Naturally-occurring versus Artificially-generated Radioactivity

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When comparing the half life of the naturally occurring radionuclides with that of the artificially generated radionuclides, it quickly becomes evident that there is a difference of many magnitudes. The radioactivity occurring in nature is mainly generated from elements existing since the birth of the earth many billion years ago. To a small extend it also results from the constantly produced radionuclides in the atmosphere due to the cosmic radiation (e.g. Carbon-14).

Potassium-40 is one of the few radionuclides that survived the history of the Earth so far, because its half-life is $1.277*10^9$ years. It is contained to about 0.0117% in naturally occurring potassium with the consequence that 1g of natural potassium shows up with a radioactivity of about 30 Bq. The natural radioactivity of potassium can easily be detected in our food and in the human body (about 100Bq/kg). With the help of dose conversion factors the activity given in the unit Bq can be converted into the biologically effective body dose of the ionizing radiation given in the unit Sievert (Sv). The dose conversion factor of Potassium-40 is $6.2*10^{-9}$Sv/Bq. Therefore, 1g natural potassium, when incorporated, yields an effective body dose of about 0.2µSv (adult > 17 years). The biological half-life and the sensitivity of the different tissues and organs are all taken into account in the conversion factor. Potassium is vitally important (in quantities of milligrams) for the human being and the animals, since it is needed for the conduction of neuronal signals. Therefore the natural organisms adapted to the naturally occurring radioactivity in environment with their immune systems.

Uranium-238 also survived the forming of our planet. It has a half life of $4.468*10^9$ years. When for example a mined uranium ore contains 1% of the U-238 isotope, this is equivalent to an activity of 12477Bq/g resulting from the uranium isotope U-238 alone. The dose conversion factor for U-238 is given as $4.5*10^{-8}$ Sv/Bq, which means when swallowing 1 g of this ore, this leads to an effective body dose of 560µSv. This is significantly more than in the case of natural potassium. The reason is the longer retention of the uranium in the body and the fact that no metabolism for uranium exists in contrast to potassium. The dose of 560µSv for sure is not a quantity that would be immediately dangerous for life. In this case it is rather the chemical toxicity of uranium, since it is a poisonous heavy metal. The lethal dose for dissolved uranium tested with laboratory rats is between 100 and 200mg per kg body mass.

For the purposes of nuclear technology, the natural uranium is extracted from the ore and the U-235 isotope which is contained to only 0.7% in the natural uranium is enriched artificially by post-processing with respect to the natural mixture of the isotopes. The reason is the fact that U-235 is fissionable and U-238 is not. Since its half-life is 700 million years, the U-235 isotope is still a naturally occurring element. Therefore the radiation emitted during disintegration is also spread over an incredibly huge amount of time.

Plutonium-239 however, is generated only artificially during nuclear reactions. In contrast to the naturally occurring radionuclides, it has a half life of only 24110 years. Even though this number sounds large compared to our sense of time, it is by multiples shorter than that of potassium or uranium. Therefore 1g of plutonium shows a much higher activity of $2.297*10^{9}$ Bq/g, or shortly 2.3 Giga-Bq. Its dose conversion factor is $2.5*10^{-7}$ Sv/Bq. This yields a rather theoretical number of 574Sv when 1g is swallowed. This number is theoretical, since a dose of 5 Sv is already lethal for human beings in 50% of the cases. For inhalation of a plutonium aerosol, the dose conversion is even $1.6*10^{-5}$ Sv/Bq, so theoretically this would yield a body dose of 36753 Sv. In other words, the lethal dose is reached for only about 136µg Pu-239.

Caesium-137, well known since the Chernobyl disaster, has an even shorter half-life of 30 years and shows an incredibly high activity of $3.22*10^{12}$ Bq/g. The dose conversion factor is a smaller than that of Pu-239 and is given as $1.3*10^{-8}$ Sv/Bq. According to this factor, a very theoretical body dose rate of $151*10^{6}$ Sv/h can be assigned to the swallowing of 1g Cs-137. This means, the lethal dose is reached from only 119µg. In the exclusion zone around the exploded nuclear power plant in Chernobyl you still can find so-called "hot spots" which result from small crumbs of Cs-137 with extremely high activity and still not yet completely disintegrated, even after 26 years.

As a conclusion, it can be stated that the gigantic difference between „healthy" potassium-containing bananas and the highly dangerous artificially generated radionuclides can simply be identified from the difference in half-life. The half-life of the naturally occurring radionuclides is in the range of billions of years, whereas the half-life of the radionuclides generated with man-made nuclear technology ranges down to seconds and even shorter. Respectively higher (a factor of billions) is the activity of disintegration and with it the ionizing radiation energy that is set free. In turn, the high ionizing radiation energy set free in a very short amount of time is the reason for the incredibly high radio-toxicity that dwarfs any chemical toxicity by far. And by the way, this high radio-toxicity is used commercially for absolute disinfection and sterilization. Mostly Cobalt-60 sources with a half life of 5 years are used for this purpose. So for example, precious paper documents are irradiated with beta and gamma radiation before they are put into archives for a long time, where they could get moldy otherwise. Therefore this high radioactivity kills any biological organism even bacteria and fungal spores.

So on one hand there is hardly any other method that is more efficient in destroying life than with artificially generated short-lived radionuclides. On the other hand, life would not exist on this planet without the minerals containing the naturally radioactive potassium.

For the calculation of the effective body dose and for the dose conversion factors of the individual radionuclides see www.bfs.de, search tag „Dose coefficients " or directly:

http://www.bfs.de/en/bfs/recht/dosis.html