The IAEA-coordinated research on characteristics, environmental behaviour and biological impact of radioactive particles

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Motivation

Radiation exposure associated to particulate radioactivity challenges assessment of radiological impact to human and the environment. Nuclear weapon tests, nuclear legacy due to past practices, incidents and accidents, mining and natural resource exploration, production of building materials lead to enhanced levels of radioactive materials, significant part of which exists in a form of particles.

Radioactive particles are now understood to be more prevalent in the environment than previously postulated, thus leading to new research tasks in measurement science and analytical techniques, radiobiology, dosimetry, remediation and recovery, radioecological and health risks assessment.

Activities

Since 2000s, the IAEA supported two coordinated research projects (CRP)

✓ CRP „Radiochemical, Chemical and Physical Characterisation of Radioactive Particles in the Environment" (2000–2008)
  - 16 Member States
  - 30+ participants

✓ CRP "Environmental Behaviour and Potential Biological Impact of Radioactive Particles" (2013–2018)
  - 16 Member States
  - 50+ participants

These CRPs were focused on characterisation of the radioactive particles, their environmental fate and behaviour, radioecological properties describing their mobility and transfer through various ecosystems or within living organisms and human body.

The projects integrated a variety of the case studies, thus covering various sources and types of particulate radioactivity:

- Nuclear weapon tests (Marshall Islands; Semipalatinsk Test Site, Kazakhstan; Maralinga and Monte Bello sites, Australia)
- Nuclear accidents (the Chernobyl accident, Belarus and Ukraine; the Fukushima Daiichi NPP accident, Japan)
- Nuclear incidents (Thule, Greenland; Palomares, Spain)
- Discharges of nuclear waste into freshwater (Yenisei River, Russia) and marine (Dounray, UK) environments
- Nuclear and NORM industries (oil and gas exploration, uranium mining and milling, phosphate and building materials production)

Future development

The contemporary conventional approaches of human or environmental dose assessments are built around concepts of average organ, tissue or whole-body doses. Radiation exposure to particulate activity often challenges these basic assumptions, especially, in case of short-ranged radiation types, which may result in high gradients of absorbed doses within an organ or tissue at spatial scale comparable to dimensions of single cells or even molecules (e.g. DNA). Biokinetic behavior of radioactive particles in many situations differs from that of non-particulate activity, thus resulting in particle-specific patterns of uptake, retention and re-distribution of the radioactivity in the body.

Scientific evidence on radiation risk comes from epidemiological studies for rare stochastic effects, e.g. cancer, and from radiobiological experiments for deterministic effects. Self-consistent simultaneous consideration of deterministic and stochastic effects in case of highly non-uniform radiation exposures is missing and should be addressed by future studies.

Particle characterisation techniques

Linking radioactive particles to specific nuclear or radiological sources and assessing their impact requires advanced characterization techniques. As a result of the projects' activities, a series of techniques and methods for the collection, isolation and characterization of radioactive particles in the environment have been identified. Information on distribution of elements/radionuclides within particles was obtained by electron microscopy in combination with micro-beam X-ray emission techniques, by synchrotron radiation-based microscopic techniques and micro-tomography. Information on spatial distribution of structures or oxidation states can also be obtained non-destructively, while destructive techniques such as mass spectrometric methods are needed for source identification (atom or isotope ratios). To estimate ecosystem transfer, pertinent extraction techniques have also been developed.

Protocols were developed and defined to study leaching properties of radioactive particles which affect solubility, remobilization, environmental transfer and biological behaviour for various living organisms.

Outcomes

The work performed within the IAEA CRPs demonstrates that the particle composition will depend on the source (burn-up), while particle characteristics of relevance for ecosystem transfer and biological uptake will also depend on the release scenarios.

Particle weathering rates and the subsequent remobilization and ecosystem transfer of particle-associated radionuclides will depend on the particle characteristics (e.g., composition, structure, oxidation state). Soil and sediment will act as sinks for particles, while contaminated soil or sediments can act as diffuse source of radioactivity if particle weathering occurs over time. Thus, information on particle weathering rates and potential biological uptake and effects is essential for assessing long-term consequences.

The objective information on properties of radioactive particles released to the environment due to past practices or events is needed. In areas affected by particle contamination, particles can bear a substantial amount of radioactivity, the radioactive contamination will be unevenly distributed, the inventories can be underestimated, and the assessment of impact and risk to human health and to the environment can be biased and suffer from unacceptably large uncertainties if radioactive particles are ignored.

Literature

- Radioactive Particles in the Environment: Sources, Particle Characterization and Analytical Techniques (2011) IAEA TECDOC-1663
- Quantification of Radionuclide Transfer in Terrestrial and Freshwater Environments for Radiological Assessments (2009) IAEA TECDOC-1616
- Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments (2010) IAEA Technical Report Series 472