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# Radiological Hazards from Uranium Mining

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## Uranium and its By-products

All natural uranium isotopes ($^{238}$U, $^{234}$U, $^{235}$U) are radioactive.[1] The most common isotope, $^{238}$U, decays naturally into a succession of 13 other radioactive nuclides. All are metals (thorium-230, radium-226, lead-210, polonium-210, etc.) except one, radon-222, which is a radioactive gas.

Uranium and its decay products emit various ionizing radiation such as alpha and beta particles and gamma radiation.

The Earth's crust has a typical $^{238}$U activity of about 40 Becquerels per kilogram (Bq/kg).[2] Since the creation of the Earth, this level of radiation has decreased by two-fold because $^{238}$U half-life is very long and equal to the age of Planet Earth (4.5 billion years).

This presence of natural uranium in the Earth's crust, and therefore in a lot of building material made out of natural minerals, is a main source of exposure of mankind to ionizing radiation.

This is especially due to the diffusion of radon gas from the soil and materials containing uranium and its accumulation in the air inside buildings and dwellings. This radiological hazard is now well documented and International (The International Commission on Radiological Protection, ICRP) and European (Euratom) regulations determine action levels and recommendations in order to lower radon concentration inside buildings and reduce cancer risks.

The health impacts of ionizing radiation even at low doses include the increase of various types of cancers , genomic instability, and life-shortening and negative impacts on all body functions.

## Uranium Extraction Increases Health Risks from Now ….

The activities of uranium ores have an important variability. Typical ore with a uranium content of 0.2 % has a $^{238}$U activity of about 25,000 Bq/kg. The total activity, including all the $^{238}$U by-products and the $^{235}$U decay chain will therefore exceed 360,000 Bq/kg. Such material should be managed with a great deal of caution due to the risks of exposure to ionizing radiation.

As long as the ore remains buried underground - the depth being a few tens and even a few hundreds of meters - the radiation levels at the surface of the Earth remain low and usually have the same order of magnitude as typical natural radiation levels. Except in places where the ore reaches the ground surface (typically a few square metres), the protection offered by the soil is sufficient to reduce the risks for the people living in the area.:

- Alpha and beta particles are stopped by a thin layer of soil (much less than 1 cm.)

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[1] Uranium exists in many different isotopes: $^{238}$U refers to a Uranium atom with 92 protons and 146 neutrons, $^{235}$U refers to a Uranium atom with 92 protons and 143 neutrons. Although isotopes exhibit nearly identical electronic and chemical behavior, their nuclear behavior varies dramatically.

[2] A Becquerel is defined as the activity of a quantity of radioactive material in which one nucleus decays per second.

- Even penetrating gamma radiation does not cross a layer of soil of a few meters.
- Most of the radon gas remains trapped inside the soil. Because of its short half-life (3.8 days) it disintegrates inside the soil during its migration before reaching the biosphere.
- The amount of nuclides in underground water remains low if the minerals containing uranium are trapped in impermeable layers.

But the radiological situation is reversed as soon as the uranium extraction begins:

- Radioactive dust is transferred to the atmosphere by mining operations, the extraction and crushing of ore, uranium milling, management of waste rocks and tailings. This has to be emphasised because some of the nuclides contained in the uranium decay chains (such as thorium-230) are very radiotoxic when inhaled. When inhaled, a given activity of actinium-227 (part of the $^{235}U$ decay chain) gives a radiation dose 5 times higher than the same activity of plutonium-238.
- Radon gas is transferred to the atmosphere by the vents of the mines and by diffusion from radioactive rocks and tailings.
- Surface and / or underground water is contaminated by uranium and its by products. Some of them are very radiotoxic when ingested. Lead-210 and polonium-210 for example are among the most radiotoxic elements. When ingested, a given activity of polonium-210 gives a radiation dose 4.8 times higher than the same activity of plutonium-239.
- Huge amounts of waste rocks, with activities exceeding the normal activity of the Earth's crust by one to two orders of magnitude are dispersed into the environment and may be used for landfill, road construction or even building.
- Huge amounts of radioactive tailings (with typical total activities exceeding 100,000 and even 500,000 Bq/kg) are generated.

## … to an Indefinite Future

Even decades after uranium mines and mills are shut down, the radioactive contamination of the environment will remain.

This is due to the fact that the half life of $^{238}U$ is very long (4.5 billion years). But even the tailings - whose uranium content is lower than the initial uranium concentration in the ore - will remain radioactive in the long-term because of the presence of thorium-230 and radium-226 whose half lives are 75,000 years and 1,600 years respectively.

This long-term impact will occur in many ways.

Some examples are given below, based on studies performed by the CRIIRAD laboratory since 1992 in France and Niger:

- Accumulation of radioactive metals in sediments and plants in **rivers, ponds, and lakes** from contaminated water from former mines, tailing deposits, uncovered waste rock deposits, etc.. In many cases, sediments, aquatic plants and soil from river banks are so contaminated that they deserve to be termed "radioactive waste" ($^{238}U$ activity or the activity of some of its by-products exceeded 10,000 Bq/kg).
- **Radioactive minerals** from the mine are kept by local people or former workers unaware of the radiological hazard. CRIIRAD recently discovered in France that an inhabitant was keeping a sample of waste rock from a former mine with a dose rate of 1 milliSievert per hour. Staying at a distance of 1

meter during only 10 minutes per day will lead to exceeding the annual maximum permissible dose for members of the public i.e. 1 milliSievert per year.

- Re-use of **radioactive waste rocks** for landfill. Recently CRIIRAD demonstrated that several places near a uranium mine in France were contaminated, including the car park of a restaurant, the yard of a farm, several sawmill buildings, and kilometres of paths and roads, etc. In one case a sawmill building had been built directly on radioactive waste rocks taken from the mine. Due to gamma radiation and radon gas accumulation, the radiation dose inside the building could exceed the annual maximum permissible dose for members of the public by a factor greater than 20. In 2003, the mining company therefore had to pay for the removal of 8,000 m3 of radioactive waste rock from the sawmill and transport back to the former open pit.
- Dispersal of contaminated **scrap metal** from the mines or mills. In Niger in 2003, CRIIRAD discovered that radioactive scrap metal was sold in Arlit city. One piece was a pipe from the uranium mill. It was sold without first being decontaminated and the $^{226}Ra$ activity of the crust inside the pipe exceeded 200,000 Bq/kg. The mining company COGEMA (now known as AREVA) stated that before 1999, no radiation limit was used for scrap metal recycling. Later, a dose limit of 1 microGray per hour at a distance of 50 cm had been applied.[3] This limit is much too high. If such metallic pieces are used inside a home – which is common in African countries – exposure of 3 hours per day at a distance of 50 cm will exceed the annual maximum permissible dose for members of the public.
- The situation in France and Niger shows that there are not yet satisfactory solutions to the storage and long-term management of **radioactive tailings**s.

## Conclusion

At all the uranium mines in France where it made radiological surveys, the CRIIRAD laboratory discovered situations of environmental contamination and a lack of proper protection of the inhabitants against health risks due to ionizing radiation.

This is due to the lack of proper regulations, a poor awareness of the radiological hazards associated with uranium and its by products, insufficient monitoring practices, and the lack of monitoring by the local and national administration, etc. When the mines are shut down, the radioactive waste remains, and it seems that the costs for managing this radioactive legacy will have to be largely supported by the society, not the companies.

If such a situation occurs in a so-called “developed country” one should fear what could actually happen in other parts of the world.
The preliminary mission made by CRIIRAD to Niger confirmed this fear.

In Gabon, the improvement of the conditions in which tailings are disposed is being paid for by the European Community and not by the mining company. The former workers and local population do not benefit any more from medical care and they receive no compensation when they become sick, years and decades after the mine shut down.

[3] One *gray* is the absorption of one joule of radiation energy by one kilogram of matter.