All models will be further developed as process understanding and parameterizations improve and more site specific data become available. Mechanistic models related to high and low LET radiation will be combined with UV, to evaluate biological radiation effects for organisms (NRPA).

To evaluate biological responses to multiple stressors, species sensitivity tools and population dynamics will be applied (NIVA, NMBU).



Zebrafish at Figaro, NMBU
Photo: Bjørn Olav Rosseland

FIELD STUDIES AND EXPEDITION

A fundamental aspect of CERAD is that the research is based on a combination of model experiments, mechanistic studies and laboratory and field studies. Results will be compared and, where possible, evaluated by field investigations using representative field sites:

1) Fieldwork concerning Accidental Releases:

The Chernobyl 30 km zone: for a range of released radionuclides, including U fuel particles containing fission products and transuranics (Pu), varying with respect to particle characteristics and weathering rates.

Mayak PA area in Chelyabinsk, Ural, Russia, a Pu production site, and downstream areas contaminated by several sources back from 1950ies.

Kara Sea expedition: dumped nuclear waste, marine samples.

Barents Sea expedition: sunken Russian submarine, marine samples.

Fukushima marine samples: collected by Woods Hole, USA.

2) Fieldwork in NORM sites:

The Fen and the Hadeland alum shale areas, with elevated levels of Th, U and other stressors (As, Cd, etc). Additional contaminated sites of interests can also be included.

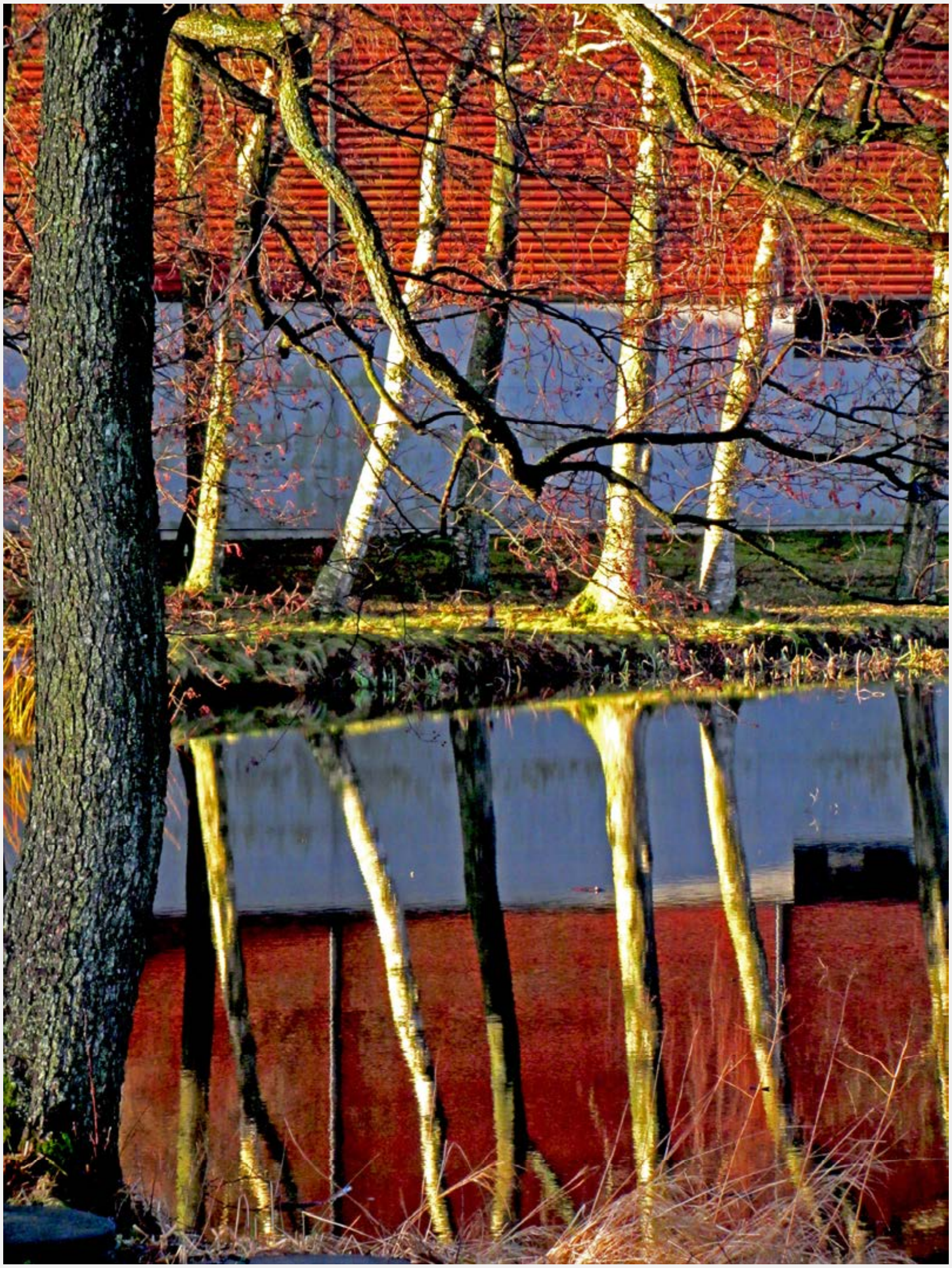
Komi, Russia: Contamination from Ra production in the 1950ies.

Uzbekistan where local U rich fertilizer is used and studies on NORM transfer into vegetables.

Poland to investigate NORM and other elements in an area contaminate by coal mining and production

Every year there are a number of expeditions and fieldwork performed.

Senior Engineer Marit N. Pettersen performing in-situ fractionation of water at RV4, Hadeland, to study the sprciation of possible elevated levels of U and other stressors (As, Cd etc).
Photo: Lindis Skipperud



Skogsdammen, GG-hallen, NMBU
Photo: Signe Dahl

CERAD Education Program

An essential ingredient in CERAD is researcher training and education (MSc, PhD) to provide an internationally attractive research environment, and to produce candidates that are internationally competitive. The EU supported MSc in Radioecology is unique in Europe. Joint MSc in Radioecology has been initiated with the University Paul Cezanne/Aix-Marseille, France, and with the Moscow State University (MSU), forming a useful recruitment base for PhD education. All courses are given in English and some courses are run intensively to make access possible for students from all over Europe.

The ultimate aim of the education and training parts of EURAC is to ensure a sustainable workforce in radioecology. To do this we are dependent on interactions with the wider radioecology community, through outreach out to students, teachers, employers and employees, and other stakeholders outside of our networks.

Since radioecology is a multidisciplinary science, students on MSc or PhD projects in radioecology have a wide range of future carrier opportunities, and one of our goals is to put students in contact with potential employers and research projects, as well as to ensure that training and education in radioecology meets the needs of those employers.

The MSc and PhD education at NMBU and collaborating universities is programmes given to proved the European nuclear stakeholders their future workforce. Of particular concern to the stakeholders (EU Commission, authorities, industry and professionals) are the significant and persistent needs for post-graduates with skills in radiochemistry, radioecology, environmental modelling, radiation protection including radiobiology and dosimetry.

Memorandum of Understanding (MoU) is signed between NMBU and University Aix-Marseille, France, and Moscow State University, Russia. Possible future joint degree will be explored. Within the CINCH-II project, MoUs or Letter of intent (LoI) and ERASMUS+ Inter-institutional agreement 2014-21 is to be signed with all participating universities in 2015: Czech Technical University in Prague (CTU, Czech Republic), Chalmers University of Technology (CHALMERS, Sweden), University of Helsinki (UH, Finland), Loughborough University (LU, United Kingdom), University of Leeds (UNIVLEEDS, United Kingdom), University of Oslo (UiO, Norway).

European MSc Program in Radioecology

The only MSc in Radioecology in Europe has been established at NMBU. Students from within Europe and outside have attended individual course modules or the whole MSc program. Expert teachers are also from institutions from different countries in Europe and in North America. Initiatives have been taken to establish Joint MSc degree between universities in Europe.

In short, the EU MSc in Radioecology is a tailored two year, Bologna accredited (120 ECTS) MSc programme consisting of obligatory and voluntary stand-alone course modules, with expert teachers from national and international institutions. At present the MSc is hosted at the NMBU, where students can take all necessary courses if needed, and obtain permits to work with open ionizing sources (passport). But, as for any EU MSc, students are free to obtain credits by taking ECTS accredited courses at other institutions and at collaborating universities.

Compulsory Courses within the MSc:

- Master thesis/Research project (60 credits)
- Accessing risk to man and environment
- Project Management and Research Methods
- Radioecology - Behaviour of radionuclides in the Environment
- Radiation and radiochemistry (provides passport for using open ionising sources)

Within CERAD, the focuses on the MSc programs are towards radioecology and radiochemistry. The courses are implemented in large European projects (STAR, COMET, CINCH-II) due to the fact that NMBU holds the only EU MSc in Radioecology. The main courses within CERAD are listed in the table below. Already today some courses in the MSc in Radioecology are linked to other EU education and training initiatives such as CINCH-II (Nuclear chemistry) and DoReMi (Radiobiology). Attending the courses included in these platforms can further expand the list of possible courses the students can attend as part of their degree. This enables a more cost effective use of the resources already invested in on-going courses and facilities in Europe.

STAR & COMET projects will hold a number of courses during the lifetime of the projects, ranging from MSc and PhD courses to workshops and professional development. The majority of these courses will be open to participants outside of the STAR & COMET projects. The Education and Training work packages are also responsible for running the PhD Research School.

See the following websites for more information on the EU-project/platform collaboration:

https://wiki.ceh.ac.uk/display/radex/The+Radioecology+Exchange
https://nucwik.wikispaces.com/
http://www.doremi-noe.net/training_and_education.html

The NMBU – MSU collaboration, funded by Norwegian Center for Internation Cooperation in Education (SiU), allows Russian students to take part in the NMBU course in Experimental Radioecology both in 2013 and in 2014. A spring school course in Separation Chemistry was given at MSU in collaboration with NMBU in 2014. International experts are included as lectureres. The course will be given in 2015 and 2016.

The Radioecology Research School

The Radioecology Research School is an international networking forum hosted by CERAD/NMBU and Stocholm university (SU) aimed primarily at PhD students in radioecology and other relevant nuclear sciences. Most European PhD students are expected to take some accredited courses as part of their PhD training. These courses are often relevant and attractive for professional training as well. The research school is open to PhD students worldwide. Benefits for research school students include priority to join CERAD and associated project organized student and training courses; and opportunities for PhD exchange visits and work placements.

The PhD course in Environmental Radiobiology (MINA 410) is a 5 ECTS course, and is part of the international Radioecology Research School and aims to give students an overview of the fundamental principles of radiobiology, but within the context of effects on non-human biota. The course covers both the history and the state-of-the-art of our knowledge on the biological effects of radiation on humans, including how recent studies are challenging established paradigms, but concentrated specifically on those issues and applications of most relevance for other organisms. This included effects and endpoints significant for non-human organisms, ways in which radiobiology methods and biomarkers are being applied in ecological research, factors influencing radiosensitivity in different organisms, and ecological risk assessment based on the ERICA tool. Case studies included ecological research in Chernobyl and Fukushima, and laboratory work focuses on biomarker analysis in exposed model organisms.

CERAD Courses Available within the Fields of Radiochemistry and Environmental Radioactivity

Course Code	Title	ECTS	Course Syllabus In Short	Course Responsible
KJM350	Radiation and Radiochemistry	10	http://www.nmbu.no/search/courses/kjm350	Lindis Skipperud
KJM352	Radiation and Radiation Protection	5	http://www.nmbu.no/search/courses/kjm352	Lindis Skipperud
KJM351	Experimental Radioecology	10	http://www.nmbu.no/search/courses/kjm351	Ole Christian Lind
KJM353	Radioecology	5	http://www.nmbu.no/search/courses/kjm353	Ole Christian Lind
MINA310	Project Management and Research Methods	10	http://www.nmbu.no/search/courses/mina310	Lindis Skipperud
KJM360	Assessing Risk to Man and Environment	10	http://www.nmbu.no/search/courses/kjm360	Deborah H. Oughton / Per Strand
MIN410	Environmental Radiobiology	5	http://www.nmbu.no/search/courses/mina410	Deborah H. Oughton
FMI309	Ecotoxicology	10	http://www.nmbu.no/search/courses/fmi309	Hans Christian Teien
FMI310	Environmental Pollutants and Ecotoxicology	15	http://www.nmbu.no/search/courses/fmi310	Hans Christian Teien

Jordfagbygget, NMBU
Photo: Signe Dahl

Cirkus, NMBU
Photo: Signe Dahl

CERAD ECONOMY 2014

(NOK 1.000)	Accounts 2014	%	Budget 2014	Budget 2015
Revenues				
RCN funding	16 500	39.4 %	16 500	17 000
NMBU funding	1 250	3.0 %	2 824	2 871
NRPA	1 000	2.4 %	1 000	1 000
Other RCN projects	3 590	8.6 %	2 302	1 392
International funds				2 000
Partners (in kind)	19 496	46.6 %	20 723	21 344
Unused funds 2014				2 707
Total funding	41 836		43 349	48 314
Expenditures				
Salaries	28 635	73.2 %	29 000	29 869
FoU	0	0.0 %	256	50
Equipment	746	1.9 %	2 000	2 000
Seminars etc.	0	0.0 %	0	200
Other operational costs	9 748	24.9 %	12 093	16 195
Total expenditures	39 129		43 349	48 314
Unused Funds 2014 , cfr *Note 1*	2 707			
Specification of partners in kind contributions:				
NMBU	11 649	58.4 %	12 842	13 227
NRPA	3 624	18.2 %	3 733	3 845
NIPH	1 070	5.4 %	793	817
NIVA	1 500	7.5 %	1 550	1 596
NVH	745	3.7 %	0	0
MET	1 353	6.8 %	1 805	1 859
Total	19 941		20 723	21 344

Note 1: Unused Funds 2014 are due to delay in employment of PhD and Post Doc positions, postponement of CERAD conference to 2015, and delay in purchase of equipment.

CERAD FUNDING AND EXPENDITURES 2014

The account reflects a high level of activity in CERAD for 2014.

The project financing constitutes of funding from the Research Council of Norway (RCN) and of a substantial In kind contribution from all CERAD institutions. In addition, several ongoing RCN (EU) funded projects at NMBU/Isotope Laboratory are included as a financial source for CERAD.

The turnover for CERAD in the second operational year is MNOK 41.8.

The RCN direct contribution, the core funding, in 2014 was MNOK 16.5 (36%). Other cash contributors (MNOK 2.25) are the Norwegian University of Life Sciences (NMBU) and The Norwegian Radiation Protection Authority (NRPA). Other In kind contributions from partner institutions, mainly personnel, amounted to MNOK 19.5 (47 %).

On the expenditure side, salaries amounted to MNOK 28.6 (73%). The sum includes overhead covering indirect costs.

Equipment amounted to MNOK 0.75 (2%), and other running expenses to MNOK 9.7 (25%).

Due to delay in employment (PhD and PostDocs), postponement of the CERAD conference to February 2015, and delay in purchase of equipment, unused funds amount to MNOK 2.7. Unused funds in 2014 will be utilized in 2015 (co-financing with other projects of 6 new PhD/PostDoc/scientist positions, and equipment).

CERADs financial situation provides a solid foundation for stable and flexible project management and long term research the years ahead.

Eika, NMBU
Photo: Signe Dahl

Skogsdammen, NMBU
Photo: Signe Dahl

Professor Brit Salbu received the 4th IUR Vernadsky award

From left to right: François Bréchignac, President of IUR, Dep. Scientific Director at IRSN; Brit Salbu, IUR Vernadsky Award winner, Professor at the Norwegian University of Life Sciences; Per Strand, Director at NRPA.

From IUR web site: *http://www.iur-uir.org/en/actualites/id-246-brit-salbu-awarded*.

Brit Salbu, Professor at the Norwegian University of Life Sciences, received the 4th International Union of Radioecology V.I. Vernadsky award in recognition of her outstanding contribution to the development and dissemination of Radioecology. She is currently head of the Isotope Laboratory and Director of the Center of excellence for Environmental Radioactivity (CERAD).

International Union of Radioecology (IUR) V.I. Vernadsky Award

APPENDIX A RESEARCH AND COMMUNICATION OUTPUT 2014

SCIENTIFIC RESULTS	NUMBER
Scientific Articles	25
Books/Monograph	0
Technical/Scientific Reports	5
Presentations internationally	54
Presentations nationally	12
Popular science presentations	2
CERAD COMMUNICATIONS	**NUMBER**
Popular science presentations	1
Oral presentations internationally	0
Oral presentations nationally	4
CERAD Seminars	1
Workshops by CERAD	1

SCIENTIFIC PUBLICATIONS, BOOKS, REPORTS, CONFERENCE PRESENTATIONS

SCIENTIFIC ARTICLES IN INTERNATIONAL JOURNALS

Beyer, J., Petersen, K., Song, Y., Ruus, A., Grung, M. Bakke, T., Tollefsen, K.E. Environmental risk assessment of combined effects in aquatic ecotoxicology: a discussion paper. Mar. Environ. Res., 2014, 96: 81-91.

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Scientific Presentations Internationally

Aleström, P. The maternal zygotic transition (MZT) in zebrafish. Invited lecture at Fish Models in Research. University of Copenhagen, Denmark, November 11-13, 2014.

Aleström, P. Epigenetic Marking of the Early Zebrafish Developmental Program. Invited lecture at workshop on molecular mechanisms of radiation toxicity at chronic low dose levels. Oxford, December 10-12, 2014.

Aleström, P. Gene expression control before and during MZT. Invited lecture at The Heart of Europe: Zebrafish Meeting. Warsaw, September 17-19, 2014.

Aleström, P. Towards a set of European Zebrafish Guidelines. Invited lecture at Zebrafish Husbandry Towards Better Research and Animal Welfare. Lisbon, November 7, 2014.

Almeida, A.C., Gomes, T., Thomas, K.V., Tollefsen, K.E. Development of Adverse Outcome Pathways for stressors in the algae Chlamydomonas reinhardtii. 5th Norwegian Environmental Toxicology Symposium. Stavanger, Norway, October 22-24 2014.

Andersson, K.G., Roos, P., Lind, O.C., Salbu, B., Bujan, A., Duranova, T., Ikonomopoulos, A., Andronopoulos, S. Improvement of radiological consequence estimation methodologies for NPP accidents in the ARGOS and RODOS decision support systems through consideration of contaminant physico-chemical forms. International conference on radioecology and environmental radioactivity; Barcelona, Spain, September 7-12, 2014.

Arve, L., Suthaparan, A., Olsen, J.E., Torre, S. High relative air humidity increases UV induced leaf damages in Pisum sativum. Plant biology Europe FESPB/EPSO. Dublin, Ireland, June 22-26, 2014.

Barnett, C.L., *et al.* The Radioecology Exchange. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Bartnicki, J., Amundsen, I., Hosseini, A., Hov, Ø., Haakenstad, H., Klein, H., Lind, O.C., Salbu, B. Szecinski Wendel, C. Worst case meteorological scenario for Norway in case of hypothetical accident related to recovery of the Russian submarine K-27. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Brown, J.E., Alfonso, B., Avila, R., Beresford N.A., Copplestone, D., Hosseini, A. Updating environmental media concentration limits and uncertainty factors in the ERICA tool. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Christensen, T., Aleksandersen, T.B., Aleström, P. *et al.* Ultraviolet radiation and multiple stressor effects on zebrafish embryos. 16th International Congress on Photobiology, Universidad Nacional de Córdoba, Argentina, September 8-12, 2014,

Graupner, A., Instanes, C., Andersen, J.M., Brede, D. A., Govasmark, E., Lind, O.C., Brandt-Kjelsen, A., Bjerke, H., Liland, A., Rasmussen, H., Oughton, D.H., Dertinger, S.D., Salbu, B., Brunborg, G., Olsen, A.K. Low dose rate gamma irradiation in combination with low Selenium diet – genotoxic effects in blood. 41st Annual Meeting of the European Radiation Research Society, Rhodes, Greece, September 14-19, 2014

Helmers, T., Fjermestad, H., Meland, S., Hagelia, P., Salbu, B., Skipperud, L. Modeling the mobility of uranium from NORM-rich bedrock using multivariate statistical techniques, International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Hosseini, A., Amundsen, I., Bartnicki, J., Brown, J., Dowdall, M., Karcher, M., Lind, O.C., Salbu, B., Standring, W. J. F. Health and environmental risk assessment associated with a potential recovery of the Russian submarine K-27. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Kleiven, M., Teien, H.C., Lind, O.C., Johnsen, I.V., Oughton, D.H., Salbu, B. Uptake and effects of uranium nanoparticles on early life stages of Atlantic salmon. International conference on radioecology and environmental radioactivity. Barcelona, Spain, Septeber 7-12, 2014.

Liland, A. Societal consequences of nuclear accidents. NATO advanced research workshop on " Preparedness for Nuclear and Radiological Threats", Los Angeles, November 18-20, 2014.

Lind, O.C. and Salbu, B. Speciation and source identification of radionuclides. Scientific Workshop, Tomsk, Russia, 2014.

Lind, O.C. Contributions to RATE by CERAD, NMBU. EU RATE kick-off meeting. Sevilla, Spain, 2014.

Lind, O.C. Radioactive particle properties. EU Prepare WP4 meeting. Athen, 2014.

Lind, O.C. The relevance of using advanced speciation techniques within radioecology. Gjesteforelesning. Tashkent, Uzbekistan, 2014.

Lind, O.C., Cagno, S., Falkenberg, G., Janssens, K., Jaroszewicz, J., Nuyts, G., Priest, N., Audet, M., Vanmeerts, F., Salbu, B. Low-level radioactive river sediment particles originating from the Chalk River nuclear site carry a mixture of radionuclides and metals. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Lind, O.C., Cagno, S., Vanmeerts, F., Nuyts, G., Alfeld, M., Falkenberg, G., Janssens, K., Teien, H.C., Hertel-Aas, T., Salbu, B. Speciation, uptake and toxicity of uranium in Atlantic Salmon (*Salmo salar*) - high resolution imaging experiments. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Mora, J.C., *et al.,* STAR Infrastructure Database: An effort to know each other" International conference on radioecology and environmental radioactivity; Barcelona, Spain, September 7-12, 2014.

Nikitin, A., Shershakov, V., Kazennov, A., Lind, B., Gwynn, J.P., Heldal, H.E., Blinova, O., Grishin, D., Rudjord, A.L., Valetova, N., Petrenko, G., Katrich, I., Fedorova, A., Osvath, I., Levy, I., Bartocci, J., Phamh, M.K., Sam, A., Nies, H., Salbu, B., Lind, O.C., Teien, H.C., Sidhu, R. S., Strålberg, E., Logoyda, I. Joint Russian-Norwegian expedition to the dumping sites for radioactive Waste and spent Nuclear fuel in the Stepovogo fjord of the Kara sea, August - September 2012: investigations performed and main results. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Nilsen, L.T. Measurements of UV exposures in sunbeds. Eurosun workshop "UV and Vitamin D in Skin Cancer Prevention", Milano, Italy, November 24 – 25, 2014.

Nilsen, L.T, Johnsen, B., Kjæraas, M.L., Egeland, J.F., Nergaard, I.M. UV exposure for the Norwegian population. Annual meeting of the Nordic Ozone and UV Group, Norrköping, May 8-9, 2014.

Olsen, J.E. Abiotic stress and climatic adaptation in plants. Guest lecture at Univ. of Saskatchewan, Saskatoon, Canada, March 6, 2014.

Olsen, J.E. Effects of UV-B and diurnal temperature variation in plant growth and development. Guest lecture at Univ. of Saskatchewan, Saskatoon, Canada, March 5, 2014.

Oughton, D.H. and Schneider, T. Indirect Impacts: Social consequences of radiation exposures, Melodi, Barcelona 7-9 October, 2014.

Oughton, D.H, Ethics, Risk and Nuclear Energy, Nuclear First, Manchester, 2 September 2014.

Oughton, D.H. Societal and Ethical Aspects of Radiation Risk Management, Nippon Foundation, Fukushima, May, 2014.

Oughton, D.H. Radiation Risk Perception, Complexities and Considerations, IAEA Health Conference, Vienna, February 2014.

Oughton, D.H. Risk Communication, Environmental Health and Ethics, Budweis, 16-18 June, 2014.

Oughton, D.H. Ecosystem Approach and Radiation Protection, Environmental Health and Ethics, Budweis, 16-18 June, 2014.

Popic, J. M., Salbu, B., Skipperud, L., Ecological and human impact assessment in the legacy enhanced and naturally occurring radiation areas", International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Roro, A.G., Dukker, S.F., Nybakken, L., Solhaug, K.A., Torre, S., Olsen, J.E. Involvement of gibberellin in UV-B-induced responses in pea. The 4th Network conference UV4 growth (COST action FA0906), Bled, Slovenia, March 30 – April 2, 2014.

Salbu, B. Challenges in radioecology. Radioekologi, Strålsäkerhetsmyndigheten. Stockholm, 2014.

Salbu, B. Challenges in radioecology. Tomsk Polytechnic University, Tomsk, Russia, June 4, 2014.

Salbu, B. Environmental impact assessments and key factors contribution to the uncertainties. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Salbu, B. Radioactive particles in the environment – sources and potential impact. International conference "Actual Problems of Radiochemistry and Radioecology", Ural Federal University, Ekaterinburg, Russia, Ekatrinburg, November 10, 2014.

Salbu, B. Radionuclide speciation/particles influencing Kd. IAEA Modaria, Oslo, 2014.

Salbu, B. Strategic issues for radioecology in support of legacy supervision. Strategic issues for radioecology in support of legacy supervision, Barcelona, 2014.

Simonsen, M., Isachsen, P.E., Sætra, Ø., Salbu, B., Lind, O.C., Klein, H., Bartnicki, J. Marine radionuclide transport in the northern North Atlantic estimated with an eddy-permitting ocean model. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Skipperud, L., Rosseland, B.O., Stegnar, P., Yunusov, M., Burkitbaev, L.M., Heier, L.S., Salbu, B., Radionuclide and metal contamination in pit lakes in former U mining sites in Central Asia. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Solhaug, K.A. Effects of ozone depletion and climate change on solar UV-radiation: Impact on plants. Guest lecture at Univ. of KwaZulu-Natal, Pietermaritzburg, South-Africa, May 21, 2014.

Song, Y., Heiås, H., Hultman, M., Petersen, K., Tollefsen K.E. De-novo assembly of the Daphnia magna transcriptome and development of a gene expression microarray. The EMBO Conference on The mighty daphnia past present and future. Birmingham, United Kingdom, January 19-22, 2014.

Song, Y., Heiås, H., Hultman, M., Petersen, K., Tollefsen, K.E. De-novo assembly of the D. magna transcriptome and development of a gene-expression array. 24th annual SETAC Europe Meeting, Basel, Switzerland, May 11-16, 2014.

Song, Y., Teien, H.C., Heier, L.S. Oughton, D.H., Lind, O.C. Rosseland, B.O. Tollefsen, K.E. Use of gene expression responses to evaluate combined effect of low dose gamma radiation and uranium on Atlantic salmon (*Salmo salar*). 4th Norwegian Environmental toxicology Symposium, Tromsø, Norway, October 16-18, 2014.

Strømme, C.B, Olsen, J.E., Julkunen-Tiitto, R., Krishna, U., Lavola, A., Nybakken, L. Temperature and UV-B radiation affect bud phenology in Populus tremula. IUFRO World Congress, Salt Lake City, Utah, USA, October 5-11, 2014.

Teien, H.C. and Salbu, B. Speciation, uptake and toxicity of uranium in Atlantic Salmon (*Salmo salar*) juveniles. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Teien, H.C., Hertel-Aas, T., Lind, O.C., Thørring, H., Skipperud, L., Oughton, D.H., Salbu, B., Speciation, uptake and toxicity of uranium in Atlantic Salmon (*Salmo salar*) International conference on radioecology and environmental radioactivity; Barcelona, Spain, September 7-12, 2014.

Tomkiv, Y., Perko, T., Gallego, E., Cantone, M.C., Prezelj, I., Melikhova, E. How does the mass media report and interpret radiation data? Content analysis of newspapers and tweets. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Velegzhaninov, I.O., Oughton, D.H. Ecosystem impacts of long term contamination: EANOR. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Wendel, C., Fifield, K., Oughton, D.H., Lind, O.C., Skipperud, L., Bartnicki, J., Tims, S., Høibråten, S., Salbu, B. Direct tropospheric transport of debris from nuclear weapon detonations at the Semipalatinsk test site to Western Europe. International conference on radioecology and environmental radioactivity. Barcelona, Spain, September 7-12, 2014.

Xie, L., Gomes, T., Song, Y., Christensen, T., Solhaug, K.A:, Salbu, B., Tollefsen, K.E. (2014) Development of an effect toolbox for Lemna minor to accommodate studies with single and multiple stressors. 5th Norwegian Environmental Toxicology Symposium, Stavanger, Norway, October 22-24, 2014.

SCIENTIFIC PRESENTATIONS NATIONALLY

Christensen, T. Introduction to UV-photobiology, Joint meeting CERAD and NOFFOF, NIPH, November 6, 2014.

Gomes, T. *et al.* Development of AOPs for ionizing radiation, UV and other stressors in the algae Chlamydomonas reinhardtii, the crustacean Daphnia magna and the aquatic plant Lemna minor. CERAD and NOFFOF kick off and dosimetry Seminar, Norwegian Institute of Public Health, November 6, 2014.

Graupner, A., Instanes, C., Andersen, J.M., Brede, D. A., Govasmark, E., Lind, O.C., Brandt-Kjelsen, A., Bjerke, H., Liland, A., Rasmussen, H., Oughton, D.H., Dertinger, S. D., Salbu, B., Brunborg, G., Olsen, A.K. Low dose-rate gamma irradiation in combination with low selenium diet - genotoxic effects in blood, NSFT vintermøte, Beitostølen, Norway, January 29 - February 1, 2014.

Hansen, E.L. The role of dosimetry in CERAD. The 1st CERAD national workshop on UV and ionizing radiation dosimetry, NIPH, November 6, 2014.

Nilsen, L.T. Estimating UV exposure for the Norwegian population. Scientific and annual meeting for Norsk Forening for Fotobiologi og Fotomedisin (NOFFOF), Oslo, November 7, 2014.

Olsen, A.K. Ideas on the interplay of repair of UV damage and other stressors. The 1st CERAD national workshop on UV and ionizing radiation dosimetry, NIPH, November 6, 2014.

Oughton, D.H. Risk and Radiation: Laypeople Knowledge and Fukushima, NENT, January 2014.

Salbu, B. Faktorer som bidrar til usikkerhet i konsekvens og risikomodeller. Case: Atomulykker, miljøkonsekvenser og klimapåvirkning. Fagdag for lærere i realfag, Ås, 2014.

Salbu, B. NMBU/CERAD – Internal and external radiation experiments at CERAD CoE/NMBU. The 1st CERAD national workshop on UV and ionizing radiation dosimetry, NIPH, November 6, 2014.

Salbu, B. Radionuklider og spormetaller i mat. Symposium 'Trygg mat, ernæring og helse', KOMITE FOR GEOMEDISIN – MAT, MILJØ, HELSE, Det Norske Vitenskaps Akademi, Oslo, November 14, 2014.

Salbu, B. Sellafield og mulige konsekvenser i Norge. Seminar for atomberedskapsorganisasjonen, Lysebu, September 4-5, 2014.

Solhaug, K. A. Mechanisms behind UV-effects on plants. The 1st CERAD national workshop on UV and ionizing radiation dosimetry, NIPH, November 6, 2014.

PRESENTING CERAD INTERNATIONALLY – ARTICLES/POPULAR SCIENCE

Christensen, T. CoE: CERAD - Centre for Environmental Radioactivity, Strålevernet, Introductory lecture for students in Radiation biophysics, March 28, 2014.

Christensen, T. UV-stråling som sekundær stressor, Ås, October 30, 2014.

Nilsen, L.T. Når og i hvilke situasjoner er nordmenn utsatt for UV-stråling? Frokostmøte «Norges høye forekomst og dødelighet av føflekkreft», Kreftforeningen, Oslo, Norway, May 13, 2014.

Skipperud, L., NMBU and CERAD in short. Gjesteforelesning, Tashkent, Uzbekistan, 2014.

PRESENTING CERAD NATIONALLY – ORAL PRESENTATIONS

Salbu, B. CERAD Centre of Excellence for Environmental Radioactivity - a Center for new opportunities, NMBU Board, NMBU, March 5, 2014.

Salbu, B. CERAD CoE 2013 - 2022 Center for Environmental Radioactivity, Department of Astrophysics, University of Oslo, May 23, 2014.

Salbu, B. CERAD, a Norwegian Centre of Excellence for environmental Radioactivity. Scientific meeting arranged by the Division of Environmental Medicine, The Norwegian Intitute of Public Health, 2014.

Strand, P. The CERAD CoE. The 1st CERAD national workshop on UV and ionizing radiation dosimetry, NIPH, November 6, 2014.

APPENDIX B - CERAD MEETINGS AND WORKSHOPS

CERAD SEMINAR 2014

Det Norske Videnskaps-Akademi (DNVA) March 13th, 2014
Drammensveien 78, Oslo

PROGRAMME

0930 *Coffee*

1000 Welcome, *Brit Salbu*

1000-1130 **RA1 – Sources** **Chair: Halvor Hektoen**

Assessing the source terms of real and hypothetical nuclear events (Ole Christian Lind, NMBU) 15 min

Modelling atmospheric transport and deposition of radioactive particles (Jerzy Bartnicki, MET) 10 min

Sellafield and Fukushima: Preliminary model results (Heiko Klein, MET) 10 min

Improved inventory for dispersion modelling (Martin Ytre-Eide, NRPA) 10 min

Marine Transport - results from Irish Sea Experiment (Magne Simonsen, MET Ocean) 10 min

Preliminary results of Cs-137 transport in Vikedal by INCA-RAD catchment model (Raoul-Marie Couture, NIVA) 10 min

15 min general discussion

1130-1230 **RA2 – Transfer** **Chair: Lindis Skipperud**

Short introduction RA2 (Hans-Christian Teien, NMBU) 5 min

Forskning i Vodnyi (Yevgeniya Tomkiv, NMBU) 10 min

Uranium speciation, accumulation and toxicity in Atlantic salmon parr (Hans-Christian Teien, NMBU) 15 min

Bioaccumulation and Effects of depleted uranium (DU) in planktonic Organisms (Knut Erik Tollefsen/Anders NIVA) 5 min

+ 20 min discussion

1230-1330 *Lunch*

1330-1500 **RA3 - Effects** **Chair: Deborah Oughton**

Short introduction (Ann-Karin Olsen, NIPH and Peter Aleström, NMBU) 5 min

Gamma irradiation of Zebrafish (Peter Aleström and co-workers, NMBU) 15 min+3 min for discussion

Chronic low dose-rate gamma irradiation in combination with low selenium diet - effects on reproduction (Anne Graupner, NIPH) 10 min + 3 min for discussion

Epigenetic profiling and transgenerational effects in mice (Ann-Karin Olsen and co-workers, NIPH) 15 min+ 3 min for discussion.

	Mixed toxicity investigations using *C. elegans* as a model (Dag Anders Brede, NMBU) 10 min+ 3 min for discussion
	Adverse Outcome Pathways for Ionizing radiation (Knut-Erik Tollefsen, NIVA) 10 min+ 3 min for discussion
	Wrap up from RA3 (Ann-Karin Olsen and Peter Aleström) 5 min
1500-1615	**RA4 - Risk Assessment** **Chair: Per Strand**
	RA4 overarching aims (Knut Erik Tollefsen and Astrid Liland)
	Risk perception and willingness to pay - UV and radon case studies in 2014 (Ståle/Lill Tove/Christina)
	Discussion
	Sellafield stakeholder dialogues (Yevgeniya Tomkiv, NMBU)
	Discussion: How do we plan stakeholder engagement processes?
	Predictive risk assessment of multiple stressors – Plans for 2014 (Karina Petersen, NIVA)
	Discussion
1615-1645	*Coffee*
1645-1815	**RA5 - UV**
	Effect of UV-B-temperature interaction on plant growth, flavonoid content and DNA damage. Progress with construction of exposure chambers (Jorunn E. Olsen, NMBU) 15 mins
	Effects of UV-B and radioactivity on lichens - progress and plans (Knut Asbjørn Solhaug, NMBU) 10 mins
	Interactive effects of UV-B and air humidity on stomata function and morphology (Sissel Torre, NMBU) 5 mins
	Effects of UV at different altitudes in Ethiopia on plant morphology and flowering. A filtration study (Amsalu Gobena Roro, NMBU) 5mins
	Effects of increased UV-B and its interaction with temperature on phenology in field-grown aspen (Christian Bianchi Strømme, NMBU) 5 min
	Natural ultraviolet radiation exposure calculated with background in monitoring data, climate and geography (Lill Tove Nilsen and Bjørn Johnsen, NRPA) 20 min
	Action spectra of ultraviolet radiation, data from zebrafish embryos (Terje Christensen) 15 min
	(Karina Petersen, NIVA - to be confirmed).
1815-1830	Wrap-up and briefing on annual report (Brit Salbu, NMBU)
1900	Dinner

NFR Site Visit til CERAD SFF

Isotoplaboratoriet, Møterom Curie, NMBU, 30. september 2014 Program

10:00 Velkommen Rektor Mari Sundli Tveit

10:10 Mal for NFR Site Visit, Liv Furuberg, NFR

10:20 Sammendrag av arbeidet 2013, Organisering, Samarbeid og Rapportering, CERAD Leder Brit Salbu

11:00 Undervisning og Rekruttering, CERAD Undervisningsleder Lindis Skipperud

11:15 Internasjonal virksomhet, CERAD Forskningsleder Deborah H. Oughton

11:30 – 12:30 Lunsj

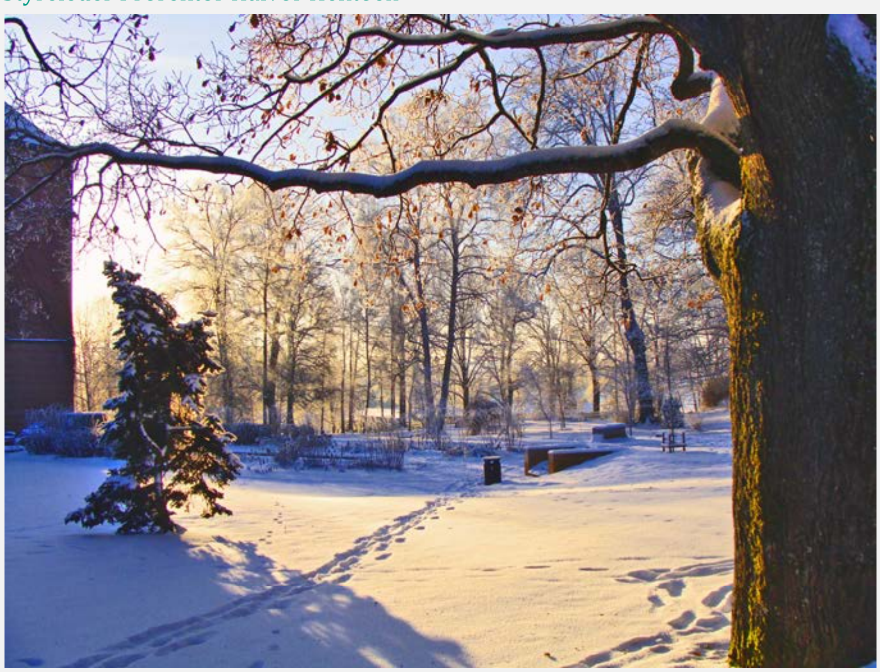
12:30 Faglige aktivitet, CERAD Forskningsleder Deborah H. Oughton

- Introduksjon – Deborah Oughton
- Biotilgjenglighet og giftighet av uran –resultater fra modellforsøk med Laks (*Salmo salar*), Hans-Christian Teien
- Mus og menn – radioaktiv stråling fra miljøet, Ann Karin Olsen
- Vurdering av doser og effekter på miljø fra Fukushima ulykken, Justin Brown
- Comparison of biological effects of low dose rate gamma radiation on model species, Dag Anders Brede
- Ultrafiolett og ioniserende stråling, Terje Christensen
- Radioaktive partiklers egenskaper kan linkes til utslippskilde, utslippsscenario, overføring og effekter, Ole Christian Lind
- Western Norway, Brit Salbu

14:15 Neste site-visit, CERAD leder Brit Salbu

14: 30 – 15:30 Omvisning Lab og Gamma kilde

Avslutning ved CERAD Styreleder Prorektor Halvor Hektoen



Parken, NMBU
Photo: Signe Dahl

The 1st CERAD national workshop on UV and ionizing radiation dosimetry

November 6th 2014, NIPH, Lovisenberggata 6, Programme

0930-1000	Registration and coffee
1000-1020	Per Strand, NRPA/CERAD – The CERAD CoE (http://cerad.nmbu.no)
1020-1030	Elisabeth Lindbo Hansen, NRPA/CERAD – The role of dosimetry in CERAD
1030-1100	Eirik Malinen, UiO – Invited talk – Ionizing radiation: dosimetry and biological effects
1100-1120	Terje Christensen, NRPA/CERAD – Introduction to UV photobiology
1120-1200	Hooshang Nikjoo, Karolinska – Invited talk – Biophysical aspects of radiation track
1200-1300	Lunch on-site
1300-1330	Jakob Stamnes, UiB – Invited talk – Models of radiation transport for dosimetry in coupled systems (atmosphere-ocean and air-tissue)
1330-1400	Marco Povoli, UiO/SINTEF – Invited talk – Silicon radiation detectors for microdosimetry
1400-1415	Brit Salbu, NMBU/CERAD – Internal and external radiation experiments at the FIGARO irradiation facility
1415-1430	Coffee break
1430-1500	Lise Lyngsnes Randeberg, NTNU – Invited talk – Optical properties and how they determine transport of light in tissue
1500-1530	Ann Karin Olsen, NIPH/CERAD – Ideas on the interplay of repair of UV damage and other stressors
1530-1600	Knut Asbjørn Solhaug, NMBU/CERAD – Mechanisms behind UV-effects on plants
1600-1630	Coffee break
1630-1800	Contributed talks and discussions
10 min	Gunnar Brunborg, NIPH/CERAD – Detection of DNA in cells revisited: UV and oxidated lesions must and can be quantified at low numbers
10 min	Asta Juzeniene, OUH – UVA and malignant melanoma in humans
10 min	Martin Album Ytre-Eide, NRPA/CERAD – UVI modelling in Norway
10 min	Sissel Torre, NMBU/CERAD – Plant experiments in CERAD – future plans
10 min	Tânia Gomes, NIVA/CERAD – Development of AOPs for ionizing radiation, UV and other stressors in the algae Chlamydomonas reinhardtii, the crustacean Daphnia magna and the aquatic plant Lemna minor
10 min	Hallvard Haanes – Ecosystem approaches by micro and mesocosm experiments
15 min	Bjørn Johnsen/Ana Alvarez Piedehierro – Validation of UV-network reference measurements, implementation of a stable radiance monitor and relevant UV sources for CERAD exposure chambers

Scientific and Annual Meeting, Norsk Forening for Fotobiologi og Fotomedisin (NOFFOF)

Norwegian Institute of Public Health 7. November 2014

09.30 Morning Coffee: Switching on the Light

10.00 *Welcome and introduction* - Pål Kristian Selbo (President of NOFFOF, Department of Radiation Biology, Institute for Cancer Research, Norwegian Radium Hospital, Oslo)

Part I Photobiology Chair: Terje Christensen (NRPA)

10.10 Antibacterial phototoxic effects of synthetic asymmetric and glycosylated curcuminoids in aqueous formulations - Marianne Lilletvedt Tovsen (PharmaLuxLab, PLL, School of Pharmacy, University of Oslo)

10.30 Design of an EGFR-targeting toxin for photochemical delivery; *in vitro* and *in vivo* selectivity and efficacy - Maria Brandal Berstad (Department of Radiation Biology, Institute for Cancer Research, Norwegian Radium Hospital, Oslo)

10.50 Repeated rounds with photodynamic therapy (PDT) induces resistance due to loss of p38-mediated death signalling in MA11 breast cancer cells while photochemical internalization (PCI) of a EGFR-targeting toxin-ligand overcome this resistance - Cathrine E. Olsen (Department of Radiation Biology, Institute for Cancer Research, Norwegian Radium Hospital, Oslo)

11.10 Intracellular studies on rat glioma cancer cell line using novel chromophores - Monica Siksjø (Dept. Physics, Norwegian University of Science and Technology, NTNU, Trondheim)

11. 30 The dark side of the Nobel prize winning light - Ellen M. Bruzell (Nordic Institute of Dental Materials, NIOM; Oslo)

11.40 Forskningsdagene 2015 - Emmy Gram Lauvanger (The Research Council of Norway)

12.00 NOFFOF annual meeting

12.30 Lunch

13.30 Rimington prize and lecture (chair: Hanne Hjorth Tønnesen (PLL, School of Pharmacy, University of Oslo)

14.10 Sun exposure patterns; lesson learnt using time-resolved personal electronic UV dosimetry - Elisabeth Thieden (Department of Dermatology, Bispebjerg Hospital, Copenhagen, Denmark)

14.45 Coffee break

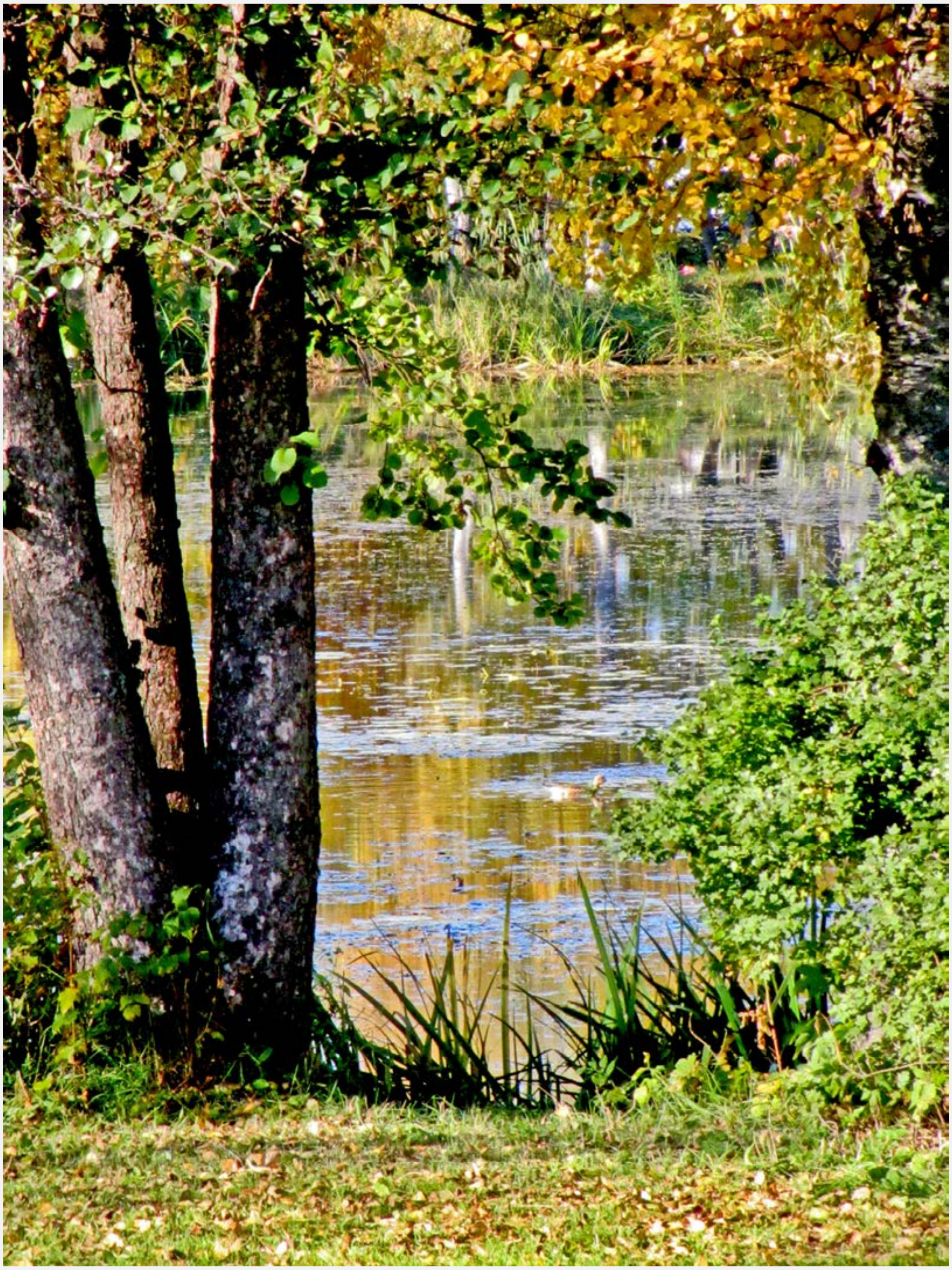
Part II UV Chair: Lill Tove N. Nilsen (NRPA)

15.00 The role of UVA radiation in melanoma progression and metastasis - Asta Juzeniene (Department of Radiation Biology, Institute for Cancer Research, Norwegian Radium Hospital, Oslo)

15.20 The research of AIRE Group on solar radiation (Spain) - Ana A. Piedehierro (Department of Physics, University of Extremadura, Badajoz, Spain)

15.40 Estimating UV exposure for the Norwegian population - Lill Tove Nilsen (NRPA)

16. 00 Some impressions from 16. International Congress on Photobiology Cordoba, Argentina - Terje Christensen (NRPA)



Skogsdammen, NMBU
Photo: Signe Dahl

APPENDIX C - CERAD PERSONNEL 2014

NAME AND TITLE	ACADEMIC GRADE	EMPLOYED
Brit Salbu, Professor	Dr. philos.	NMBU
Lindis Skipperud, Professor	Dr. scient.	NMBU
Ole Christian Lind, Ass. professor	PhD	NMBU
Deborah H. Oughton, Professor	PhD	NMBU/CERAD
Bjørn Olav Rosseland, Professor Emeritus	Dr. philos.	NMBU
Eirik Romstad, Scientist	PhD	NMBU
Ståle Navrud, Professor	Dr. scient.	NMBU
Knut Einar Rosendal, Professor	PhD	NMBU
Olvar Bergland, Professor	PhD	NMBU
Jorun Olsen, Professor	Dr. scient.	NMBU
Sissel Torre, Ass. professor	Dr. scient.	NMBU
Hans Christian Teien, Ass. professor	Dr. philos.	NMBU/CERAD
Dag Brede, Scientist	PhD	NMBU/CERAD
Cato Chistian Szacinski Wendel, Scientist	PhD	NMBU
Yevgeniya Tomkiv, Scientist	MSc	NMBU
Per Strand, Avdelingsdirektør	Dr. scient	NRPA
Åste Søvik, Section manager from 01.05.2014	PhD	NRPA
Justin Brown, Senior scientist	PhD	NRPA
Astrid Liland, Section manager to 31.03.2014	Cand. scient.	NRPA
Håvard Thørring, Scientist	Cand. scient.	NRPA
Ali Hosseini, Scientist	Cand. scient.	NRPA
Christina Hassfjell, Scientist	PhD	NRPA
Hallvard Haanes, Scientist	PhD	NRPA
Martin Album Ytre-Eide, Scientist	Cand. scient.	NRPA
Mikhail Iospe, Senior scientist	PhD	NRPA
Alicja Jaworska, Senior scientist	PhD	NRPA
Louise Kiel Jensen, Scientist	PhD	NRPA
Ingrid Helen Ryste Hauge, Scientist	PhD	NRPA
Terje Christensen, Senior scientist	Dr. philos.	NRPA/CERAD
Bjørn Johnsen, Scientist	Graduate engineer	NRPA
Lill Tove Nilsen, Senior scientist	PhD	NRPA
Knut Asbjørn Solhaug, Professor	Dr. scient.	NMBU
Line Nybakken, Ass. professor	PhD	NMBU
Øystein Hov, Director	Dr. philos.	MET
Jerzy Bartnicki, Senior scientist	PhD	MET
Pål Erik Isachsen, Senior scientist	Dr. scient.	MET
Heiko Klein, Senior scientist	PhD	MET
Øyvind Sætra, Senior scientist	PhD	MET

Name and title	Academic grade	Employed
Knut Erik Tollefsen, Senior Researcher/Prof II	Dr. scient.	NIVA
You Song, Scientist	Dr. scient.	NIVA
Maria Hultman, Scientist	MSc	NIVA
Raoul Marie Couture, Scientist	Dr. scient.	NIVA
Anders Ruus, Scientist	Dr. scient.	NIVA
Karina Petersen, Scientist	Dr. scient.	NIVA
Yan Lin, Scientist	MSc	NIVA
Peter Aleström, Professor	Dr. philos.	NMBU
Jan Erik Paulsen, Scientist	Dr. med. vet	NMBU
Ian Mayer, Professor	Dr. scient.	NMBU
Jan L. Lyche, Scientist	Dr. med. vet	NMBU
Ann-Karin Olsen, Scientist	Dr. philos.	NIPH
Gunnar Brunborg, Department director	Dr. philos.	NIPH
Christine Instanes, Scientist	Dr. philos.	NIPH
Nur Duale, Scientist	Dr. philos.	NIPH
Kristine Bjerve Gutzkow, Scientist	Dr. philos.	NIPH
Dag Marcus Eide Scientist	DVM PhD	NIPH
Oddvar Myhre, Scientist	Dr. scient.	NIPH
PhD students		
Merethe Kleiven	MSc	NMBU
Selma Hurem	DVM	NMBU
Magne Simonsen	MSc	NMBU/CERAD
Jelena Mrdakovic Popic	MSc	NMBU
Hildegunn Dahl	MSc	NIPH/CERAD
Astrid Liland	MSc	NRPA/CERAD
Post Doc		
Sachin Nehete	PhD	NMBU
Tania Gomes	PhD	NIVA/CERAD
Simone Cagno	PhD	NMBU
Elisabeth Lindbo Hansen	PhD	NRPA/CERAD

Technical/Administrative		
Mirian Wangen	Higher executive officer	NMBU
Anja Nieuwenhuis	Administration manager	NMBU
Lene Valle	Senior engineer	NMBU/CERAD
Karl Andreas Jensen	Senior engineer	NMBU
Marit Nandrup Pettersen	Senior engineer	NMBU/CERAD
Øyvind Enger	Senior engineer	NMBU/CERAD
Yetneberk Kassaye	Senior engineer	NMBU/CERAD
Nana Asare	Scientist	NIPH/NRPA
Jill Andersen	Senior engineer	NIPH
Hildegunn Dahl	Senior engineer	NIPH
International Guest Scientists - SAC		
David Clarke, USA		
Dr Valeriy Kashparov, Ukraine		
Professor Koen Janssens, Belgium		
Professor Peter Stegnar, Slovenia		
Professor Carmel Mothersill, Canada		
Professor Colin Seymour, Canada		
Dr Tom Hinton, France		
Dr Clare Bradshaw, Sweden		
Dr. Marcel Jansen, Ireland		
Professor Janet Bornman, Australia		

Eika, NMBU
Photo: Signe Dahl

Tårnbygningen, NMBU
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