BEYOND ECOSYSTEM APPROACHES IN RADIOECOLOGY

IN-PRESENCE & VIRTUAL SYMPOSIUM

organised by the International Union of Radioecology

BOOK OF ABSTRACTS

6-8 SEPTEMBER 2023

Grangegorman Campus
Technological University
DUBLIN - IRELAND

www.iur-uir.org

McMaster University

TU DUBLIN

iUR

DSA

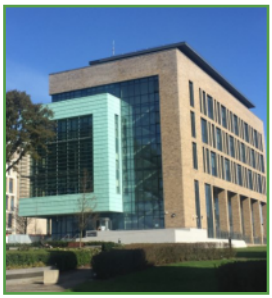
THE VENUE: ESHI

Environmental Sustainability and Health Institute - Greenway Hub - N°8
3rd floor, Room GW302
Grangegorman Campus - Technological University - Dublin 7, D07 H6K8

ON THE CAMPUS

The area next to the ESHI is called 'an croi' the irish word for 'the heart' of the campus. ESHI is beside (on the other side) this area and these building.

This is the walk from ESHI to 'an Croi'.
ESHI is on the left of the path



Content

Foreword

The aim of this Symposium is to bring together scientists from all over the world to work on the challenges faced by environmental radiation protection to ensure the preservation of ecosystems. Under the auspices of the International Union of Radioecology and with the support of the Technological University of Dublin, McMaster University (Canada) and DSA (Norway), this scientific meeting aims to pave the way for IUR future directions suitable to inform decision-making.

Overall, the cross-disciplinary scientific program will enable to explore recent scientific achievements, the scientific activities to be strengthened and the novel ones to be launched: evolution of environmental radiation protection, ecosystem approach, multiple stress factors, AOP and multi-level approaches, limits of linear or multi-level approaches to systems... An overarching concern is to tackle the issues through systemic and multiple levels such as to meet the protection goals of environmental radiation protection.

Welcome from the local organisers...

Dear participants

Fàilte to the in-presence and virtual BEAR Symposium in Dublin!

We are very honoured and happy to be hosting this exciting event dedicated to the environmental radiation protection. Environmental sustainability and radiation research are strong research areas in the Technological University of Dublin.

We will do our utmost to make this symposium a memorable and intellectually stimulating occasion for all.

We hope you will participate in the social activities to strengthen existing networks as well as to develop new networks and meet new people.

Our thanks to the ESHI and TUDublin staff for great assistance and to the audiovisual system designer, Theo Zioutos that makes it possible to hybridize the event.

Have a stimulating meeting, and enjoy our new Grangegorman campus and the city of Dublin in the autumn sunshine!

Orla HOWE, TU Dublin

from the Chair...

Dear friends and colleagues

We are thrilled to be in the city of Dublin with participants from around the world in attendance.

These are important and uncertain times; debates concerning ecosystems have become increasingly pertinent. This symposium addresses the ongoing global struggles for ecosystem preservation and human radiation protection.

I would like to express my sincerest gratitude to all the presenters for their valuable contribution. By sharing your expertise and research findings with us you contribute in advancing the field of radioecology and promoting sustainable ecosystems.

Thank you to all the in-presence and remote participants for being a part of this event, your contribution through interactive discussions are eagerly awaited.

Carmel MOTHERSILL, McMaster University

Technological University of Dublin

TU Dublin is Ireland's 1st Technological University. Students and staff come from around the world and our strong international partnerships provide opportunities for exchange programmes, major cross collaboration research projects, and employment opportunities. Our ambitious vision is to create a better world together, build on three pillars of People, Planet and Partnership.

The Environmental Sustainability and Health Institute (ESHI) is a multi-disciplinary research institute, addressing global challenges, through national and international collaborations.

and the city of Dublin

Dublin is a friendly capital, rich in history and literature. The narrow streets of the city center are filled with colorful historic buildings and traditional pubs. The river Liffey flows through the center of Dublin to its mouth within Dublin Bay, a UNESCO World Heritage Site..

… and from the IUR Board

Dear participants and IUR members,

We would like to extend a warm welcome to all of you. We are thrilled to have such a diverse group of researchers gathered here, coming from different corners of the globe.

This symposium is a remarkable opportunity for us to exchange knowledge, insights, and experiences, focusing on radioecology and radiation's impact on ecosystems. We are confident that this event will provide a unique platform for fruitful discussions and collaborations.

We hope that this congress will inspire all of you, foster collaborations, and generate innovative ideas that will contribute to the advancement of radioecology and the preservation of our precious ecosystems.
This is this is IUR's *raison d'être* and ambition.

We would like to express our gratitude to the organizing team for their tireless efforts in making this congress a reality.

Our thanks go to Carmel Mothersill for her hard work in building such a coherent and stimulating scientific program, to Orla Howe for her hard work in hosting this important event and to Armelle Guilloux for helping on various aspects.

Last but not least, the latest research and results presented at the Symposium will give rise to a special issue of the Journal of Environmental Radioactivity.

Best wishes,

Per STRAND, President of the IUR
François BRECHIGNAC, General Secretary

International Union of Radioecology

IUR is an independent, non-political & non-profit Knowing Society operating as a Think Tank. The overall objective of the Union is to promote radioecology worldwide, in all its dimensions, from research activities to expert advice and operational management.

IUR activities are organised through a number of Task Groups, meetings, workshops, conferences and training courses.
IUR promotes the dissemination of recent scientific achievements for its members and for wider scientific community. It is facilitated by an affiliation with the Journal of Environmental Radioactivity.

www.iur-uir.org

Practical information

WIFI on campus: eduroam

For user of eduroam, your device automatically connect to eduroam at TU Dublin.
https://www.tudublin.ie/connect/technology-services/wi-fi/

PUBLIC TRANSPORTATION

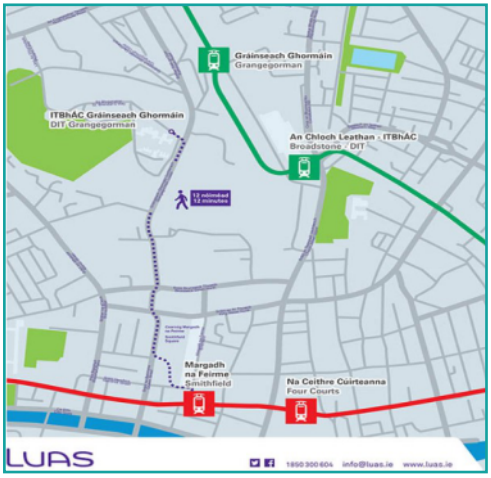
AIRPORT <--> CITY CENTRE

Dublin's Airport is situated 30 minutes from the city centre.

- By shuttle bus Dublin Express (zone 1, terminal 1 / zone 21, terminal 2) €8 one way or €10,50 return
- By Dublin bus

IN THE CITY CENTRE

- **By tramway Luas -** Grangegorman campus is a few stops from O'Connell Street. The quickest way to get to campus is by taking the Green Line Luas, Broadstone or Grangegorman stops. You can also take the Red Line to the Smithfield stop, with a 10-min walk away.



The Green Line goes directly into the centre of Dublin to 'O'Connell Street', 'Trinity College Dublin' and 'St Stephens Green' beside Grafton street.

- **By bus -** The Dublin Bus journey planner find your best bus route to a TU Dublin campus
https://www.transportforireland.ie/plan-a-journey/

CURRENCY: Euro (€)

Visa and Mastercard are accepted everywhere; American Express is accepted in some places. Credit cards can be used for purchases and withdraw cash from ATMs.

TICKETS

- **Per unit**

Numerous kiosks and other stores sell tickets all over the city. But the easiest way is to buy ticket on the bus, putting the exact amount - from €2.15 to €3.80, depending on the lengt**,** in a piggy bank (drivers don't give change).

- **Prepaid Leap Visitor Card**

€8,00 for 1 day (24 h) / €16.00 for 3 days, for unlimited travel on all public transport in the city (including travel to/from Airlink 747 airport). To be bought at the airport or in some places downtown.

TFI LIVE APP (Transport for Ireland)

Download and search the details of your journey by entering your departure and arrival location in the search bar or by using the map. You will see various transport options appear for your journey which you can filter by exploring the modes of transport options (train, bus, tram, cycling, or walking) and time options (leave now, leave after, or arrive by).

Social Program

Welcome reception - Symposium Venue

Wednesday 6 September

18:00-20:00

A Wine reception will take place at the end of the first day. Enjoy a friendly time and network with your peers.
An interactive time can be shared with remote participants, who are invited to join us for a coffee, a glass of beer or wine, between 18:00 and 18:30.
Offered by the DSA

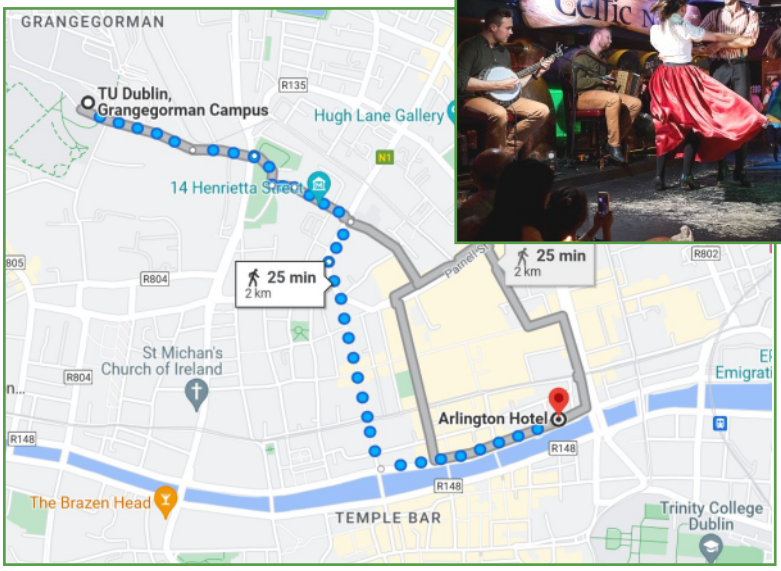
Celtic Nights Dinner - Arlington Hotel

Thursday 7 September

19:30-22:30

Available only to participants who have registered for.

An Irish experience in the heart of Dublin, at the Arlington Hotel, next to O'Connell Bridge.
The distance is 2km from Grangegorman Campus.
The dinner includes a three-course meal.
The show "Celtic Nights", traditional live Irish Music and Dancing show, starts at 20:30



Arlington Hotel
23-25 Bachelors Walk
O'Connell Bridge
North City, Dublin 1

Wednesday 6 September

Times shown are Irish times (UTC+1)

09:00-10:00 IUR Board Meeting

10:00-11:00 Registration

11:00-11:15 **Opening talks**

Per STRAND
Director of the Norwegian Radiation and Nuclear Safety Authority (DSA) - Norway
President of the IUR

Carmel MOTHERSILL
McMaster Faculty of Science - Canada
Treasurer of the IUR

11:15-12:45 **Session 1 - Background**

11:15-11:45 On the evolution of radioecology - And how we lost ecology along the way (virtual)
Thomas G. HINTON

11:45-12:15 Neglecting the ecosystem dimension of life hinders proper assessment of ecological risk (from radiation)
François BRECHIGNAC

12:15-12:45 Discussion

12:45-14:00 *Lunch*

14:00-17:00 **Session 2 - AOP and multi-level approaches** - Part 1

14:00-14:20 Adverse Outcome Pathways (AOPs) - An introduction
Knut Erik TOLLFESEN

14:20-14:40 Application of Adverse Outcome Pathways in Space Research - *Virtual*
Vinita CHAUHAN

14:40-15:00 Building an AOP for plants chronically exposed to ionizing radiation: Lemna minor as a case study
Nele HOREMANNS

15:00-15:30 *Break*

15:30-15:50 Identification of biomarkers for use in environmental radiation protection - *Virtual*
Awadhesh JHA

15:50-16:10 Human biomarkers with potential use for environmental protection
Orla HOWE

16:10-16:30 Lessons for radioecological research from the Deepwater Horizon oil spill
Andrea BONISOLI ALQUATI

16:30-17:00 Discussion

18:00-20:30 *Welcome Reception*

Thursday 7 September

09:00-12:00 **Session 2 - AOP and multi-level approaches** - Part 2

09:00-09:20 Meaningful and objective inference in radioecological field studies
Mike WOOD

09:20-09:40 Field applications, Fukushima: Possible Low-dose radiation effects on wild animals
Kentaro ARIYOSHI

09:40-10:00 Assessing potential environmental impacts of NORMs from offshore oil and gas infrastructure decommissioning - *Virtua*l
Tom CRESSWEL

10:00-10:30 *Break*

10:30-10:50 Formal semantics in data integration and analysis; content and applications of the Radiation Biology Ontology
Paul N SCHOFIELD

10:50-11:10 A brief overview of ongoing multi-level integrative studies of radionuclides toxicity at LECO (IRSN)
Frédéric ALONZO

11:10-11:30 Novel spectroscopic methods for environmental protection research
Aidan MEADE

11:30-12:00 Discussion

12:00-13:30 *Lunch*

13:30-16:00 **Session 3 - Limitations of linear or multi-level system approaches Beyond systems**

13:30-13:50 Complex structure and function
Lawrence (Larry) A. KAPUSTKA

13:50-14:10 Competing risk model; a new integrated approach to assessing contextual impacts of ionising radiation
Colin SEYMOUR

14:10-14:30 Development of population level biomarkers for low dose radiation: the importance of non-targeted effects
Carmel MOTHERSILL

14:30-15:00 *Break*

15:00-15:20 Modelling the effects of ionising radiation and chemical pollutants on wildlife populations
Jordi VIVES I BATLLE

15:20-16:00 Discussion on Impacts of climate change - Interface between radiation and temperature and holistic approaches at the macro and micro level
Led by Carmel Mothersill and Colin Seymour

19:30-22:00 *Dinner - Celting Nights at Arlington Hotel*

Friday 8 September

09:00-12:30 **Session 4 - Social/psychosocial aspects**

Led by
Deborah OUGTHON & Mike WOOD
CERAD - Norway *University of Salford - UK*

- Evacuations of humans
- Damage/benefit of remediation
- SMR issues for the ecosystem

  Including a presentation describing the Health Physics approaches being developed at McMaster University
  Soo Hyun BYUN
  Department of Physics and Astronomy
  McMaster University

- Competing interests

12:30-14:00 *Lunch*

14:00-16:30 **Concluding session and paper writing**

Wednesday 6 September

Session 1 - Background

11:15-11:45

On the evolution of radioecology - And how we lost ecology along the way

Thomas G. Hinton

Retired
1. Centre for Environmental Radioactivity,
Faculty of Environmental Sciences and Natural Resource Management,
Norwegian University of Life Sciences, Norway
2. Institute of Environmental Radioactivity, Japan

Four major themes are made in presenting a historical perspective of radioecology (RE).

1) The International Union of Radioecology's (IUR) efforts over the last decade to bring more ecology into RE are highlighted. Levels of increasing complexity in biological organisations are reviewed (i.e., molecules to ecosystems framework), along with the IUR's desire to manage contaminated environments at the population - community - ecosystem levels, rather than at the level of individuals.

2) Evidence is presented that ecology was very strong in RE over 60 years ago, followed by the question if ecology was a fundamental part of RE years ago, what happened?

3) To address the question a historical development of the ecological aspects of RE are presented (strongly biased by the United States history) from Oppenheimer's initial influence through the nuclear accidents of Chernobyl and Fukushima.

4) Perspective is given on why we lost the ecological component in today's radioecological science.

Wednesday 6 September

Session 1 - Background

11:45-12:15

Neglecting the ecosystem dimension of life hinders proper assessment of ecological risk (from radiation)

François Bréchignac

IUR General Secretary
Retired
Institut de Radioprotection et de Sûreté Nucléaire (IRSN)

There is still no consensus within the scientific community as to whether or not radioactive environmental contamination, such as resulting from the Chernobyl or Fukushima disasters, is promoting a deleterious ecological impact. This situation is critical as it is prone to favor unjustified distrust from society with respect to the ability of authorities to take adequate measures for mastering nuclear risk and protecting the environment. It is argued that one key challenge for radiation research when facing this general context is to widen traditional radiation biology, focused on DNA and cells of individual organisms, towards radiation ecology featuring an ecosystem-centered conceptualization. If life is driven by processes that act at subsystem level, i.e. the molecular engineering that founds the organisms' physiology, it depends as well on processes that act at system level, i.e. emergent properties of the ecosystem dimension such as life support and biodiversity, since both types of processes have jointly emerged through evolution. Organisms and populations of species only exist as embedded within an ecosystem featuring multispecies interactions.

Due to this basic consideration, environment protection measures that are developed exclusively from subsystem understanding (dose-response curves established for individual organisms) for practical reasons, as in current radioprotection guidance, may actually miss their protection objective and explain some recently reported discrepancies in assessing ecological impact. Efforts to apply an "ecological network analysis" (ENA) have been developed on a well-documented case of aquatic ponds radioactively and chemically contaminated (Anna-Lea Golz et al., submitted). It demonstrates that ENA indicators of ecosystem species richness and interconnectedness, featured as nodes (species) and links (interactions), can characterize the extent of the radiation damage of a contaminated ecosystem and consequently be usefully used in risk assessments.

Keywords: radioecology, ecosystem approach, ecological network analysis, environmental protection, radiation risk assessment

Wednesday 6 September

Session 2 - AOP and multi-level approaches

14:00-14:20

Adverse Outcome Pathways (AOPs) - An introduction

Knut Erik Tollfesen

Norvegian Institute for Water Research - Norway

Wednesday 6 September

Session 2 - AOP and multi-level approaches

14:20-14:40

Application of Adverse Outcome Pathways in Space Research

Vinita Chauhan[1], V. Grybasa[2], D. Hoopfer[2], C. Higginson[2], D. Flores[1], R. Wilkins[1]

1. Health Canada, Ottawa, Canada
2. Carleton University, Ottawa, Canada

The Organisation for Economic Co-operation and Development (OECD) Adverse Outcome Pathway (AOP) framework organizes biological information of measured events to an outcome based on empirically supported evidence. AOPs begin with a molecular initiating event (MIE), that leads to intermediate key events (KEs) to an adverse outcome (AO) of interest to regulatory decision-making. KEs are connected by key event relationships (KERs) for which causality is evaluated according to the modified Bradford-Hill (BH) criteria. Conventionally, AOPs have been used to organize information on the effects of chemicals on human and ecological outcomes. Recently there has been growing interest to expand AOP use in the radiation field. As of June 2021 a Radiation/Chemical AOP joint topical group has been formed through the Nuclear Energy Agency (NEA) that is working to promote and integrate AOPs into radiation research and regulation. As part of these efforts case examples of AOPs are underway to multiple AOs including ones relevant to space exploration. Long-duration spaceflight exposes astronauts to a multitude of stressors that can impact human physiology in the hostile space environment. The combination of stressors may interact with biomolecules, cells, and tissues and organs leading to short and long-term effects. Through expert consultation, an AOP network to four intersecting AOs was constructed to non-cancer health outcomes (cataracts, vascular remodeling, learning and memory impairment and bone loss). The novelty in our approach was the use of scoping review methodology to inform the evidence evaluation. This presentation will detail the workflow for evidence gathering using systematic tools and highlight knowledge gaps. It is anticipated the qualitative AOP will be used to support future experiments that can strengthen its quantitative understanding and provide guidance on relevant data to inform risk models to protect future space travelers.

Keywords: Adverse outcome pathways, scoping review, space research, AOPs, non-cancer effects

Wednesday 6 September

Session 2 - AOP and multi-level approaches

14:40-15:00

Building an AOP for plants chronically exposed to ionizing radiation: Lemna minor as a case study

Nele Horemanns[1,2], Luca Boldrini[1,3], Gustavo Duarte[1]

1. Belgian Nuclear Research Centre SCK CEN, Belgium
2.Hasselt University, Belgium
3.Roskilde University, Denmark

Living organisms are constantly exposed to ionizing radiation coming from natural sources. Nonetheless, exposure to radionuclides and radiation can be locally increased as a result of anthropogenic activities. Moreover, comparative studies on lab experiment and data coming from the Chernobyl area have demonstrated that under natural conditions species show a higher sensitivity to radiation compared to lab or controlled field experiments. As a consequence, concerns were raised over whether lab-based risk assessment approaches, mainly based on estimating, measuring or modelling the risks of individual compounds to individual organisms grown under ideal lab-conditions, were sufficient to correctly estimate when the environment is protected from radiation. In particular, as in field conditions organisms are usually chronically exposed within or even over generations, in a multiple stressor context, and live in communities in which they compete and interact with other species, particular attention has to be drawn to research on long-term consequences of chronic exposure to ionizing radiation of humans and wildlife in order to come to a profound and integrated risk assessment.

As part of our ongoing research we study the response of plants to radiation at different levels of biological complexity from the molecular, cellular up to the organism level. Here we report specifically on Lemna minor (common duckweed) plants exposed chronically (up to 6 weeks) to elevated but environmental relevant radionuclide levels (Sr-90 or Cs-137). These kind of experiments allow for building Adverse Outcome Pathways. As part of this exercise our results will be compared to the already available AOPs for plants/duckweeds in the AOPwiki (e.g. no 245, 263, 386, 388 and 389) that are more focused on higher more acute exposure scenarios. The differences for chronically exposed plants will be discussed as well as the possibility to include new molecular and epigenetic endpoints.

Acknowledgements: financial support CHRONIC Marie Curie ITN project (Proposal number 956009)

Wednesday 6 September

Session 2 - AOP and multi-level approaches

15:30-15:50

Identification of biomarkers for use in environmental radiation protection

Awadhesh N. Jha

School of Biological and Marine Sciences,
University of Plymouth, Plymouth, PL4, 8AA, UK
Email: a.jha@plymouth.ac.uk

Genetic material or DNA is considered to be the most important target for the actions of ionising radiations. As DNA is the blueprint of the life, impact of chronic low level exposures to ionising radiations could be manifested in varieties of sub-lethal biological or biomarker responses, in addition to induction of heritable mutations which could subsequently lead to loss of total genetic diversity with implications for the long-term survival of the species. At higher levels of biological organisation, however, the problem of identifying a particular biological response to ionising radiations in the complex environment, where other stressors are also present in all the combinations, becomes very complex. This hinders our understanding of the consequences of exposures of ionising radiations or other stressors at the population level in the natural biota. One of the recent approaches in this direction has been to dissect the problem into smaller organisational levels (i.e., biomarkers at different levels of biological organisations: from molecular to individual levels), with each level controlling the structure and function of the subsequent level, and then raising mechanistic questions pertaining to organism–environment relationship. This could help in our understanding of how individual radiological responses may be expressed at higher levels of biological organisation and conversely what mechanisms precipitate in the observed effects in a stressed ecosystem. In terms of risk assessment, this may also provide clues to determine the level of organisation which provides the most sensitive and robust method of assessing environmental health. In contrast to human health arena, due to many inherent and logistic difficulties, limited progress has been made to assess the impact of ionising radiations in the natural environment. In this context, recent advances in the development of varieties of techniques and tools are certainly enhancing our understanding of how an organism interacts with its environment at the molecular, cellular or individual level following exposures to ionising radiations. The presentation will discuss some of the limitations and the progress being made to assess the potential impact of ionising radiations in aquatic biota which could help to assess the impact at the ecosystem level.

Wednesday 6 September

Session 2 - AOP and multi-level approaches

15:50-16:10

Human biomarkers with potential use for environmental protection

Orla Howe

1. School of Biological, Health and Sports Sciences, Technological University Dublin (TUDublin)
2. Environmental Sustainability and Health Institute, Greenway Hub, TUDublin
3. Radiation and Environmental Science Centre, FOCAS Research Institute, TUDublin

The World Health Organisation (WHO) listed the ideal characteristics of a biomarker as sensitive, specific, reproducible, with known variability in the general population, and common between species. There are several categories of radiation biomarker to measure exposure, susceptibility, late and persistent effects with much of the biomarker work focused on human samples that are easily obtained and minimally invasive such as human blood.

Much of our radiation biomarker studies used healthy donor and patient blood samples in addition to blood-derived lymphoblastoid cell lines with conventional chromosomal biomarkers to predict patient response to radiotherapy treatment and as biomarkers of occupational or accidental exposure. In the last decade, our focus has shifted from conventional to emerging and novel molecular biomarkers such as radio-responsive genes, proteins and miRNA's for the prediction and monitoring of human low dose radiation response. Our novel biomarkers were validated with the conventional biomarkers, which we deemed essential for the development of new radiation biomarkers. However, while molecular biomarkers demonstrated dose-dependent radiation response and biomarker potential, this response often did not correlate nor align with the conventional biomarker response and therefore added complexity to their validation and development.

Here we present these human biomarker studies with development potential for use on other species at different levels of biological organization. In addition to the biological parameters presented in previous human-focused studies, physiological and environmental parameters must be included and related to radiation dosimetry for other species. This can then assist the translation of human biomarkers in different species for future usage in environmental protection protocols.

Keywords: Biomarkers, Chromosomal, Gene, Proteomic, miRNA

Wednesday 6 September

Session 2 - AOP and multi-level approaches

16:10-16:30

Lessons for radioecological research and assessment from the Deepwater Horizon oil spill

Andrea Bonisoli Alquati

Department of Biological Sciences, Cal Poly Pomona, Pomona, USA

A robust, scientifically informed system of environmental radiation protection requires sensitive and specific endpoints of effects. It also hinges on an understanding of ecosystems over spatial and temporal scales that account for their variation in composition and processes. The breadth of the required disciplinary expertise and the costs of research activities at these scales make this a daunting task. As a result, examples of such broad radioecological research are rare if not absent. The assessment of natural resources damages from oil spills may provide a valuable blueprint for structuring radioecological research and assessment at scale. Specifically, research consortia established after the Deepwater Horizon oil spill provide an example of integrated, interdisciplinary activities that (a) spanned multiple levels of biological organization, and (b) explicitly connected ecological components over multiple years, to disentangle direct oil toxicity from cascading ecological effects. This contribution will recount experiences from a research consortium centered on the functional and structural consequences of oiling on salt marsh ecosystems. The Consortium targeted certain species for integrative work that spanned from biomarker analysis to life history effects. It also positioned knowledge about those species within the context of other ecosystem components, including by investigating food web links and habitat variation. Some simple yet powerful lessons may have emerged. First, the translation of toxicological effects to higher levels of biological organization may not be easy to document, due to complexity and noise. Second, large efforts may be needed to even initiate research and assessment at scale, due to gaps in the understanding of the species or ecosystem of interest. This is essentially an argument for monitoring activities and the gathering of natural history information, both unpopular in the eye of funding agencies. A way forward may lie in open collaboration networks that advance fundamental ecological knowledge while also informing environmental radiation protection.

Keywords: biomarker analysis, ecosystem approach, interdisciplinary research

Thursday 7 September

Session 2 - AOP and multi-level approaches

09:00-09:20

Meaningful and objective inference in radioecological field studies

Mike D. Wood[1], Joseph A. Jackson[1], Rachael E. Antwis[1], Nicholas A. Beresford[1,2] †

1. University of Salford, Salford, M5 4WT, United Kingdom
2. UK Centre for Ecology & Hydrology, Lancaster Environment Centre, Bailrigg, Lancaster LA1 4AP, United Kingdom

†Dedicated to the memory of our co-author, Professor Nick Beresford, who passed away in May 2023.

Anthropogenic releases of radiation are of on-going importance for environmental protection, but the radiation doses at which natural systems begin to show effects are controversial. More certainty is required in this area to achieve optimal regulation for radioactive substances. We recently undertook a large field-study (278 sampled animals and 20 sites) of the association between environmental radiation exposures and small mammal gut-associated microbiomes (fungal and bacterial) in the Chornobyl Exclusion Zone. Using individual measurements of total absorbed dose rates and a study design and analyses that accounted for spatial non-independence we found no, or only limited, association. Our findings contradicted those of other studies on the effects of radiation on small mammal microbiomes. The authors of those other studies challenged our findings, including criticising our study design. In reflecting on and responding to these criticisms, it became apparent that there are significant misunderstandings of the true nature of independent replication in field studies. Recognising the importance of spatial non-independence is essential in the design and analysis of radioecological field studies, but this has seemingly been overlooked in a numerous publications reporting associations between radiation and biological effects in wildlife under field conditions. In this presentation we explore some of the pitfalls in methodological design of radioecological field studies and approaches to avoiding falling foul of these pitfalls.

Keywords: study design; statistical inference; spatial non-independence; Chornobyl

Thursday 7 September

Session 2 - AOP and multi-level approaches

09:20-09:40

Field applications, Fukushima: Possible Low-dose radiation effects on wild animals

Kentaro Ariyoshi

Integrated Center for Science and Humanities
Fukushima Medical University - Japan

Since the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident, wildlife within the alert zone have been exposed to low-dose-rate (LDR) radiation. We have been examined the effects of chronic and LDR exposure associated with the FDNPP accident in multiple organs of animals (i.e. wild mouse, monkey, trout etc). We performed chromosome analysis in wild animals and relatively higher frequency of chromosome abnormalities were observed several years after the accident. Although there was no significant difference in the DNA damage of bone marrow and spleen cells from control and contaminated wild mice in 2014, there was a decrease in the number of hematopoietic progenitor cells (HPC) colonies in two contaminated areas (ambient dose-rate: 178–240μGy/day and 377-564μGy/day). Furthermore, number of spermatogenic cells and proliferating cell nuclear antigen (PCNA)-positive cells per seminiferous tubule was significantly higher in another contaminated area (ambient dose-rate: 407–447μGy/day). Moreover, an accumulation of radionuclides and reduced regenerative activities were observed in freshwater planarians in two contaminated areas in 2018 (ambient dose-rate: 43μGy/day and 101μGy/day). These results suggest that LDR radiation affected the number and regenerative activities of stem/progenitor cells in wild animal.

Keywords: FDNPP accident, wild animal effect, stem cell effect

Thursday 7 September

Session 2 - AOP and multi-level approaches

09:40-10:00

Assessing potential environmental impacts of NORMs from offshore oil and gas infrastructure decommissioning

Tom Cresswell

Australia's Nuclear Science and Technology Organisation ANSTO - Australia

At the end of their field life, offshore oil and gas infrastructure must be removed from the ocean due to existing legislation within Australia and other global jurisdictions. However, certain infrastructure may be left in-situ if there is a net environmental benefit (e.g., provision of an artificial reef). In order to adequately assess potential ecological risk from infrastructure left in situ, associated contaminants must be fully characterised, including naturally occurring radioactive materials (NORMs) that may form scales or films on internal surfaces of production equipment.

This presentation will highlight ANSTO's recent research into the presence, fate and consequence of NORMs in subsea oil and gas infrastructure. It will also discuss why the radioecology community needs to work together to adequately assess ecological risks from NORMs during offshore infrastructure closure, both for leave in-situ and for full removal to terrestrial waste management facilities decommissioning options. Current scientific understanding and opportunities for further research into the fate of NORMs from decommissioned offshore oil and gas infrastructure will be presented.

Keywords: NORM, risk assessment, decommissioning, petroleum, environmental management

Thursday 7 September

Session 2 - AOP and multi-level approaches

10:30-10:50

Formal semantics in data integration and analysis; content and applications of the Radiation Biology Ontology

Paul N Schofield[1] and Luke Slater[2]

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We introduce the Radiation Biology Ontology (RBO), a formally structured ontology designed to cover key concepts in the domain of radiation biology. The primary use-cases for RBO were archiving data in the STOREDB database (https://www.storedb.org/), the repository for the RadoNorm and Pianoforte Projects, and in GeneLab (https://genelab.nasa.gov), NASA's 'omics database. Its scope ranges from fundamental physics to environmental concepts and human behaviour. The RBO was developed using the OBO Foundry-led Ontology Development Kit, and published through GitHub, the OBO foundry, and the NIH/NCBI BioPortal website. To date, concept modelling has yielded an ontology that has more than 350 declared classes, with more than 3500 additional classes imported from 13 other OBO Foundry ontologies with relevance to radiation biology (for example, concepts from the ISO standard Basic Formal Ontology, the Environment Ontology and the Gene Ontology).
In addition to its primary purpose for descriptive metadata in support of data integration, discovery and FAIR data support, RBO can be used to federate and automate data searches across multiple databases, for example using web services, and through semantic web technologies supporting data discovery.

The formal semantics of the RBO can be used to leverage automated reasoning, logical inference and deep axiomatisation of entity annotations, and we discuss briefly the uses of the RBO, and ontologies more widely, for knowledge extraction from the scientific literature and social media, the construction of knowledgebases and knowledge graphs, for example to structure databases of AOPs, and finally how, using graph embeddings, the symbolic representation of multiple types of data can be integrated with quantitative data for use in machine learning and AI.

Keywords: Ontology, Biosemantics, Machine learning, AI, Text-mining, Radiobiology

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Thursday 7 September

Session 2 - AOP and multi-level approaches

10:50-11:10

A brief overview of ongoing multi-level integrative studies of radionuclides toxicity at LECO (IRSN)

Frédéric Alonzo

Institut de Radioprotection et de Sûreté Nucléaire
IRSN - France

Thursday 7 September

Session 2 - AOP and multi-level approaches

11:10-11:30

Novel spectroscopic methods for environmental protection research

Aidan Meade

Head of Learning Development,
Faculty of Sciences and Health
Technological University Dublin
Funded Investigator, SFI ADAPT Research Centre

Thursday 7 September

Session 3 - Limitations of linear or multi-level system approaches – Beyond systems

13:30-13:50

Complex structure and function

Lawrence A. Kapustka

LK Consultancy
Diamond Valley, Alberta - Canada

Evaluating risks of ionizing radiation to humans and ecological receptors has been pursued for at least eight decades. Early research demonstrated differential susceptibility of different species exposed to radionuclides. Subsequently, work on understanding the mechanisms that caused harm centred on molecular events, especially alterations of genetic material. As important as such work was in establishing protective measures, especially for humans, we have come to realize that more is needed. The IUR pursued an initiative in the last decade to promote the adoption of an ecosystem approach to inform our collective understanding of both direct and indirect effects of ionizing radiation. One critical consideration of an ecosystem approach is the holistic nature of complex, social-ecological systems. Yet, there remains a disconnect in that humans are often viewed as being apart from their ecological support system.

In this presentation, I will explore the importance of recognizing the complexity of social-ecological systems, in particular the non-linear interactions, as a prerequisite for advancing environmental management of ionizing radiation.

Thursday 7 September

Session 3 - Limitations of linear or multi-level system approaches – Beyond systems

13:50-14:10

Competing risk model; a new integrated approach to assessing contextual impacts of ionising radiation

Colin Seymour and Carmel Mothersill

McMaster University - Canada

Global heating is now accepted with heatwaves and forest fires seriously impacting air quality and resulting in massive areas being subjected to air pollution. Nuclear energy is therefore increasingly being identified as a "green" alternative to provide for our energy needs. However there is much public resistance due to fear of radiation effects. Radiation protection approaches do little to ease this fear as they are grounded in the idea that any dose has a potential to harm. This approach ignores other risks associated with other forms of energy production focusing solely on determining the risk from radiation alone. The model we are proposing here is an attempt to set radiation risk in context – to balance the risks of action to limit or optimise factors impacting climate change with those of inaction – for example excluding a nuclear action without proper analysis. Existing attempts to approach this problem include adverse outcome pathway analysis (AOP) which proposes to evaluate causal relationships. It links in a linear way existing knowledge along one or more causally connected key events between two points – a molecular initiating event caused by the stressor of interest, and an adverse outcome. However the commonality of response pathways between radiation and other stressors such as heat, drought, flood, food scarcity, air pollution, or environmental degradation plays into a competing cause model for the same endpoint outcome rather than a single agent risk model. The aggregate exposure pathway analysis (AEP) is a more quantitative approach known as STOP (source to outcome pathway) which tries to look at multiple stressors. Here only the most relevant pathway and stressor is considered using logical inference from available data. This is different from competing risk analysis (CRA) which is a special type of survival analysis that aims to estimate correctly, the marginal probability of an event in the presence of competing events. In a CRA all risks can be compared by using a Baysian inference to identify the most relevant risks to the system under consideration. Crucially for CRA it is not necessary to know the exact pathway involved in determining the outcome. This concept has been developed here to try to examine the important possibilities and threats to, for example, the ecosystem. If nuclear energy is to be a part of the solution to the energy and climate crisis a CRA would point to environmental benefits such as habitat preservation. Habitat degradation is a human and environmental health risk; nuclear power generation could demonstrably mitigate against this by making new builds such as small modular reactors eco-friendly – setting aside land to offset environmental harm from the build. A CRA approach would also involve attributing a societal value to biodiversity, carbon storage properties of trees and bogs etc. In conclusion the advantages of a CRA approach are that a basket of stressors can be assessed to predict different outcomes not all of which need be adverse.

Thursday 7 September

Session 3 - Limitations of linear or multi-level system approaches – Beyond systems

14:10-14:30

Development of population level biomarkers for low dose radiation: the importance of non-targeted effects

Carmel Mothersill and Colin Seymour

McMaster University - Canada

Recent moves within ICRP to develop an integrated approach to radiation protection of both humans and non-human biota are focused on regulating dose to exposed populations based on behaviour, size, lifestyle and "radiosensitivity". Currently man and 12 reference organisms are used covering various taxonomic groups, behaviours, and exposure scenarios - e.g. marine, terrestrial, sediment or airborne. However most biologists agree that particularly in low dose exposure legacy sites, the factors determining effects and outcomes are far more complex that this simple framework suggests. The issue is developing reliable predictors of system or ecosystem health rather than relying on biomarkers that give information about effects on individual cells, organs or organisms. Approaches to this include the Adverse Outcome Pathway (AOP) which looks at multiple levels of organisation from gene to ecosystem Another approach used by our group is to look at the role of non-targeted effects such as genomic instability (GI) and bystander effects (BE). These mechanisms involve transmission of information between different levels of organisation. In the case of BE signals from exposed to unexposed cells or organisms coordinate response at higher levels of organisation permitting population responses to radiation to be optimised. GI is more complex as it involves not only signalling but also trans-generational transmission of genetic or epigenetic changes and may lead to long-term adaptive evolution. GI may also be involved in memory or legacy effects, which contribute a further component to the dose effect measured in legacy sites. Our recent analysis of the contributions of memory and legacy effects to the total effect using data sets from Chernobyl and Fukushima (voles, birds and butterflies) suggest this type of analysis may help reduce uncertainties over lab to field extrapolations. Given the clear discrepancy between actual data measured in the field and dose effects generated using databases populated mainly with acute lab based experimental data, it is imperative that we strive to develop meaningful holistic systems for protection of those living in contaminated ecosystems.

Keywords: ecosystem approach, radiation protection , low dose, non-targeted effects, radiation effects

Thursday 7 September

Session 3 - Limitations of linear or multi-level system approaches – Beyond systems

15:00-15:20

Modelling the effects of ionising radiation and chemical pollutants on wildlife populations

Jordi Vives i Batlle

Belgian Nuclear Research Centre (SCK CEN) - Belgium

We present a conceptual model, developed under both IAEA Modaria and EC RadoNorm projects, designed to study the combined effects of ionising radiation and chemical pollutants on wildlife. A set of first order, non-linear, logistic differential equations combines mortality, morbidity and reproduction phenomena with life history data and ecological interactions. This population model also includes adaptation/acclimatisation as a possible mechanism acting at low levels of radiation or chemical concentration. Radiation and chemical-induced damages are represented by a 'repairing pool' acting between healthy, damaged, adapted and irrecoverable individuals. Damages to population, fecundity and the repairing pool are represented by a linear-quadratic function combining radiation dose and chemical concentration terms. The model endpoints include mortality, morbidity and reproductive effects.

A mixed radiation/arsenate scenario is used to illustrate the combined effects of radiation and chemical pollutants on a hypothetical population, given the assumption that the repair of both radiation and toxicity damages share the same mechanism. A sensitivity analysis of the model parameters is presented, exploring possible modes of action for the radiation/chemical mixture on the population.

This model provides a conceptual framework to assess the effect of a radiation/chemical mixture at the population level, hinting at a practical regulatory model that could inform ongoing debates on the robustness of protection benchmarks in wildlife risk assessment. The approach could help to draw conclusions about the most restrictive mixed exposure situations in terms of effects to the population. It is possible to improve the model with emerging experimental data and compare it with well-established approaches for chemical risk assessment, signalling the direction of future investigations

Keywords: Ecological modelling population model; mixture effects

Friday 8 September

Session 4 - Social/psychosocial aspects

09:00-12:30

Deborah Oughton
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NMBU
Norway

Mike Wood
University of Salford
UK

- Evacuations of humans
- Damage/benefit of remediation
- SMR issues for the ecosystem

The Health Physics approaches being developed at McMaster University

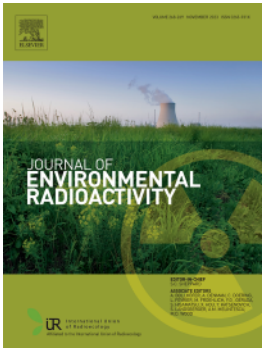
Soo Hyun Byun
Department of Physics and Astronomy
Radiation Sciences Graduate Program
McMaster University, *Canada*

- Competing interests

Friday 8 September

Concluding session - Paper writing

14:00-16:30



The latest research and results presented at the Symposium will give rise to a special issue of the Journal of Environmental Radioactivity.

Picture presentation

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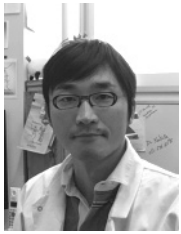

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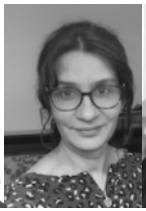

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