Uranium (U)

In a nutshell

Uranium (U) is a relatively abundant dense hard weakly radioactive metal which occurs naturally as relatively insoluble U(IV), mainly in rock, and as oxidised water-soluble U(VI), which is more mobile in the environment and more toxic in the body.

The primary toxicity of uranium is kidney damage; it may also increase blood pressure and bone turnover. Major dietary sources of exposure are drinking water, shellfish, and less in fresh vegetables, cereals and fish. Dietary exposure is normally well below maximum safe levels, except in areas with high background levels in drinking water, especially for infants consuming large amounts of formula diet made with such water.

Relatively high concentrations of uranium may be present in some mined phosphate mineral fertilizers. This is not expected to significantly increase food or water uranium levels, but it is still prudent to keep uranium levels in mineral fertilizers as low as possible.

What is uranium?

Uranium is a silvery-white actinide metal, very dense (70% heavier than lead) and very hard (approximately equal to titanium) but malleable and ductile. It occurs naturally in low concentrations in soil, rock and water, and is commercially extracted from uranium-bearing minerals such as uraninite. It has several radionuclide forms, almost entirely weakly radioactive U-238, and several chemical forms, mainly U(IV) and U(VI).

U(IV) is relatively insoluble; it is found in rocks as hydroxides, phosphates and fluorides. It is readily oxidised to soluble U(VI) in surface and shallow groundwater, which in turn can form insoluble complexes with carbonate, phosphate and sulphate anions which may precipitate in groundwater. Because U(VI) is the most water-soluble form, it is more mobile in the environment and more toxic in the body.

In the early 20th century, uranium salts were widely used as yellow-green colorants in stains and dyes, especially in glazes for pottery and tiles (because of the availability of cheap and plentiful pitchblende waste remaining after industrial radium extraction).

Uranium ore is enriched for use as nuclear fuel (containing ca. 3% U-235) and highly enriched for nuclear weapons (20-90% U-235). Depleted uranium, the by-product of the enrichment process, is used for armour plating and armour piercing ammunition.

Contamination from different sources

Uranium is among the 20 most abundant elements on earth and is present in a variety of minerals. Its relative abundance is similar to that of silver or gold, and higher than tin, mercury and lead. The concentration of U in soil ranges from 0.05 to 10 mg/kg, but may reach up to 200 mg/kg in certain areas ("geogenic hotspots"). Due to its widespread presence, natural U occurs also in human food and drinking water. Extremely high values have been measured in groundwater in Finland and in other Nordic countries, linked to high concentrations in geologic formations.

Human exposure and health effects

Food and drinking water are the major human exposure pathways for uranium in the general, non-occupationally exposed population. According to WHO, average intake of uranium in food is about 1-4 µg/day. Highest concentrations of uranium are found in shellfish, with lower levels in fresh vegetables, cereals and fish. Estimated median uranium intake from drinking water is about 1 ug/day, but may be much lower or higher; drinking water concentrations between <1 ng and >20 ug/L are reported.

U is poorly absorbed following oral exposure, and the small amount absorbed is rapidly excreted in the urine. The average human contains about 40-90 µg uranium, more than half in bone. Its half-life is about 6-12 months for the whole body, about 2 weeks in the kidney.

The toxicity of natural uranium is primarily due to chemical toxicity rather than radiotoxicity. Some regulators assume uranium to be potentially carcinogenic at occupational exposure levels due to its weak radioactivity, but the International Agency for Research on Cancer (IARC) has no classification for uranium. The primary toxicity of uranium is kidney damage; it may also increase blood pressure and bone turnover.

The WHO and EU EFSA Tolerable Daily Intake (TDI), i.e. safe lifetime dose, is 0.6 µg U/kg body weight/day. Uranium exposure in European consumers via food and water is well below this level (each about 0.1-0.2 µg/kg/day), but in regions in Europe with high levels of geogenic uranium in drinking water, exposure may be up to about 0.5 µg/kg/day; infants consuming large amounts of formula diet made with such water may be at risk. The WHO provisional guideline value for drinking water is 30 µg U/L. Some countries use a lower value (e.g. 10 µg U/L in Germany).

Codex Alimentarius has no maximum level standard for uranium as a chemical contaminant in food. In the USA, the maximum contaminant level for uranium in drinking water is 20 µg/L (the lowest feasible level). The World Health Organization (WHO) has established a tolerable daily intake (TDI) for soluble uranium of 0.6 µg/kg bodyweight per day, which is endorsed by the European Food Safety Authority (EFSA). EFSA noted that in infants fed with

infant formula reconstituted with water containing uranium, the exposure may be up to 3 times higher than the uranium exposure of adults on the body weight basis, and so concluded that such exposure in infants should be avoided.

Variable concentrations of uranium are present in phosphate rock and thus as a contaminant in mined phosphate mineral fertilizers. Under oxidizing environmental conditions, uranium has a relatively medium to high mobility in soils, depending on the acidity or alkalinity, and it is therefore expected that it will leach out from the soil. Both geogenic sources and mineral phosphate-based fertilizers can contribute to uranium in water. The relative contribution of mineral fertilizers to uranium levels in water is likely to be undetectable except in regions with low geogenic background levels of uranium, e.g. North Germany. Nonetheless, it seems prudent to keep uranium levels in mineral fertilizers as low as possible to minimize water contamination.

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