Abstract: Radioecotoxicology refers to responses, usually negative and detrimental responses, in living organisms exposed to radionuclides in ecosystems contaminated with artificially produced radionuclides or enriched with naturally occurring radionuclides. The key focus is put on the link between radionuclide exposures and the subsequent biological effects in flora and fauna. Radioecotoxicology is therefore an essential ingredient in impact and risk assessments associated with radioactive contaminated ecosystems. The radionuclide exposure depends on the source, release scenarios, transport, deposition and ecosystem characteristics as well as processes influencing the radionuclide speciation over time, in particular bioavailability, biological uptake, accumulation and internal distributions. Radionuclides released from a source may be present in different physico-chemical forms (e.g. low molecular mass species, colloids, pseudocolloids, particles) influencing biological uptake, accumulation, doses and biological effects in flora and fauna. Following releases from severe nuclear events, a major fraction of refractory radionuclides such as plutonium will be present as particles, representing point sources if inhaled or ingested. When organisms, and especially sensitive history life-stages, are exposed to radionuclides, free radicals are induced and subsequently, effects in several umbrella biological endpoints (e.g. reproduction and immune system failures, genetic instability and mutation, increased morbidity and mortality) may occur. However, radionuclides released into the environment rarely occur alone, but may co-occur in a mixture of other contaminants (e.g. metals, pesticides, organics, endocrine disruptors), which potentially could lead to synergisms or antagonisms. Thus, the relationships between radionuclide exposure and especially long-term effects are difficult to document and quantify, reflecting that the challenges within radioecotoxicology are multiple.

Keywords: ecotoxicology; multiple stressors; radiation
Introduction

When radionuclides are released from a source, the receiving ecosystems might be affected by radioactive contamination. To identify the degree of contamination, sampling and analysis are needed, and for alpha and beta emitters radiochemistry is needed that is the separation of radionuclides of interest from the bulk of interfering radionuclides prior to analysis. To assess the environmental impact and risks associated with the radionuclide contamination, information based on radioecology is needed; that is knowledge on the behaviour of radionuclides, in particular radionuclide species (Salbu, 2000; Salbu et al., 2004), in affected ecosystems. As ecosystem characteristics are essential for the behaviour of trace amounts of substances (e.g. pH in soil water, redox conditions, interacting components such as humic substances and clays) knowledge and principles from ecology should be implemented in radioecology. Serious consequences from radioactive contamination refer most often to negative or detrimental biological effects in exposed organisms such as man or organisms living in the affected environment. Since some organisms and some history life-stages are more susceptible to radiation exposures than others, knowledge from radiobiology is essential. To evaluate biological early responses, toxicity or detrimental effects from radionuclide exposures, knowledge from human toxicology or ecotoxicology is needed. The radiation characteristics of radionuclides, their environmental mobility, bioaccumulation and doses are important determinants of the exposure and thereby the magnitude of the consequences following radionuclide releases. Thus, the phrase radioecotoxicology refers to the responses, usually negative or detrimental responses, in living organisms exposed to radionuclides, that is, key focus is put on the link between radionuclide exposures and the subsequent biological effects in flora and fauna.

The exposure (i.e. the radionuclide composition, their amounts and the radionuclide speciation) depends on the source, and in many cases several sources may contribute to the contamination (Fig. 1). Furthermore, the release scenarios (temperature, pressure, presence of air) may influence on the speciation of radionuclides deposited in an ecosystem. Following a severe nuclear accident a major fraction of refractory radionuclides such as plutonium is present as radioactive particles (Salbu et al., 1994, 2000; Salbu 2001; Salbu and Lind, 2005). Following an explosion under high temperature and pressure conditions, radioactive particles can be rather inert towards weathering, while during a fire the released oxidised particles are more readily dissolved Salbu et al., 2004. Thus, for radionuclides mobilised from oxidised particles, the soil to vegetation and animal transfer is rapid, while delayed for inert particles. External exposures reflect contaminated (gamma, high energy beta emitters) habitats, while the internal exposure depends on the presence...