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Radionuclides in the environment

Information Sheet

Radioactivity is a natural phenomenon that occurs when unstable atoms (isotopes) seek stability by emitting energy in the form of radiation (radioactive decay). The amount of energy and the form of emitted radiation vary a lot among the radioactive elements. Highly radioactive substances such as cesium-137, are transformed very quickly, with a high number of disintegrations per second and a short half-live. Isotopes such as uranium-235 or uranium-238 only decay with a few disintegrations per second and their corresponding half-lives are in the range of several hundred million years. According to these different properties, radionuclides have many different applications. This stretches from their use as tracers of biological, physiological, and geological processes, in medicine, all the way to their use in weapons of mass destruction.

Sources of radiation in the environment

Small amounts of radioactivity are present in virtually every biotic and abiotic environmental compartment. This background radioactivity comes from long-lived radionuclides originated from the formation of the Earth or its daughter radionuclides, and from cosmic radiation. Our bodies also contain natural radionuclides, for example potassium-40. Moreover, small amounts of radiation are produced by consumer products such as TVs, some smoke detectors, or radioluminescent paints among others. The main source of radiation to the general population is indoor radon gas, which is produced from the natural radioactive decay of uranium found in rocks and soil. According to the World Health Organisation, exposure to radon at home and workplace is one of the main risks of ionizing radiation causing tens of thousands of deaths from lung cancer each year globally. In industrialised countries, the dose from medical exposure may be higher than the dose from radon. The highest concern among the population and the media, however, is the accidental release of anthropogenic radionuclides.

Fate in ecosystems

The characteristics of radioactive particles will depend on the source and the release conditions. During accidents, such as the nuclear disasters of Chernobyl and Fukushima Daiichi, radioactive particles with different composition, size, shape, and structures are released. Fragments and large particles settle close to the site, whereas small-sized particles are transported far away in the atmosphere. Mobile colloids and nanoparticles can also be transported a great distance in water. With time, these particles eventually settle and accumulate on soil and sediments, constituting a potential long-term diffuse source of radiation to the environment.

Exposure to radionuclides

Radionuclides are not chemically different from their stable isotopes. The same characteristics and processes that determine the fate and internal accumulation of any element in the environment apply to both its stable isotope and radioisotopes. Yet, while exposure to chemical contaminants occurs only at the site of contact (i.e. target organs), radionuclide exposure is both internal and external. Internal exposure is analogous to that caused by chemicals and results from accumulation in tissues and transit through the alimentary tract. External exposure occurs through close contact with radionuclides in contaminated soil, sediment or water. The dose will depend on many factors, such as: the nature and amount of radionuclides, the spatial association of the organism and the source, the characteristics of the media, and the location and size of the organisms. Exposure to multiple radionuclides is additive, and total exposure to radiation is the sum of internal and external doses for all radionuclides considered.

What are the effects on organisms and populations?

In general, organisms respond similarly to radiation exposure. The dissipation of radiation energy in tissues produces an increase in temperature, the excitation and ionisation of atoms, the breaking of chemical bonds, and eventually biological effects. These biological effects can be produced directly, although most commonly they are caused indirectly from free radicals, which can easily break chemical bonds and produce a number of different DNA lesions. Free radicals are not unique to radiation, but are also produced in response to many stressors such as exposure to solar UV radiation, or exposure to other contaminants. Damage caused from free radicals is so abundant that very efficient repair mechanisms have evolved within all biological species, from yeast to humans. An overwhelming amount of errors in these repair mechanisms can result in cell death, chromosome aberrations, or mutations.

While there are similarities in the responses to radiation exposure, differences between organisms exist in their radiosensitivity. The range in lethality from acute exposure to radiation varies by three to four orders of magnitude among organisms. Mammals and birds are among the most sensitive whereas viruses and molluscs are among the most radioresistant.

The impacts of mutations within a population will depend on the type of cell in which they occur. A mutation within a somatic cell can lead to cell death or - if the cell remains viable but the DNA has undergone mis-repair - it can lead to cancer. If mutations occur in reproductive germ cells, they can lead to a decrease in the number of gametes, increase in embryo mortality, or be inherited by the offspring. In most cases, mutations are deleterious and are subsequently removed from the population because they offer no advantage to the individual that possesses it. If neutral, they can persist over several generations within a population. Whereas the risk of non-fatal cancer and of hereditary effects in offspring of exposed individuals has been estimated for humans, major data gaps exist to understand the significance of molecular effects and the extent of inherited, transgenerational effects to populations for non-human biota exposed to radiation.

During the nuclear disaster in Fukushima 2011, mainly 131Iodine, 134Cesium and 137Cesium were released. A part of the radioactivity got directly into the atmosphere, another part into the ocean through contaminated cooling waters and atmospheric deposition. Researchers already found the first effects on organisms: genetic defects in local butterflies were more pronounced six months after the accident than two months after the accident. Moreover, the number of birds, butterflies and cicadas was reduced at locations with higher background radiation. From the nuclear accident of Chernobyl in 1986 we have learnt that the number of species and the abundance of birds, bumblebees and other animals is still reduced there at locations with higher background radiation 25 years after the accident. While in Fukushima so far the radiotoxicity has been responsible for the decrease in animals, in Chernobyl it has been the mixture of radioactivity and mutation accumulation, because chronic exposure for many generations has allowed for the accumulation of mutations. In Chernobyl, higher mutation rates and developmental abnormalities in birds, mammals, fish and plants have been found; in addition survival rate and fertility are decreased.

Not many data from Fukushima have been published so far. One of the particularities of the accident at the Fukushima Daiichi plant is the massive release of radiation to the ocean. Little is known about the impact of radioactivity on marine organisms, in part because they are more resistant than humans, which makes it difficult for researchers to conduct lab experiments. Nevertheless, marine organisms can accumulate radioisotopes with no apparent harm, and the transfer of these accumulated radioisotopes along the food chain may increase the risk of harm to larger organisms. It remains to be shown in which way and for how long the animals near Fukushima remain affected.

Useful links

Information sheet on radon in Switzerland from the Federal Office of the Environment (FOEN)
http://www.bafu.admin.ch/dokumentation/medieninformation/00962/index.html?lang=de&msg-id=8366

Wiki site on radiological protection of the environment, including external links to national and international agencies and databases, and virtually all relevant tools for the environmental risk assessment of radiation in the framework of the projects funded under the umbrella of the European Commission
https://wiki.ceh.ac.uk/display/rpemain/Radiological+protection+of+the+environment+-+sharing+knowledge

Site of the International Commission on Radiological Protection
http://www.icrp.org/

Site of the United Nations Scientific Committee on the Effects of Atomic Radiation http://www.unscear.org/
last compendium of effects of ionizing radiation on non-human biota
http://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_E.pdf

Site of the International Atomic Energy Agency
http://www.iaea.org/

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