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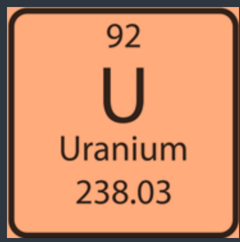
Poison of the month



Uranium – Toxic Heavy Metal, Radioisotope and Geopolitical Flashpoint

With growing military conflicts, continued reports on Iran’s nuclear program, and the use of bunker-busting bombs in current wars, uranium has returned to the forefront of public and scientific debate.

Uranium is a naturally occurring heavy metal that is abundantly present in the Earth’s crust. To meet the energy needs of modern societies, it is laboriously mined, enriched, and used as nuclear fuel in nuclear power plants. In addition to civilian use, uranium also has military applications, for example in armor-piercing ammunition (“depleted uranium,” DU) and, as highly enriched uranium, in nuclear weapons. Humans are exposed to uranium not only through food, drinking water, and dust, but also in workplaces such as uranium mines and nuclear power plants, where both uranium dust and increased radiation are of concern. In addition, the use of DU ammunition in war zones can result in inhalation of fine uranium particles.

Uranium combines chemical heavy metal toxicity with radiotoxic aspects. Acutely, oral or inhalational intake of high amounts can lead to nausea, vomiting, acute kidney damage, respiratory tract irritation, and circulatory failure. Chronically, kidney damage, reproductive impairments, embryotoxic effects, behavioral changes, and developmental disorders already occur at significantly lower concentrations. *In vitro* studies indicate genotoxic effects, but no increased cancer risk has been demonstrated in humans so far.

Numerous studies show that the chemical toxicity of depleted uranium corresponds to that of natural uranium. The form of uranium plays a major role. Well-soluble uranium compounds such as uranyl salts are rapidly

Uranium oxides

In the environment, uranium is mostly present as poorly soluble oxide. Uranium dioxide (UO_2) is used as fuel in reactors. Other compounds such as uranium trioxide (UO_3) or triuranium octoxide (U_3O_8) are chemically more reactive and more soluble, making them more biologically available. Before the health risks became known, uranium oxides were also used as pigments for glazes due to their luminosity.

Isotopes of uranium

Isotopes are atoms of the same element with identical proton numbers but different neutron numbers. Uranium has 25 known isotopes, dominated in nature by ^{238}U (99.27%), ^{235}U (0.72 %), and traces of ^{234}U. ^{235}U is the only naturally occurring, easily fissionable isotope. Through enrichment, the proportion of ^{235}U can be specifically increased for civilian or military purposes. The half-lives of the isotopes range from billions of years (^{238}U: 4.5 billion years) to microseconds.

Uranium as nuclear fuel

In nuclear power plants, uranium is used as fuel for electricity generation. Mainly the isotope ^{235}U is used, which occurs in natural uranium at only 0.72 %. Through enrichment, the proportion is increased to about 3–5 % (“Low Enriched Uranium,” LEU), making it fissionable in light water reactors. The enriched uranium is processed into uranium dioxide (UO_2), filled in the form of small pellets into fuel rods, and used in reactor cores. The radiation of the fresh fuel is relatively low (mainly α-radiation) and primarily a chemical risk. Only after irradiation in the reactor (“burn-up”) are highly radioactive fission products produced, which require special protective measures.

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Uranium in nuclear weapons

In the history of nuclear weapons development, uranium played a central role. The first atomic bomb used in war, dropped on Hiroshima on August 6, 1945, used about 80% enriched uranium (^{235}U) as fissile material, as only this isotope is sufficiently fissionable in a fast, unmoderated neutron flux. The bomb over Nagasaki three days later was already based on plutonium-239, which is produced in nuclear reactors from uranium-238. For military purposes, uranium must therefore be enriched much more extensively than for fuel use. Above a proportion of 20 % ^{235}U, it is considered "Highly Enriched Uranium" (HEU). With a proportion of about 85 % ^{235}U, it is considered weapons-grade. The immediate effect of a uranium bomb is mainly due to shockwave, heat, and intense γ- and neutron radiation. The long-lived radioactive residues of a uranium bomb are, however, less pronounced than with a plutonium weapon. The survivors suffered immediate thermal and mechanical injuries. In the long term, an increased rate of leukemia and solid tumors was observed, caused by acute radiation exposure.

Uranium ammunition

Armor-piercing ammunition with DU exploits the high density of uranium (19.1 g/cm³) to achieve maximum penetration power. The α-radiation of DU is militarily irrelevant, but fine uranium particles can be generated on impact, which can then be inhaled. DU ammunition was first used extensively in the 1991 Gulf War. Its health consequences are disputed. Bunker-busting bombs, on the other hand, rarely use uranium, but usually have tungsten cores.

absorbed and accumulate in the kidneys and skeleton, whereas poorly soluble uranium oxides are much less bioavailable. Inhaled uranium particles can also deposit in the lungs.
Most of the ingested uranium is excreted in urine within a few days. Nevertheless, chronic exposure is critical. Kidney damage is considered the key symptom of uranium toxicity, which is why it has been used for risk assessment and to derive a tolerable daily intake (TDI) of 0.6 µg uranium/kg body weight per day. Exposures from natural sources such as drinking water in Europe are generally well below this threshold and do not pose a relevant health risk.

Long-term observations of Gulf War veterans who carry DU fragments in their bodies show no serious health consequences to date, despite demonstrably elevated uranium levels in the blood. Nevertheless, the European Parliament already called for a moratorium on the use of DU ammunition in 2008, a demand that has not yet been actively supported by the German government (EP 2008).

Given geopolitical developments and the continued use of uranium, it is crucial to minimize exposure for both the public and workers by adhering to workplace limits, regularly monitoring uranium in drinking water, and, above all, carefully decontaminating war zones.

By Ute Haßmann

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