Our world is radioactive and has been since it was created. Radioactive elements are often called radioactive isotopes or radionuclides. Radionuclides are found in the environment as naturally occurring elements and as products or by-products of nuclear technologies.

One of the most common radionuclides is Uranium (U). U with atomic number of 92 is the heaviest known natural element. All U isotopes are radioactive. So it is very important their quantity to be under control. Natural U is used in the generation of nuclear fuel. U – 235 is one of two fissile materials used for the production of nuclear weapons and in some nuclear reactors as a source of energy. Because of its importance in the fission process U is found in large quantities in stored nuclear waste.

Other important source of U to the environment is nuclear weapon tests, especially during the second half of 20th century. Artificial radionuclides may also be released into the environment from non – nuclear cycle activities in industry and research and from usage in diagnostic and therapeutic medicine.

Erosion of agricultural soils may input the 238U decay radionuclides in to drinking water supplies in areas with heavy fertilizer usage.

The most common routes of U contamination are through handling, ingesting and inhaling. Inhaling and ingesting increase the risk of lung and bone cancer. U is also chemically toxic at high concentrations.

U may also affect reproductive organs and the fetus, and may increase the risk of leukemia and soft tissue cancer.

Key words: Uranium, Contamination, Depleted uranium, Nuclear waste, Nuclear energy, Nuclear weapons.

URANIUM CONTAMINATION

Uranium, with an atomic number of 92, is the heaviest known natural element. It has a specific density of 18.7 g/cm³. It is a slightly radioactive, naturally. Uranium is 40 times more common than silver. Uranium occurs naturally
in the +2, +3, +4, +5 and +6 valence states, but it is most commonly found in the hexavalent form. In nature, hexavalent uranium is commonly associated with oxygen as the uranyl ion, UO$_2^{2+}$. Naturally occurring uranium (n$^{\text{at}}$U) is a mixture of three radionuclides ($^{234}$U, $^{235}$U, and $^{238}$U), all which decay by both alpha and gamma emissions. Natural uranium consists almost entirely of the $^{238}$U isotope (99.282%), with the $^{235}$U and $^{234}$U isotopes respectively comprising about 0.712% and 0.006% of the natural uranium. Uranium is widespread in nature. It occurs in numerous minerals such as pitchblende (olive-green colored mineral), uraninite (UO$_2$), carnotite ([K$_2$(UO$_2$)$_3$V$_2$O$_8$·1.3H$_2$O]), autunite ([Ca(UO$_2$)$_3$(PO$_4$)$_2$·10H$_2$O]), uranophane and tobernite. It is also found in phosphate rock [Ca$_3$(PO$_4$)$_2$], lignite ([Ca, La, Th, Nd, Y]PO$_4$), monazite sands, and can be recovered commercially, from these sources.

Uranium is a heavy silvery-white metal which is pyrophoric when finally divided. It is a little softer than steel, and is attacked by cold water in a finally divided state. It is malleable, ductile, and slightly paramagnetic.

Uranium has sixteen isotopes, all of which are radioactive. Some of them are: $^{230}$U, $^{231}$U, $^{232}$U, $^{233}$U, $^{234}$U, $^{235}$U, $^{236}$U, $^{237}$U, $^{238}$U). Naturally occurring uranium nominally contains 99.28305% by weight $^{238}$U, 0.7110% $^{235}$U, and 0.0054% $^{234}$U. Studies show that the percentage weight of $^{235}$U in natural uranium varies by as much as 0.1% depending on the source.

Everyone is exposed to radiation on a daily basis, primarily from naturally cosmic rays, radioactive elements in the soil, and radioactive elements incorporated in the body.

Ingesting and inhaling some uranium, usually from food, is inescapable however, in the normal Earth environment, and we humans basically take in, on
average 5 Bq per year of uranium 238 in equilibrium with its decay products. This gives an effective radiation dose equivalent to the whole body of 0.005 mSv. Using measure, we normally ingest about 0.000436g a year. This is a mixture of soluble and insoluble compounds, absorbed mostly through the gut.

Natural uranium in soil is about 1 to 3 parts per million, whereas in uranium ore it is about 1000 times more concentrated, reaching about 0.05 to 0.2% of the total weight.

Table 1

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Activity used in calculations</th>
<th>Mass of Nuclide</th>
<th>Activity found in the volume of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium</td>
<td>0.7pCi/g (25Bq/kg)</td>
<td>200kg</td>
<td>0.8 curies (31 GBq)</td>
</tr>
</tbody>
</table>

Uranium is also found into the oceans, at an average concentration of 1.3 parts per billion. Other incidental radionuclide sources include non-nuclear technologies and industrial activities that enhance environmental levels of natural radionuclides, such as fossil fuel combustion and the production and use of phosphate rock products. The combustion of fossil fuels (e.g., coal) for electric power generation releases 238U decay series radionuclides in fly ash.

The mining of phosphate rock, which contains relatively high concentrations of uranium, may release radionuclides in mining and processing effluent, as may the use of phosphate rock products (e.g., fertilizer). Erosion of agricultural soils, for example, may input the 238U decay radionuclides into drinking water supplies in areas with heavy fertilizer usage.

Levels of natural radionuclides in drinking-water may be increased by a number of human activities.

Uranium mining and fuel preparation operations released 238U, 234U, and its decay products, elevating terrestrial radionuclide levels above background.

The global average human exposure from natural sources is 2.4mSv/year. There are large local variations in this exposure depending on a number of factors, such as height above sea level, the amount and type of radionuclides in the soil, and the amount taken into the body in air, food, and water.

About 80% of back-ground radiation originates from naturally occurring sources with the remaining 20% resulting from man-made sources. There are a number of locations in different parts of the world where it occurs in economically-recoverable concentrations. When mined, it yields a mixed uranium oxide product (U3O8).

Anthropological sources of uranium pollution can be shared into three main groups:

- Uranium from weapons.
- Uranium from nuclear energy activities.
- Uranium from scientific and other uses.
Uranium from different kind of weapons is presented like depleted uranium (DU). A typical example for DU effect is a 1991 Gulf War.

The specific activity of DU is 21,100 Bq/g. Depleted uranium is the waste product of the process to enrich uranium ore for use in nuclear weapons and reactors.

Depleted uranium is chemically toxic like other heavy metals such as lead, but it is also primarily an alpha particle emitter, with a radioactive half-life of 4.5 billion years.

DU has about half the radioactivity of the natural mixture of uranium isotopes. However, because of the concentration of the uranium in the depleted uranium waste, DU is much more radioactive than uranium in its natural state.

Depleted uranium weapons contaminate impact areas with extremely fine radioactive and toxic dust. U.S. Army testing found that 18 to 70% of a depleted uranium penetrator rod burns and oxidizes into extremely small particles during impact. The impact of one 120 mm depleted uranium penetrator fired from an American Abrams tank therefore creates between 900 and 3400 grams (roughly 2 to 7 pounds) of uranium oxide dust. U.S. Army testing further found “the DU oxide
Contamination with uranium from natural and anthropological sources

aerosols formed during the impact of DU into armor has a high percentage of respirable size particles (50 to 96%)” and 52 to 83% of those respirable size particles are insoluble in lung fluids. Respirable size particles (less than 5 microns in diameter) are easily inhaled or ingested. Insoluble particles are not readily excreted from the body, and may remain in the lungs or other organs for years.

U.S. Army research recently found that some respirable size uranium dust remains suspended in the air for hours after an impact.

U.S. Army testing also discovered depleted uranium dust can be resuspended by the wind, or the movement of people and vehicles.

In addition to the fine uranium dust created by impacts, depleted uranium fragments and impact DU penetrators also pose a hazard. In March 1991, an internal U.S. Defense Nuclear Agency Memorandum noted: “Alpha particles (uranium oxide dust) from expended rounds is a health concern, but Beta particles from fragments and intact rounds is a serious health threat with a possible exposure rate of 200 milliards per hour on contact”.

There is no dispute of the fact that at least 320 tons of depleted uranium was “lost” in the Gulf War, and that much of that was converted at high temperature into an aerosol, that is, minute insoluble.

The corrosion rate for DU penetrator in soil depends upon the chemical makeup of the soil and other environmental conditions. Weathered DU penetrators principally corrode into uranium dust that is soluble in water.

DU’s mobility in water is due to how easily it dissolves. Soluble compounds of DU will readily dissolve and migrate with surface or ground water. Drinking or washing or other contact with contaminated water will spread the contamination. The end result of air and water contamination is that DU is deposited in the soil. Once in the soil it stays there unless moved. This means that the area remains contaminated, and will not decontaminate itself.

Established limits on intake of DU dust attest that just a small amount posses a serious health threat. The limit for intake by an occupational worker has been set at 0.01 gram/one week (U.S. Nuclear Regulatory Commission) and 0.008 gram/one year (UK ministry of Defense). The limit on intake for a member of the public is set at 0.002 gram/one year (UK Atomic Energy Authority).

The route of depleted uranium in the body depends upon the method of exposure (inhalation, ingestion, implantation, or wound-contamination), and the size and solubility of the particles.

Recent research found depleted particles may remain in the lungs if inhaled, or travel in the blood-stream and deposit it in the brain, kidney, bone, reproductive organs, muscle and spleen.

Accordingly, we must learn from the lessons of the use of depleted uranium weapons in the Gulf war and take steps to minimize and prevent the adverse effect on soldiers, civilians, and food and water supplies.
DU is stored either as UF₆ or it is de-converted back to U₃O₈, which is more benign chemically and thus more suited for long-term storage. It is also less toxic. Every year 50,000 tones of DU joins already substantial stockpiles in USA, Europe and Russia. World stock is about 12 million tones.

The enrichment process not only produces the enriched product, but also a waste stream of uranium hexafluoride depleted in uranium – 235 (DU), typically to 0.3%.

The enrichment technologies require the prior conversion of the uranium to the gaseous form of uranium hexafluoride (UF₆).

Most of the depleted uranium produced to date is being stored as UF₆ in steel cylinders in the open air in so-called cylinder yards located adjacent to the environment plants. The cylinders contain up to 12.7 tones of UF₆. In the US alone, 560,000 metric tones at depleted UF₆ have accumulated until 1993 and they are currently stored in 46,422 cylinders.

Meanwhile, their number has grown by another 8000 cylinders.
Uranium hexafluoride is the chemical form of uranium that is used during the uranium enrichment process. Within a reasonable range of temperature and pressure, it can be a solid, liquid, or gas. Solid UF₆ is a white dense crystalline material that resembles rock salt. Fig. 3B

Uranium hexafluoride does not react with oxygen, nitrogen, carbon dioxide, or dry air, but it does react with water or water vapor (including humidity of air). When UF₆ comes into contact with water, the UF₆ and water react forming corrosive hydrogen fluoride (HF) and a uranium-fluoride compound, called uranyl fluoride (UO₂F₂). For this reason, UF₆ is always handled in leak tight containers and processing equipment. Although very convenient for processing, UF₆ is not considered a preferred from long-term storage of disposal because of its relative instability.

The hydrofluoric acid causes skin burns, and after inhalation damages the lungs. Further health result from the chemical toxicity of the uranium to the kidneys, and from the radiation of the uranium (an alpha emitter).

In the storage yards, the cylinders are object to corrosion. The integrity of the cylinders must therefore be monitored and the painting must be refreshed from time to time. This maintenance work requires moving of the cylinders, causing further hazards from breaching of corroded cylinders, and from handling errors.

![Fig. 5 – Damages caused by corrosive HF.](image)

Another source of uranium contamination is nuclear energy, and especially UO₂.

Uranium dioxide (UO₂) is the chemical form most often used for nuclear reactor fuel. Uranium fluoride compounds are also common in uranium processing, with uranium hexafluoride and uranium tetra fluoride, being the two most common.

Over 16% of the world’s electricity is generated from uranium in nuclear reactor. This amounts to about 2400 billion kWh, as much as from all sources worldwide in 1960.
It comes from about 440 nuclear reactors with a total output capacity more than 350 000MW operating in 31 countries. A further thirty reactors are under construction and another 70 are on drawing board.

Owners and operators of U.S. civilian nuclear power reactors purchased from U.S. and foreign suppliers a total of 23,904 million kilograms U₃O₈ (equivalent) of deliveries during 2002.

So, the waste products from the nuclear power plants is continuously rising and become a serious problem, problem which must be solved carefully.

The third main source of anthropological uranium pollution is from scientific or other purposes.

The contamination with uranium and waste products from medical and scientific uses is relatively low but nevertheless, these products must be handled with care.

Uranium is widely used in human activities of today. Unfortunately these activities are connected with different types of uranium waste products. For example spent reactor fuel is removed and stored, either to be reprocessed or disposed of underground. Another way to solve the problem is putting nuclear wastes on to the ocean bottom in to lead containers, which methods are with very high degree of danger.

In Russia there are 320 cities and 1548 other locations used to store radioactive material. In Ukraine approximately 100 000 small nuclear facilities exist and there are 11 000 in Moldova. Geologists in Kazakhstan have found about 80 million tons of radioactive waste.

Because of the radiation hazard, uranium and its compounds should only ever be handled by properly trained professionals in a properly accredited institution. Its compound can cause major kidney problems. Uranium is a carcinogen that causes cancer. Its high radioactivity makes uranium subject to special handling techniques and precautions.

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