A Strategic Research Agenda for Radioecology

Thomas Hinton

Paris; 19 June 2012
In June 2009, the Director Generals of **EIGHT** European organizations signed a Memorandum of Understanding to address emerging problems in radioecology.
Memorandum of Understanding

• will address **scientific and educational challenges** relative to the **impact of radioactive substances on humans and the environment**

• will **integrate** portions of their **respective research efforts** into a **trans-national programme**
The ALLIANCE intends to be international, and many organizations have expressed interest in joining.
In February 2011, ALLIANCE members, with Stockholm University and the Norwegian University of Life Sciences, acquired funding from the European Commission to establish a NETWORK of EXCELLENCE in Radioecology.

A major task within STAR is to develop a Strategic Research Agenda for radioecology.

Alliance Members:
- IRSN (France)
- NERC (UK)
- CIEMAT (Spain)
- SCK-CEN (Belgium)
- NRPA (Norway)
- STUK (Finland)
- BfS (Germany)
- SSM (Sweden)
The **Strategic Research Agenda** is a suggested prioritisation of research topics in radioecology, with a goal of improving research efficiency and more rapidly advancing the science.

It responds to the question:

“What topics, if critically addressed over the next 20 years, would significantly advance radioecology?”
The SRA is a VISION, in which the developers were asked to think creatively and without bounds as they imagine the results that could most shape the future of radioecology and benefit stakeholders...
Development of the Strategic Research Agenda


Development of the Strategic Research Agenda


**Challenges in ecotoxicology.** 2004. Eggen et al. *Environmental Science & Technology*


Networking—a way for maintaining and enhancing radioecological competences in Europe. FUTURAE. 2008. *Deliverable 4*

**Radioecology, radiobiology, and radiological protection: frameworks and fractures.** Pentreath. 2009. *Journal Environ. Radioactivity*

**Challenges in radioecology.** Salbu. 2009. *Journal Environ. Radioactivity*

Radioecology for tomorrow: An international challenge, both scientific and operational. Repussard. 2011. *International Conference on Radioecology and Environmental Radioactivity*

Towards a renewed research agenda in ecotoxicology. Artigas et al. 2012. *Environ. Pollution*
The SRA was formed by considering:

(i) recent changes in policy

(ii) new scientific advancements

(iii) improving credibility with stakeholders

(iv) science deficiencies

(v) integration issues

(vi) potential future risks

(vii) early lessons from the Fukushima disaster
Development of the Strategic Research Agenda

MELODI

DoReMi
Integrating Low Dose Research

NERIS-TP

...the portal of the European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery

RODOS
Realtime Online Decision Support system

Sharing Knowledge
Interests of ALLIANCE member organisations...
STRATEGIC RESEARCH AGENDA

The SRA identifies three important Scientific Challenges that radioecology needs to address.

Each Scientific Challenge includes a Vision Statement of what should be accomplished over the next 20 years in that area of radioecology.

Each Scientific Challenge includes Key Research Lines required to accomplish the vision.

(a total of 15 research lines were prioritised within the SRA)
CHALLENGE ONE

To Predict Human and Wildlife Exposure More Robustly by Quantifying the Key Processes that Most Influence Radionuclide Transfers

Our strategic vision is that over the next 20 years radioecology will have achieved a thorough mechanistic conceptualisation of radionuclide transfer processes within major ecosystems (terrestrial, aquatic, urban), and be able to accurately predict exposures to humans and wildlife by incorporating a more profound understanding of environmental processes.
Simplistic Model of Some Major Processes

- **SOURCE**
  - dispersion
  - deposition
  - resuspension

- **AIR**
  - inhalation

- **SOIL**
  - root uptake
  - soil loading
  - ingestion
  - mortality
  - deposition
  - resuspension

- **PLANTS**
  - ingestion
  - mortality
  - leaching
  - physical decay

- **SINK**

- **CARNIVORES**
  - ingestion
  - mortality egesta

- **HERBIVORES**
  - mortality egesta
  - ingestion

- **DETRITUS**
  - ingestion

- **FOOD WEB**
Modelers appreciate the simplicity of the CR:

\[ CR = \frac{Bq \, kg^{-1} \, plant}{Bq \, kg^{-1} \, soil} \]

It allows the contaminant concentration in a plant to be estimated merely by multiplying the soil concentration by a CR.
**CR** for $^{137}$Cs can easily span three orders of magnitude, even for individual soil-crop combinations.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soil Type</th>
<th>Concentration Ratio</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>Sand</td>
<td>0.021</td>
<td>0.00170</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Loam</td>
<td>0.014</td>
<td>0.00045</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Clay</td>
<td>0.011</td>
<td>0.00057</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Organic</td>
<td>0.043</td>
<td>0.00380</td>
<td>0.49</td>
</tr>
<tr>
<td>Tubers</td>
<td>Sand</td>
<td>0.110</td>
<td>0.0140</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>Loam</td>
<td>0.029</td>
<td>0.0029</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>Clay</td>
<td>0.029</td>
<td>0.0034</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Organic</td>
<td>0.055</td>
<td>0.0060</td>
<td>0.51</td>
</tr>
</tbody>
</table>

**Table** — Recommended $C_r$ for radiocesium by crop and soil type.
Regression analysis of Cs-137 uptake by plants as a function of numerous soil parameters

plant $^{137}$Cs = 0.39 (soil $^{137}$Cs) + 0.44 (Na) – 0.28 (pH) – 0.41 (K)

43% of the variation in $^{137}$Cs plant concentrations was explained by the soil parameters examined

Our ability to predict contaminant concentrations in plants is moderate, at best, even after 50 years of data collection!
CHALLENGE ONE

To Predict Human and Wildlife Exposure More Robustly by Quantifying the Key Processes that Most Influence Radionuclide Transfers
CHALLENGE TWO

To Determine Environmental Effects
under the Realistic Conditions that
Organisms are Exposed

Our strategic vision is that over the next 20 years radioecology will have gained
a thorough mechanistic understanding of the processes that induce radiation
effects at different levels of biological organisation, including consequences on
ecosystem integrity, and be able to accurately predict effects under the realistic
conditions in which organisms are actually exposed.
Most Contaminant Research Is Not Directly Relevant to Responses in Nature

<table>
<thead>
<tr>
<th>Data Plentiful; but Least Relevant</th>
<th>Data Scarce; but Most Relevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual response</td>
<td>Population response</td>
</tr>
<tr>
<td>Mortality</td>
<td>Reproduction</td>
</tr>
<tr>
<td>Acute exposure</td>
<td>Chronic exposure</td>
</tr>
<tr>
<td>External gamma</td>
<td>Multiple exposure routes</td>
</tr>
<tr>
<td>Laboratory</td>
<td>Field</td>
</tr>
<tr>
<td>Short-term</td>
<td>Long-term</td>
</tr>
<tr>
<td>Direct effects</td>
<td>Indirect effects</td>
</tr>
<tr>
<td>Single contaminants</td>
<td>Multiple stressors</td>
</tr>
</tbody>
</table>
Extrapolating effects from the molecular level to the cellular level, or from individuals to groups of many individuals and species, is a major objective in ecotoxicology that has yet to be achieved.

Calow & Forbes
CHALLENGE TWO

To Determine Environmental Effects under the Realistic Conditions that Organisms are Actually Exposed

**RESULTS**
- Process Understanding; Population and ecosystem effects models;
- More robust assessment factors and screening values

**Vision & Strategy**

**Realistic Exposure Conditions**
- Chronic versus acute exposure
- Low versus high LET
- Internal versus external exposure
- Indirect effects
- Environmental factors and multiple stressors

**Tools and Approaches**
- Systems Biology
- Biokinetic Models
- DEB-Tox Models
- Epigenetics
- "-omic" Sciences

**Hypothesis Driven Research Areas**
- Understanding mechanisms and processes
- Biomarkers of exposure and effects
- Understanding radiosensitivity
- Multigenerational exposure and adaptation

**Different Levels of Biological Complexity**
- Sub-organism
- Individual
- Population
- Community
- Ecosystem

Results in:
CHALLENGE THREE

To Improve Human and Environmental Protection by Integrating Radioecology

Our Strategic Vision is that over the next 20 years radioecology will develop the scientific foundation for the holistic integration of human and environmental protection, as well as their associated management systems.
CHALLENGE THREE

To Improve Human and Environmental Protection by Integrating Radioecology

Integration...

- of Human and Environmental Protection Frameworks
- of Risks from Radiation with Co-contaminants and other Stressors
- of Ecosystems Approach and Environmental Services
- of Uncertainty from Exposure and Effects into Risk Estimation
- with other Disciplines and Multi-criteria Analyses
- of numerous Decision Support Systems
Increasing Area of Land

Decrease the Uncertainty of Contaminant Transport, Effects and Risks

High Level Waste

Required Remediation

Remediation Threshold

Remediation Not Needed

Increasing Contaminant Concentrations

Integrate Decision Support Tools and Optimize via Multi-criteria Analyses
NEXT STEPS

25 June to 1 October….we invite all stakeholders to download the SRA and a questionnaire to provide input (www.star-radioecology.org)

Build Consensus on the SRA

- STAR’s External Advisory Board
- International Organizations (IAEA, ICRP, UNSCEAR, IUR)
- Other Networks of Excellence (DoReMi, NERIS, NCoRE)
- Larger radioecology community
- Interested stakeholders

12-13 November 2012….stakeholder workshop on SRA, Paris

Develop other aspects of the Strategic Agenda

- Education
- Recruitment
- Maintenance of key infrastructures
- Knowledge management

Next draft due January 2014
Develop a ROADMAP for the SRA

April 2013 --- July 2015

…the how and means of accomplishing the research items within the SRA…

The Roadmap will link the SRA with the evolution of the science by providing the necessary action plans, resource allocation, and milestones required to achieve the components of the SRA.
STAR has produced the first *Draft* Strategic Research Agenda in Radioecology!!

3 Scientific Challenges….with 15 associated research lines

An SRA for radioecology will focus and prioritise our collective efforts…
enhancing value to stakeholders and more rapidly advancing our understanding of environmental radioactivity
CHALLENGE ONE: Quantify Key Processes that Most Influence Radionuclide Transfers

Strategic Research Agenda

1. Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife.

2. Acquire the data necessary to parameterise the key processes that control the transfer of radionuclides.

3. Develop transfer and exposure models that incorporate physical, chemical and biological interactions, and enable predictions to be made spatially and temporally.

4. Represent radionuclide transfer and exposure at a landscape or global environmental level with an indication of the associated uncertainty.
Determine Ecological Consequences under Realistic Exposure Conditions

Strategic Research Agenda

1. Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity.

2. Understand what causes intra- and inter-species differences in radiosensitivity (among cell types, tissues, life stages, among contrasted life histories, influence of ecological characteristics including habitats, behaviour, feeding regimes).

3. Understand the interactions between ionising radiation effects and other co-stressors.

4. Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (maternal effects, hereditary effects, adaptive responses, genomic instability, and epigenetic processes).

5. Understand how radiation effects combine at higher levels of biological organisation (population dynamics, trophic interactions, indirect effects at the community level, and consequences for ecosystem functioning).
**Improve Human and Environmental Protection by Integrating Radioecology**

**Strategic Research Agenda**

1. Integrate uncertainty and variability from transfer modelling, exposure assessment and effects characterisation into risk characterisation.

2. Integrate human and environmental protection frameworks.

3. Integrate the risk assessment frameworks for ionising radiation and chemicals.

4. Provide a multi-criteria perspective in support of optimised decision-making.

5. Integrate ecosystem services, ecological economics and ecosystem approaches within radioecology.

6. Integrate Decision Support Systems