

Health and Environmental Hazards of Uranium

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1. Basics about Uranium

Uranium (U) is a natural, radioactive and toxic heavy metal, which is found in traces in all rock, soils and water (Merkel et al. 2008 – see references section at the end of this paper). Unavoidably taken up with solid and liquid food, uranium is a possible health risk and may affect all species due to the impact of radiation from uranium isotopes and uranium-decay elements as well as the toxicity of the heavy metal (Human Biomonitoring Commission of the German Federal Environment Agency 2005, Schnug et al. 2008).

Uranium was first discovered in 1789 by Martin Heinrich Klaproth, who was a leading German chemist of this time. Almost 100 years later Antoine Henri Becquerel found out about the radioactivity of uranium salts. Since 1985 radioactive contamination in food has been measured in Becquerels (Fleckenstein 2004). Marie Curie in Paris produced for the first time 0.1 gramme radium from 1000 kg uranium ore; she died of leukemia on 4th of July, 1934.

Uranium resources have been subject to intensive mining since the German physicists Otto Hahn, Fritz Straßmann and Lise Meitner showed that uranium could be split into parts to yield energy. Uranium is the fuel for nuclear reactors and the main raw material for nuclear weapons. Uranium appears in more than 200 minerals, but mainly occurs in 'trace' (i.e. very small) quantities.

2. Uranium Decay chain

Natural uranium consists of three isotopes: **uranium-238, uranium-235, and uranium-234**. Isotopes are atoms of the same element that have the same number of protons (and hence the same chemical properties), but a different number of neutrons, and therefore, different atomic weights. Uranium isotopes are radioactive.

The nuclei ²of radioactive elements are unstable, meaning they are transformed into other elements, typically by emitting particles (and sometimes by absorbing particles). This process, known as radioactive decay, generally results in the

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² nucleus: The nucleus of an atom is the central core that comprises almost all the weight of the atom. All atomic nuclei (except Hydrogen-1, which has a single proton) contain both protons and neutrons.

emission of alpha or beta particles from the nucleus. It is often also accompanied by emission of gamma radiation which is electromagnetic radiation, like X-rays. These three kinds of radiation have very different properties in some respects but are all ionizing radiation - each is energetic enough to break chemical bonds, thereby possessing the ability to damage or destroy living cells (Makhijani 2006).

Summary of Uranium Isotopes				
Isotope	Percent in natural uranium	No. of Protons	No. of Neutrons	Half-Life (in years)
Uranium-238	99.284	92	146	4.46 billion
Uranium-235	0.711	92	143	704 million
Uranium-234	0.0055	92	142	245,000

Uranium-238, the most prevalent isotope in uranium ore, has a half-life of about 4.5 billion years – half the atoms in any sample will decay in that amount of time. Uranium-238 decays by alpha emission into Thorium-234, which – in its turn – decays by beta emission to Proactinium-234, which decays by beta emission to Uranium-234, and so on. The various decay products, (sometimes referred to as "progeny" or "daughters") form a series starting at uranium-238. After several more alpha and beta decays, the series ends with the stable isotope lead-206.

3. Longevity of Uranium Decay Product

Uranium and associated decay products such as Thorium-230 and Radium-226 will remain hazardous for thousands of years. Governmental regulations these days, where they exist, cover a period of 1,000 years for mill tailings and at most 500 years for "low level " radioactive waste. This means that future generations – far beyond those promised protection by these regulations – will likely face significant risks from uranium mining, milling, and processing activities (Makhijani 2006).

The property of uranium important for nuclear weapons and nuclear power is its ability to split into two lighter fragments when bombarded with neutrons, releasing energy in the process (artificial nuclear fission).

Of the naturally-occurring uranium isotopes, only uranium-235 can sustain a chain reaction – a reaction in which each fission produces enough neutrons to trigger another fission, thus the fission process is maintained without any external source of neutrons.

In contrast, uranium-238 cannot sustain a chain reaction; however, it can be converted to Plutonium-239, which can sustain a fission process. Plutonium-239, virtually non-existent in nature, was used in the first atomic bomb tested July 16th 1945 and the one dropped on Nagasaki on August 9th 1945. Since that time man-made radioactivity has been increasing rapidly on Earth.

4. Uranium in Namibia

In **Namibia**, uranium is found in low-grade ore bodies located in the Namib Desert. Uranium was discovered in Namibia in 1928, and mining started in 1976 by **Rössing Uranium Limited, which is today owned to a large part by Rio Tinto.**

The ore is mined through drilling and blasting in open pit mines which means that a large territory is already and will be affected by mining and processing the uranium. Large quantities of water and chemicals are used and leave lots of dangerous tailings and rock piles. Due to the desert climate and strong winds, the uranium dust contaminates large areas of land and people in the vicinity of the mines. Plants, animals, soil and drinking water can be poisoned.

The production of uranium oxide (yellow cake) begins with mining the ore in the open pits, then it runs through crushing, grinding and leaching processes. At that stage the uranium content of the pulped ore is oxidised by ferric sulphate and dissolved in a sulphuric acid solution (Rössing 2008). Through slime separation, thickening and continuous ion exchange (CIX), a more concentrated uranium solution is attained. Chemical processing in the solvent extraction plant (SX), then precipitation, filtration, drying and roasting finally produces uranium oxide, so-called “yellow cake”. The product is then packed into metal drums and transported overseas to converting facilities and further on to enrichment plants for further processing.

In 2007, Rössing workers mined 34 millions tonnes of rock. At full capacity Rössing can produce 4,500 tonnes of uranium oxide per year while having 1,400 workers and 400 contractors employed (Rössing 2008).

5. Uranium and Health risks – the past

Uranium was mined in **Germany** from 1848 till 1990 by the Soviet-German company Wismut; it left behind:

- more than 1,400 square kilometres of open uranium mines and pits,
- 311 million cubic metres of tailings and
- 160 million cubic metres of radioactive and toxic sludges.

More than half a million people had worked for Wismut. Many workers died of uranium related sicknesses. 5,237 uranium miners received compensation because they suffered from lung cancer. There are many other negative health effects from exposure to uranium, the decay and by-products of uranium. The radioactivity which is taken into the body by inhalation and ingestion of nuclides sustains great damages to the organism. Silicosis, Tuberculosis and lung cancer were well known within the German Wismut (uranium mining) workers population (Schmitz-Feuerhake 2007).

After unification of former East Germany (GDR) and West Germany (FRG) in 1990, the German government invested €6.2 billion to minimize environmental damages.

6. Mining and processing of uranium increases health risks dramatically.

For 100 years it has been well known that uranium mining causes lung cancer. The “Schneeberger Krankheit” (Schneeberger disease) goes back to the 16th century, when it was first mentioned in literature.

Research has defined a causal relationship between uranium mining and milling and incidence of kidney and respiratory diseases 25 years after exposure. There are also clearly proven uranium effects in humans other than diseases of the respiratory tract caused by radon, uranium and uranium decay products (Schmitz-Feuerhake and Bertell 2008): all solid cancers, benign and unspecified tumours, blood diseases, leukaemia, lymphoma, multiple myeloma, gastric cancer, liver cancer, cancer of the gallbladder and extrahepatic bile ducts, kidney cancer, mental disorders and birth defects. All of them have been found in health studies on uranium miners over the years.

Uranium health effects

(I. Schmitz-Feuerhake and R. Bertell 2008)

Table 2. Uranium effects in humans other than diseases of the respiratory tract.

Diseases	Collective	Reference
All solid cancers	Uranium workers	Ritz 1999
Benign & unspecified tumors	Uranium miners	Roscoe 1997
Blood diseases	Uranium miners	Roscoe 1997
Leukemia	Uranium miners Underground miners	Mohner <i>et al.</i> 2006; Rericha <i>et al.</i> 2006 ; Darby <i>et al.</i> 1995
Lymphoma	Uranium workers	McGeoghegan <i>et al.</i> 2000
Multiple Myeloma	Uranium miners	Tomásek <i>et al.</i> 1993
Gastric cancer	Underground miners Population in U contaminated region	Darby <i>et al.</i> 1995; BEIR IV 1988; Wilkinson 1985
Liver cancer	Uranium miners Underground miners	Tomásek <i>et al.</i> 1993 Darby <i>et al.</i> 1995
Cancer of the gallbladder & extrahepatic bile ducts	Uranium miners	Tomásek <i>et al.</i> 1993
Kidney cancer	Uranium workers	Dupree-Ellis <i>et al.</i> 2006
Mental disorders	Uranium miners	Tomásek <i>et al.</i> 1994
Birth defects	Uranium miners Population in U contaminated region	Müller <i>et al.</i> 1992 Shields <i>et al.</i> 1992

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Uranium is also long-known as a nephrotoxin (poison to the kidneys). The most remarkable damage caused by uranium is cancer. More recently, uranium has been proven to mimic the effect of oestrogen at drinking water levels, which are considered as being “safe” by authorities (Schnug *et al.* 2008). In addition, studies showed that the brain as well is a target for uranium toxicity (Envirhom 2005). The early stages of life are known to be most sensitive to radiation.

An advanced biochemical and biophysical aspect of uranium contamination is described as “photoelectron enhancement effect” (Busby & Schnug 2008); this means: uranium particles (or uranium atoms bound to DNA) amplify effects from external irradiation. Common dose-effect assumptions are therefore not sufficiently reliable to deny possible detrimental health impacts from radioactivity taken into the body. This is especially true for uranium miners and affected populations.

7. Underestimation of health effects, Critique of ICRP and IAEA dose limits

There is a need for a broader understanding of health effects within the nuclear community. In 2007 the German Society for Radiation Protection (Gesellschaft für Strahlenschutz e.V., GSS) and the European Committee on Radiation Risk (ECRR) published statistics about the **underestimation of health effects** due to low level radiation to the population. The official risk estimations must be multiplied by a factor of 100 to 2,000 (see table below).

This means that **radiation is 100 to 2,000 times more dangerous than previously thought** (Schmitz-Feuerhake 2008). That is a fundamental criticism of the guidelines given by the International Commission on Radiological Protection (ICRP). The ICRP together with the International Atomic Energy Agency (IAEA) advises governments in implementing legislation addressing radiation protection for employees, the public and the environment.

Underestimation of health effects (I. Schmitz-Feuerhake 2007)

Tabelle 1:
Gesundheitsschäden durch chronische Niederdosisexposition einer Bevölkerung

	Genetische Erkrankungen	Krebssterblichkeit	Effekte nach Exposition im Mutterleib	Erkrankungen außer Krebs und Tumoren
ICRP Risikoangaben	1,3 % pro Sv	5 % pro Sv	kein Effekt unter 0,1 Sv	kein Effekt
Bewertung durch ECRR	Unterschätzung um Faktor 100 - 2000	Unterschätzung um Faktor 100 - 2000	Krebs Fehlbildungen Geistige Behinderung Geisteskrankheiten Downsyndrom Kinderkrankheiten Totgeburten Säuglingssterblichkeit Spontane Aborte Geringes Geburtsgewicht	vielfach

8. Need for independent research

There is an **urgent need for independent expertise**. At this point in time, health data concerning uranium miners are handled as private property of companies or officially locked in government drawers, or both. The public must have unrestricted access to environmental and health information to insure their right to uncontaminated drinking water and safe food. Finally, when it comes down to legal cases, the mining industries and nuclear companies should have to prove that uranium is not harmful to workers and the public.

It is well known that official calculation of radiation dose limits and risk models is not in line with scientific knowledge (Lange 2008). The dose-effect assumptions used to evaluate “incorporated radioactivity” (radioactivity taken into the body) done by the International Atomic Energy Agency (IAEA) are wrong. At least, the experience in populations affected by the Chernobyl accident has shown this. Not only are there higher effects than predicted by the estimated dose but also a broad spectrum of health defects has appeared which had not shown up in the survivors of the Atomic bomb (ECRR 2006).

It is also necessary to get access to health data from companies and governments to help people to fight for their rights, including gaining **compensation** according to the demands of the UN-Declaration of Human Rights, adopted in 1948.

In the United States, compensation was finally paid in 2002 to workers and families who had either developed lung cancer or already died of lung cancer. No other obviously uranium related sicknesses were recognized.

In Germany compensation law acknowledged 5,237 lung cancer cases. The federal government now wants to limit the approval of the occurrence from health effects caused by Wismut uranium to 10 (!) years after exposure.

9. No safe dose for radiation

Dr. Alice Stewart, who passed away in June 2002, was a medical doctor and Professor for Social Medicine, winner of the Alternative Nobel Prize and expert on low level radiation.

In September 1992, she attended the World Uranium Hearing in Austria, where she pointed out that “probably every childhood cancer, except the man-made ones from x-rays, could be due to background radiation.” Dr. Gordon Edwards, a Mathematician from Quebec in Canada, added: “Now we know that not only cancer is caused by radiation, even down to the lowest levels – also genetic mutations and mental retardation are caused by low level-radiation” (WUH 1992). By “mutation” we mean a disturbance of the behaviour of a cell brought about by damage to the DNA (Stewart 1992). It is important to acknowledge that neither natural background radiation nor man-made artificial radioactivity do any good to health and the environment.

Chromosome aberrations in bloodcells are known as good indicators for radiation exposure and damage of the organism (Schmitz-Feuerhake & Pflugbeil, 2008).

10. Natural and man-made Uranium Contaminations

The concentration of **natural uranium in the ore** is calculated from 0.005 up to 7 milligrammes per kilogramme (mg/kg) in the Earth's crust. Some rock and soil may contain greater amounts of uranium, like those found in Saskatchewan in Canada or Kerala in India. Quartz minerals may have a uranium content of 5 to 8 mg/kg (Bernhard 2004).

The uranium deposit at Rössing lies in granite, which contains quartz and is also surrounded by quartzite (Dropkin 1992).

According to the Geochemical Atlas of Germany, **uranium concentrations in surface water** are in the range of 0.007 microgrammes per litre ($\mu\text{g/l}$) up to 43.7 microgrammes per litre ($\mu\text{g/l}$). This high figure is due to German uranium mining in the Gera-Ronneburg region of Wismut in Thuringia. The median concentration in Germany was found at a level of 0.33 microgrammes uranium per litre and lies within European ratings of 0.32 microgramme uranium per litre (Birke et al. 2004). A survey of the German Federal Institute for Geoscience and Natural Resources (BGR) was conducted over the past decade and found high concentrations in stream sediments caused by uranium mining and processing. Also arsenic in stream sediments is a big problem. Sources of anthropogenic contamination are smelters, mine waste dumps, and the use of mine waste as fill (BGR 2004).

Uranium contamination in water and soil, which is induced by human activity, can be observed in mining and processing of uranium and mining of other resources such as gold, silver, coal, oil and gas, copper, tin and rock phosphates.

Uranium contamination goes along with all stages in the civil – military nuclear chain and shows up with highly toxic and radioactive waste coming out of each step of processing uranium (Lindemann 2007).

Scientists from the Institute for Crop and Soil Science at the Federal Research Centre JKI in Braunschweig (Brunswick) looked at agricultural use of fertilizers containing uranium which they found already spoiled the water table and contaminated soils in Germany (De Kok et al. 2008). Fertilizer production from rock phosphates causes damage to the environment and people (Falck 2006).

Thus, anthropogenic activities increase uranium contents and the spread of uranium in the environment. Through inhalation, ingestion and digestion of air, solid food and drinking water uranium and its by-products such as radon, thorium, radium, polonium, bismuth and lead accumulate in the body. This enhances the damage uranium causes in organs, bone, tissue, blood and DNA (Schmitz-Feuerhake & Bertell 2008, Schnug & Haneklaus 2008, Thomas 2008, ENVIROM 2005).

Uranium in drinking water is an issue of increasing importance, since relatively high uranium levels were discovered in bottled mineral water. German tap water has been tested for uranium but in most cases the uranium content was below 2 microgrammes uranium per litre (Knolle 2008). Uranium in drinking water may increase the daily intake and result in accumulation of uranium in bone, liver and kidney (Thomas 2008). Uranium intake is a serious health concern (Schnug et al. 2008).

11. Uranium endangers the environment and all species

Once uranium is inside the organism, it is transferred to the extracellular fluids and transported through the blood to other organs. Uranyl, the soluble form, builds complexes with protein and anions in the body.

The risks related to uranium can be both chemical and radiological. The first is related to the binding of uranium to biological molecules. Uranium follows calcium in its distribution within the body and therefore builds up in bone, and it targets lung and kidney. Other research found that uranium shows up in the brain and in the placenta (Royal Society 2001, ENVIRHOM 2006).

Uranium shows toxic effects in all forms of life. The most common and unspecific one is the DNA-damage followed by mutation. Radiation effects of uranium are widely observed and still underestimated (Schmitz-Feuerhake 2008). Obviously there is **no safe dose** for radioactivity (Hoffmann 2008) nor a so-called “no-observed adverse-effect level (NOAEL) for impacts of uranium toxicity. According to EU guideline (67/548/ EWG), uranium and uranium compounds have to be labelled as very toxic for inhalation and ingestion.

Uranium can accumulate in the body and may have synergistic effects with other chemical and radioactive substances. In addition, uranium is considered as hazardous to the environment and especially toxic and dangerous to water organisms. The energy of the uranium decay elements, their radioactivity and their toxicity weakens the immune system and causes all sorts of health disorders including dermatitis and allergic reactions. In particular, uranium has a high affinity to DNA, which results in anomalously high absorption of natural background radiation and accelerates genotoxic effects (Busby et al. 2008). Uranium is proven genotoxic as recently published by the French Nuclear Safety authority IRSN (Henner 2008). And it was found that mammals have a particularly high sensitivity to uranium. There is ongoing uranium research which shows increasing destructive impacts of uranium on people and environment.

Despite this knowledge, access to uranium and fissile material assures governments of being members of the international “power game“. “It was all for nuclear weapons”, said Gordon Edwards 1992 at the WORLD URANIUM HEARING. “That’s the main reason for the aggressive dispute of health impacts by the mining industry in spite of huge knowledge about health risks“. Nuclear Energy cannot be a safe and reliable energy source for the future. We need to find a better solution.

According to the International Atomic Energy Agency in Vienna uranium has been mined in at least 25 countries in the past and is likely to expand to over 30 (IAEA 2008).

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