Radioecology in 2014
Current research directions and trends for the future
What is Radioecology

A multidisciplinary scientific discipline:

- biology, chemistry, physiology, ecology, biogeochemistry, geophysics, ecotoxicology, mathematics (models, statistics), metrology, ...

- centered on the environment,
- aimed at describing, understanding and predicting

- the fate of radioactivity in environmental systems,
  (artificial and natural)
- its impact on man (via the environment) and on the environment itself (biota, ecosystems)
  (human and ecological risk assessment)
- biogeochemical processes by means of tracer studies
Main research directions of radioecology

On-going move from anthropocentric to ecocentric

Conclusion: challenges from Fukushima
The main research directions of Radioecology

Axis 1: Source term
- Speciation, mobility (in the various environmental media)

Axis 2: Transfers
- In abiotic compartments, within the human food chain
- In abiotic compartments, within the biota trophic network

Axis 3: Effects
- (On man)
- On biota, populations, ecosystems

Axis 4: Risk assessment
- Human risk assessment
- Ecological risk assessment (organism-based/ecosystem-centred approach)

Axis 5: Tracer studies
- Biogeochemical cycles, ocean streams, run-off
Releases (normal, accidental) TNORMs

AXIS 1
Source term
Speciation, mobility

AXIS 2
Transfers
In abiotic compartments
Within the human food chain

AXIS 3
Effects
(On man)

AXIS 4
Risk assessment
Human risk assessment

AXIS 5
Tracer studies
Biogeochemical cycles, streams, run-off…

ATMOSPHERE
BIOSPHERE
GEOSPHERE

Scientific designs
Experimental approaches, models, field investigations

Union Internationale de Radioécologie
International Union of Radioecology
Releases (normal, accidental)

Source term
Speciation, mobility

AXIS 1

Fauna

ECOSYSTEM

Flora

AXIS 2

Transfers
In abiotic compartments
Within the human food chain
Within biota trophic networks

AXIS 3

Effects
(On man)
On biota, ecosystems

Life support
Services

AXIS 4

Risk assessment
Human risk assessment
Ecological risk assessment

AXIS 5

Tracer studies
Biogeochemical cycles, streams, run-off…

Scientific approaches
Experimental designs, models, field investigations

Waste in deep geological repository

Itemized

ATMOSPHERE

BIOSPHERE

GEOSPHERE

Union Internationale de Radioécologie
International Union of Radioecology
Radiation effects on wildlife: missing knowledge

Research priorities

- Long-term (trans-generational)
- Low doses and dose rates
- Internal contamination
- Observations at population, community and ecosystem level
- More species (biodiversity)
Historical anthropocentric approach

- **External (to man) medium** (exploitation of abiotic resources)
- **Animals and plants, but only for agricultural purposes (produce human food)**
- **Animals and plants as vectors of contamination to humans, not as targets**
- **Man was considered out of the environment, and as the exclusive target of concern**

**Linear Transfers**

- **Sources**
  - PLANTS
  - ANIMALS
  - Man
From anthropocentric to biocentric … today

Environment

- Pristine nature (the wilderness and its biota, fauna and flora)
- Radioactivity effects on wild animals and plants
- Animals and plants as targets

Effects

Linear Transfers to biota
## Effects under chronic exposure

### Dose rate

<table>
<thead>
<tr>
<th>Dose rate (\mu\text{Gy.h}^{-1}(\text{mGy.d}^{-1}))</th>
<th>(&lt; 10^2) (&lt; 2.5)</th>
<th>(10^2-10^3) (2.5-25)</th>
<th>(10^3-5.10^3) (25-125)</th>
<th>(5.10^3-10^4) (125-250)</th>
<th>(10^4-2.10^4) (250-500)</th>
<th>(&gt; 2.10^4) (&gt;500)</th>
<th>(&gt; 10^5) (&gt;5000)</th>
<th>(&gt; 10^6) (&gt;50000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants</td>
<td>Growth red. Morphologic al. mortality</td>
<td>Canop. ind. modification</td>
<td>Coniferous mortality</td>
<td>Leaves growth reduction &amp; mortality</td>
<td>Reduction of reproductive potential</td>
<td>Mortality of all plants</td>
<td>Reduction of biodiversity</td>
<td></td>
</tr>
<tr>
<td>Fishes</td>
<td>Reprod. anomalies</td>
<td>Germ cells alteration. Reduced fecundity</td>
<td>Par. Nuptial Reduced fertility</td>
<td>Reduced spermatogenesis</td>
<td>Larvae mortality</td>
<td>Severe sterility</td>
<td>Vertebral growth reduction</td>
<td></td>
</tr>
<tr>
<td>Mammals</td>
<td>Alt. Germ cells</td>
<td>Brain cells mortality</td>
<td>Weight reduction</td>
<td>Mortality of embryos</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Effect endpoints focused on individual organisms:
- Mortality
- Morbidity
- Reproductive success
- Chromosome damage

---

**Recent literature compilation (ERICA EC project)**
Xenobiotic introduction

DNA-RNA
Membrane receptors
Key enzymes
Biochemical integrity

Site of action

Toxicological approach

Ecosystemic approach

Ecosystem effects

Biochemical parameters
Stress proteins
Metabolic indicators
Acetylcholinesterase inhibition
Adenylate energy charge
Metallothionin production
Immunological suppression

Population parameters
Population density
Productivity
Mating success
Alterations in genetic structure
Competitive alterations

Community parameters
Structure
Diversity
Energy transfer efficiency
Stability
Successional state

Chemical parameters
Ecosystemic approach

Individual physiological and behavioral parameters
Chromosome damage
Lesions and necrosis
Tumors and teratogenic effects
Reproductive success
Behavioral alterations
Mortality
Compensatory behaviors
Tomorrow: moving to an ecocentric view with the ecosystem approach

Environment including man

- Ecosystem = biotope + biocenose
- Services (waste recycling, provision of resources, ...)
- Life support (water recycling, air bioregeneration, biomass production, ...)
Conclusion: How is radioecology challenged by Fukushima?

Remediation, mitigation, decontamination techniques (terrestrial)
- Speciation,

Impacts on the marine ecosystem
- In-sediment accumulation?
- Long-term distribution and impact on the local marine trophic network

Better understanding of the multiple stressors context
- Tsunami physical reshaping of the coastal area
- Radioactive releases to the environment (terrestrial and marine)
- Integrated Ecological risk assessment

Tracer studies
- Ocean streams, run-off