The Legacy of Depleted Uranium in the United States

Robert Alvarez
Senior Scholar
Institute for Policy Studies
June 2003
Introduction

Depleted uranium (DU) constitutes one of the largest radioactive and toxic-waste byproducts of the nuclear age.

Over the past-half century, 732,000 metric tons of DU -- more than half of all the uranium ever mined in the world-- was produced at three uranium enrichment plants in Oak Ridge, Tennessee, Paducah, Kentucky, and Portsmouth, Ohio.

A small proportion of the U.S. depleted uranium inventory has been used in projectiles and armament (About 300 metric tons were used in the 1991 Gulf War).
Physical and Chemical Properties

Uranium is a very dense, silvery-white, ductile, and malleable metal. It melts at 1,132°C and boils at 3,818°C.

Uranium metal oxidizes or corrodes slowly in dry air, but rather rapidly in moist air. Fine uranium metal powder can ignite spontaneously in air at room temperature, but large metal pieces are stable and are often heated in air above 600°C in uranium-processing operations.

Uranium metal and oxide dissolve readily in oxidizing acids, such as nitric acid.
Different Types of Uranium

- Natural uranium contains 0.7% uranium 235.
- Low enriched uranium used in power reactors contains 4 to 5 % uranium 235.
- Highly enriched uranium contains 20 to >90 % uranium 235.
- Depleted uranium contains 0.3 to 0.5% uranium 235.
Human Health Risks

- Uranium can harm the health of workers, military personnel and the public.

- Uranium enters the body through inhalation, ingestion, or direct contamination of open wounds.

- The health consequences found among uranium workers have been confined primarily to the organs of concentration: lung, kidney, and bone. (Recent studies of US uranium workers, however, suggest higher mortality risks from all causes.)

- Soluble forms of inhaled uranium (and a small fraction of less soluble forms) are absorbed into the blood, and deposit in the kidneys and skeletal bone. Uranium deposited in the kidneys interferes with the transport of nutrients through the cell membrane, resulting in cell death and, if enough cells are killed, potential loss of kidney functions.

- Uranium exposes organs to ionizing radiation, which can cause cancer and non cancerous diseases.
The United States has the World's Largest Inventory of Depleted Uranium

- United States: 732 million kgs (54%)
- Russia: 430 million kgs (32%)
- France: 135 million kgs (10%)
- Urenco*: 29 million kgs (2%)
- United Kingdom: 30 million kgs (2%)
- China: 20 million kgs (1.5%)
- Others**: 5 million kgs (0.3%)

* Urenco operates plants in Germany, the Netherlands, and the United Kingdom

** Japan, South Africa, etc.
The U.S. Department of Energy’s Inventory of Depleted Uranium

- **DUF6** - 96.2%  
  704 million kgs

- **Other** 3.8%  
  28 million kgs

  - **U03** - 19.7 million kgs
  - **Metal** - 5.3 million kgs
  - **Scrap** - 0.4 million kgs
Depleted Uranium at DOE Sites

Stars denote Locations of DUF6
How is DU Produced and Used?
Production of 1 kg of low-enriched uranium yields about 5 to 10 kg of DU.

Production of 1 kg of highly enriched uranium yields about 200 kg of DU.
How Gaseous Diffusion Works

- Large amounts of heated uranium hexafluoride gas are pushed through miles of pipes and ultra fine barriers, which capture the heavier uranium 238 isotope.

- Eventually the amount of uranium 235 present in natural uranium is increased from 0.7 percent to 3 to 5 percent for use as commercial nuclear power fuel, and over 90 percent for nuclear weapons and nuclear navy reactor fuel.

- The remaining uranium-238 is called “DU” because it is depleted of its U-235 content.
Depleted uranium hexafluoride now sits in some 55,000 steel cylinders, each weighing about thirteen tons, stacked in huge piles outside the enrichment plants.
A major leak in one of the cylinders poses acute risks. The most immediate hazard from a release would be lung injury or death from inhalation of hydrogen fluoride (HF), a highly corrosive gas formed when UF6 reacts with moisture in air. Uranyl fluoride is also formed. Uranyl fluoride, once inhaled is easily absorbed into the bloodstream resulting in kidney toxicity.
Recycled Uranium

• Between March 1952 and March 1999, four DOE production sites produced recycled uranium containing plutonium 239, Neptunium 237, Technetium 99, and other fission products from spent nuclear fuel and targets at chemical separation plants.

• About 130,000 metric tons of previously irradiated uranium was sent to processing sites.

• Based on complex-wide inventories and the blending operations, it appears that there was more than 250,000 MTU of recycled uranium within the DOE complex.
Figure 2. Simplified recycled uranium flow.
 ESTIMATED BONE SURFACE DOSES FROM RECYCLED URANIUM TO WORKERS AT THE PADUCAH GASEOUS DIFFUSION PLANT

(Committed Effective Dose Equivalent – CDE)*

<table>
<thead>
<tr>
<th>Average Air Concentrations</th>
<th>Maximum Air Concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>48.06 -- 188 rems</td>
<td>599.24 -- 2,238 rems</td>
</tr>
</tbody>
</table>

Some workers were required to strike large cloth filter bags with metal rods to remove heavy concentrations of uranium laced with neptunium and plutonium.

Despite secret concerns raised by plant officials, workers were provided little protection and no effort was made to measure exposures or inform workers.

Risks to Uranium Workers

Oak Ridge Y-12 weapons Plant, Tennessee.

- Elevated death rates were found for cancers of the lung, brain lymphopoetic (immune system), prostate, kidney, pancreas, and female breast. Lung cancer showed evidence of a dose/response.*

The K-25 Gaseous Diffusion Plant, Tennessee. **

- Excess risks of dying from all causes, cancers of the respiratory system, bone cancer, mental disorders and all respiratory diseases including pneumonia. Increased risks of dying from kidney cancer and chronic nephritis (kidney disease) were found. The latter condition was more than 600 percent higher when deaths from the last decade of follow up was observed.

---


Risks to Uranium Workers

Fernald Uranium Processing Plant, Ohio. *
- Elevated death rates for all cancers (21 percent higher) and lung cancer (26 percent higher).
- Evidence of a radiation-dose relationship for both nonmalignant respiratory diseases and lung cancer.

Linde Air Products Co., NY. **
- Elevated death rates for all causes (18 percent higher), laryngeal cancer (447 percent higher), all circulatory diseases (18 percent higher), arteriosclerotic heart disease (19 percent higher), all respiratory diseases (52 percent higher) and pneumonia (217 percent higher) were found among workers who processed uranium at this facility between 1943 and 1949.

Mallinkrodt Chemical Works, Missouri. ***
- Significant increased death rate from all cancers (10 percent higher).
- Respiratory diseases, chronic nephritis/kidney disease (218 percent higher) and lymphatic cancers.
- Significant increased risks for cancers of the esophagus (40 percent higher), rectum (45 percent higher), pancreas (31 percent higher), larynx (36 percent higher) kidney (34 percent higher) and multiple myeloma/bone marrow (33 percent higher).
- Kidney cancer showed a significant positive dose-response association with external radiation.

"I spent all those years breathing uranium hexafluoride gas so thick and heavy that you could see the haze in the air, you could taste it coated on your teeth and in your throat and lungs."

Joe Harding, a uranium worker at the DOE’s Paducah, KY plant.

After his death, Harding’s bones were found to contain up to 34,000 times the expected concentration of uranium.

Claire Harding with a picture of her husband, taken shortly before his death in 1980.

Cincinnati Enquirer
(Patrick Reddy photo)

The law established a federal compensation program for workers who were made ill as a result of exposure to ionizing radiation, beryllium and silica. It covers some 700,000 men and women who worked at over 300 federal and private facilities.

Employees or their survivors are eligible for a lump sum payment of $150,000 plus medical benefits.

The law also creates a “Special Cohort” category of workers employed at the gaseous diffusion plants in Portsmouth, OH, Paducah, KY, and Oak Ridge TN, and the Amchitka nuclear test site in Alaska.

The burden of proof is shifted to the government for workers at these facilities, because of the absence of exposure records and the presence of hazardous workplace conditions.
The Environmental Legacy at the Paducah, KY Gaseous Diffusion Plant

- Three groundwater plumes heavily contaminated with radioactive and hazardous material is flowing toward the Ohio River. Trichloroethelene (TCE) has been found at levels up to 700,000 parts per billion – 140,000 times greater than the EPA drinking water standard.

- Thousands of tons of contaminated scrap and waste water discharges from the plant have created significant surface water and soil contamination. An estimated 72 areas are severely contaminated and will require the removal of 35,000 cubic yards of soil.

- There are 12 burial grounds containing a variety of radioactive and hazardous material which will require remediation.

- Some 52,000 barrels of hazardous and radioactive wastes are stored at the site.
TCE and Technetium 99 Groundwater Plumes at the Paducah Plant

Source: ATSDR
Public Health Assessment (2001)
Radionuclide Concentrations in Buffer Zone Soil at Paducah

Source: ATSDR Public Health Assessment (2001)
Radionuclide Concentrations in Offsite Soil at Paducah

Source: ATSDR Public Health Assessment (2001)
The Environmental Legacy

The cost for environmental restoration, waste management, decontamination and decommissioning and at the three gaseous diffusion plants (GDPs) is estimated at $20 to $30 Billion.

The stabilization and disposal of depleted uranium at the GDPs is estimated to cost between $3 to $10 billion over the next 25 years. This will involve:

- conversion of DUF6 to uranium oxide (U$_3$O$_8$) and disposal,
- removal and conversion of some 190,000 tons of contaminated anhydrous fluoride for disposal.

About 1.9 million waste containers will be required to dispose of about 925,000 cubic meters of depleted U$_3$O$_8$.

About 550 thousand cubic meters of contaminated fluoride wastes may have to be disposed, if it cannot be recycled -- a 13% addition to the projected DOE complex-wide LLW disposal volume.
The total volume of DUF6 wastes would more than fill the Empire State Building.

- DUF6 Wastes: 1.475 Million m³
- Empire State Building: 1.04 Million m³
Summary and Conclusion

- The United States has generated the largest amount of depleted uranium (DU) in the world (732,000 metric tons) – representing more than half of all uranium mined worldwide.

- More than 96 percent of the U.S. DU inventory is stored as a hexafluoride compound in some 55,000 large steel canisters, which pose potentially significant human health and environmental risks.

- The preponderance of the US inventory of DU is contaminated with plutonium 239, neptunium 237, and technetium 99 from recycled uranium.

- Workers involved in making DU probably received very large radiation doses. In some instances workers were knowingly put at risk without their knowledge.

- DOE-sponsored epidemiological studies show that uranium workers at five facilities have significant mortality risks from cancer and non-cancerous diseases. Several diseases show dose response relationships.

- The production of DU has led to profound contamination at several DOE sites, creating the prospect of “national sacrifice zones.”

- Environmental restoration, waste management and D&D expenses associated with the production of DU are between $20 to $30 billion and will result in the disposal of massive quantities of soil, groundwater, uranium and fluorine wastes.