SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Biosphere Impact Studies

Context

Radioactive environmental contamination may result from the use of nuclear energy for electricity production, military and industrial applications, applications in medicine and research or from the exploitation and treatment of ores and materials containing natural radionuclides.
To estimate the radiological impact of these activities on man and environment, in depth knowledge on the environmental behaviour of radionuclides and their effects induced is required. The reliability of the predictions largely depends on the degree of understanding of the biological and physico-chemical processes governing the flux of radionuclides in the biosphere and of the way, type and magnitude of biological effects induced.

Objectives

Our major objectives are to:
- Enhance competence in the understanding of the behaviour of radionuclides in the biosphere.
- Develop a groundwater-soil-vegetation interaction model to assess the long-term impact of perennial vegetation systems on the dispersion of radionuclides and contamination of the food chain.
- Improve our knowledge, expertise and international recognition in the research domain of biological effects induced in plants by radiation, radionuclide uptake and mixed contaminant conditions.
- Develop and improve our tools and models for assessing the radiological impact on man and environment.

Main activities

Study of the behaviour of radionuclides in the biosphere

SCK•CEN studies the mechanisms and processes to better understand and predict the behaviour of radionuclides in the terrestrial and aquatic environment. Emphasis is on critical radionuclides in nuclear waste disposal (e.g. ^{99}technetium, ^{94}niobium), (post-)emergency planning (^{137}cesium, ^{90}strontium), industries dealing with materials containing natural radionuclides (e.g. ^{238}uranium, ^{226}radium) and in the context of the probabilistic risk assessments for MYRRHA (e.g. ^{210}polonium). We also perform tracer studies for heavy metals (e.g. ^{109}cadmium, ^{65}zinc, ^{60}cobalt) in collaboration with Belgian universities.

To study the effects of environmental factors on radionuclide behaviour, we use dedicated modelling tools, laboratory set ups, greenhouse experiments and field studies. We evaluate for example:
- How soil properties affect uptake of radionuclides.
- If presence of other contaminants influences radionuclide availability.
- Uptake and translocation mechanisms of radionuclides by plants.
- If presence of soil fungi influences root uptake and transfer of radionuclides to upper plant parts.
- How water and sediment properties affect their repartitioning.

The acquired knowledge is applied to develop risk assessment models, to propose countermeasures and land management options for contaminated areas.


Field studies in Chernobyl


Rhizoplan experiments


Greenhouse experiments

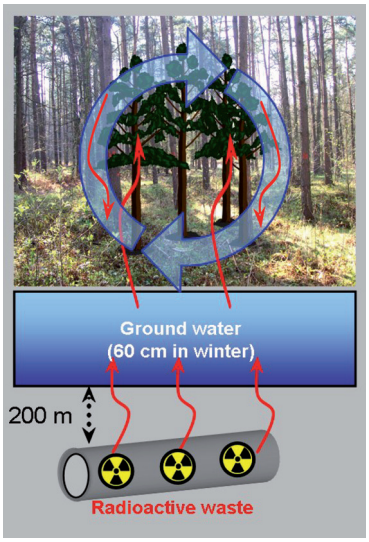

Collection of Belgian soils


Micro-organism interaction

Development of a groundwater-soil-vegetation interaction model

Currently, there are no assessment models of (semi) natural vegetation directly applicable for long-term radioactive waste assessment. Since perennial ecosystems may directly access groundwater, they are a potential source of biosphere contamination.

To assess the transport and accumulation of bio-available contaminants in a perennial ecosystem, this study makes use of a Soil-Vegetation-Atmosphere Transfer (SVAT) model. SVAT models explicitly consider the role of vegetation in affecting water, energy and carbon balance by taking into account its physiological properties. These models are often process-based and therefore suitable to simulate the water and carbon fluxes in natural and managed ecosystem under different environmental conditions, including climate change. We use these fluxes because they help us to determine the rates at which contaminants will be partitioned in the environment.
We will perform sensitivity tests of the selected SVAT model for different vegetation/soil/climate conditions.



Potential interaction of a forest vegetation with groundwater contaminated by releases from a high level nuclear waste repository.

A validation of simulated fluxes against in-situ measurements will be followed by a coupling of nutrient and radionuclide fluxes to the water and carbon fluxes. This adapted model allows us to assess the influence of perennial ecosystems on the radionuclide dispersion and the subsequent exposure to man. For this research we strongly collaborate with UCL, ULg and Gembloux Agro-Bio Tech (Gx ABT).

Biological effects induced in plants after exposure to external radiation, uptake of radionuclides or mixed stressor conditions

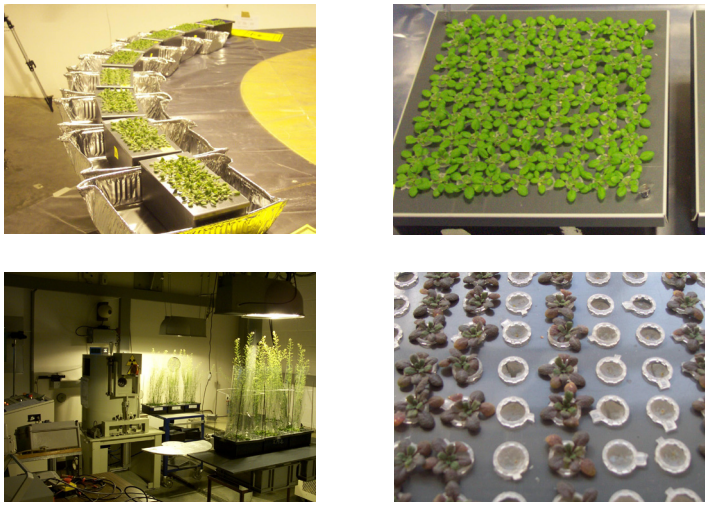
The paradigm "if man is protected, then the environment is protected" has been strongly contested. Over the last decade, the need for a system to protect the environment against ionising radiation has been recognised internationally. One of the outcomes of the EC-ERICA project was that there was an important lack of quality experimental data on effects of radiation on non-human biota, certainly with respect to chronic exposure experiments under realistic exposure conditions.
In this context, SCK•CEN performs chronic exposure experiments on plants and concentrates on individual (mortality, morbidity, reproduction, mutation) and population (mortality, reproduction) measurement endpoints.

We also evaluate how stressors trigger the oxidative defence system both at enzymatic, metabolic and genetic level. DNA damage and DNA repair mechanisms under different stressor conditions are being assessed. To identify the biochemical pathways and genetic changes after exposure to stressors, we performed under controlled conditions genome micro-array analysis to compare gene expression patterns.

We evaluate effects on the terrestrial plant *Arabidopsis thaliana* and/or the aquatic plant *Lemna minor* (duckweed) following exposure to uranium, gamma, alpha (^{241}americium), beta radiation (^{90}strontium).
Effects are also studied under multiple contaminant exposure, mimicking relevant exposure conditions:

- Uranium, thorium, arsenicum, cadmium for uranium mining areas.
- Combined alpha, beta and gamma radiation and heavy metals for releases from nuclear power plants.
- Gamma and neutrons to mimic space conditions.

Research is mainly carried out in collaboration with UHasselt, UAntwerp and in the frame of the European NoE-STAR.



Examples of exposure conditions and test plants.

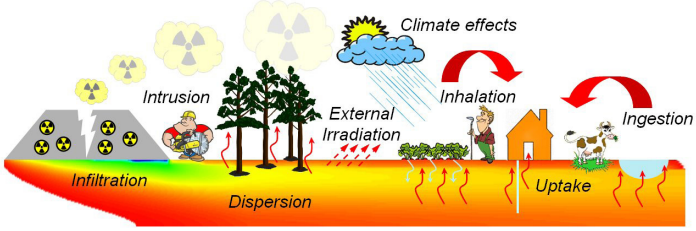
Human and environmental risk assessment

In radiological protection, human and environmental risk assessments constitute an important discipline. In compliance with basic radiation protection rules, we have to assess environmental impact of routine and accidental releases of radioactivity. Therefore, SCK•CEN developed radiological models to predict the dispersion of radionuclides in the biosphere and the resulting health impact on man and environment.

The most important action domains are to:

- Develop, test and improve biosphere models for assessing the long-term, post-closure safety of radioactive waste disposal.
- Assess the radiological impact of routine and accidental discharges and past releases (dose reconstruction).
- Determine the need for remediation of contaminated sites and estimate countermeasure effectiveness.
- Develop and improve surface water models for routine and accidental releases.
- Develop non-human biota impact assessment models and perform environmental risk assessments.

Most of these studies are performed on behalf of ONDRAF/NIRAS, GDF-Suez and in international collaborations under the auspices of the IAEA. Dedicated research and surface water model improvement is done in collaboration with VUB and in the frame of the European NoE-STAR.



Conceptual biosphere model

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