



## Radiation Protection

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# Plutonium

Plutonium (chemical symbol Pu) is a radioactive metal with Atomic Number 94. Plutonium is considered a man-made element, although scientists have found trace amounts of naturally occurring plutonium produced under highly unusual geologic circumstances. The most common radioisotopes of plutonium are plutonium-238, plutonium-239, and plutonium-240.

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## The Basics

## Who discovered plutonium?

Plutonium was identified by nuclear chemist Glenn T. Seaborg and his colleagues Joseph W. Kennedy, Edwin M. McMillan, and Arthur C. Wahl, in 1941 at the University of California - Berkeley. However, wartime secrecy prevented them from announcing the discovery until 1948.

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## Where does plutonium come from?

Plutonium is created from uranium in nuclear reactors. When uranium-238 absorbs a neutron, it becomes uranium-239 which ultimately decays to plutonium-239. Different isotopes of uranium and different combinations of neutron absorptions and radioactive decay, create different isotopes of plutonium.

Some of the plutonium-239 in the fuel rods burns (fissions) along with uranium and helps produce heat, which is converted into electricity. As fission continues, the reaction products remain in the fuel pellets and absorb neutrons, slowing ("poisoning") the fission process. Finally, the ratio of poisons to fissional materials reaches a point at which the fuel is said to be "spent" and must be replaced. However, even spent fuel contains some plutonium.

The majority of plutonium was produced for nuclear weapons in several government reactors designed to maximize the production of plutonium. Between 1944 and 1988, the U.S. built and operated these 'production reactors' at high-security government facilities. In all, the U.S. produced about 100 metric tons of plutonium.

The reactors made plutonium by bombarding special fuel rods containing uranium with neutrons. Once the maximum amount of plutonium was produced, workers removed the fuel rods (now called 'spent fuel') from the reactor. The spent fuel rods were extremely radioactive, and the process for recovering the plutonium used only remote-controlled equipment.

First workers used strong acid to dissolve the fuel rods. Then they treated the mixture with chemicals to precipitate the plutonium so that it would settle out. The process was very expensive and at the time made plutonium about the most expensive material on earth. This processing also left behind over 100 million gallons of exceedingly hazardous mixed wastes of acids and radioactive fission products. Part of our legacy of nuclear weapons production is dealing with these high-level wastes.

In extremely rare cases, rocks with a high localized concentration of uranium can provide the right conditions for making small amounts of plutonium naturally. This natural process is called spontaneous fission. Only very small (trace) amounts of natural plutonium have ever been found in nature.

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## What are the properties of plutonium?

Plutonium is a silvery-grey metal that becomes yellowish when exposed to air. It is solid under normal conditions, and is chemically reactive.

Plutonium has at least 15 different isotopes, all of which are radioactive. The most common ones are Pu-238, Pu-239, and Pu-240. Pu-238 has a half-life of 87.7 years. Plutonium-239 has a half-life of 24,100, and Pu-240 has a half-life 6,560 years. The isotope Pu-238 gives off useable

heat, because of its radioactivity.

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### **What is plutonium used for?**

Plutonium-239 is used to make nuclear weapons. For example, the bomb dropped on Nagasaki, Japan, in 1945, contained Pu-239. The plutonium in the bomb undergoes fission in an arrangement that assures enormous energy generation and destructive potential.

The isotope, plutonium-238, is not useful for nuclear weapons. However it generates significant heat through its decay process, which make it useful as a long-lived power source. Using a thermocouple, a device that converts heat into electric power, satellites rely on plutonium as a power source. Tiny amounts also provide power to heart pacemakers.

Some foreign countries mix isotopes of plutonium and uranium to manufacture special reactor fuel called mixed-oxide fuel, for commercial nuclear power reactors. The plutonium increases the power output. The U.S. does not currently manufacture mixed-oxide fuel, but is funding research in this type of reactor fuel as a means of dealing with excess plutonium in U.S. stockpiles.

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## **Exposure to Plutonium**

### **How does plutonium get into the environment?**

Plutonium was dispersed world wide from atmospheric testing of nuclear weapons conducted during the 1950s and '60s. The fallout from these tests left very low concentrations of plutonium in soils around the world.

Nuclear weapons production and testing facilities (Hanford, WA; Savannah River, GA; Rocky Flats, CO; and The Nevada Test Site, in the United States, and Mayak and Semi Plafinsk in the former Soviet Union), also released small amounts. Some releases have occurred in accidents with nuclear weapons, the reentry of satellites that used Pu-238, and from the Chernobyl nuclear reactor accident.

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### **How does plutonium change in the environment?**

All isotopes of plutonium undergo radioactive decay. As plutonium decays, it releases radiation and forms other radioactive isotopes. For example, Pu-238 emits an alpha particle and becomes uranium-234; Pu-239 emits an alpha particle and becomes uranium-235.

This process happens slowly since the half-lives of plutonium isotopes tend to be relatively long: Pu-238 has a half-life of 87.7 years; Pu-239 has a half-life is 24,100 years, and Pu-240 has a half-life of 6,560 years. The decay process continues until a stable, non-radioactive element is formed.

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### **How do people come in contact with plutonium?**

Residual plutonium from atmospheric nuclear weapons testing is dispersed widely in the environment. As a result, virtually everyone comes into contact with extremely small amounts of plutonium.

People who live near nuclear weapons production or testing sites may have increased exposure to plutonium, primarily through particles in the air, but possibly from water as well. Plants growing in contaminated soil can absorb small amounts of plutonium.

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### **How does plutonium get into the body?**

People may inhale plutonium as a contaminant in dust. It can also be ingested with food or water. Most people have extremely low ingestion and inhalation of plutonium. However, people who live near government weapons production or testing facilities may have increased exposure. Plutonium exposure external to the body poses very little health risk.

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### **What does plutonium do once it gets into the body?**

The stomach does not absorb plutonium very well, and most plutonium swallowed with food or water passes from the body through the feces. When inhaled, plutonium can remain in the lungs depending upon its particle size and how well the particular chemical form dissolves. The chemical forms that dissolve less easily may lodge in the lungs or move out with phlegm, and either be swallowed or spit out. But, the lungs may absorb chemical forms that dissolve more easily and pass them into the bloodstream.

Once in the bloodstream, plutonium moves throughout the body and into the bones, liver, or other body organs. Plutonium that reaches body organs generally stays in the body for decades and continues to expose the surrounding tissue to radiation.

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## **Health Effects of Plutonium**

### **How can plutonium affect people's health?**

External exposure to plutonium poses very little health risk, since plutonium isotopes emit alpha radiation, and almost no beta or gamma radiation. In contrast, internal exposure to plutonium is an extremely serious health hazard. It generally stays in the body for decades, exposing organs and tissues to radiation, and increasing the risk of cancer. Plutonium is also a toxic metal, and may cause damage to the kidneys.

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### **Is there a medical test to determine exposure to plutonium?**

There are tests that can reliably measure the amount of plutonium in a urine sample, even at very low levels. Using these measurements, scientists can estimate the total amount of plutonium present in the body. Other tests can measure plutonium in soft tissues (such as body organs) and in feces, bones, and milk. However, these tests are not routinely available in a

doctor's office because they require special laboratory equipment.

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## Protecting People from Plutonium

### What can I do to protect myself and my family from plutonium?

Since plutonium levels in the environment are very low, they pose little risk to most people. However, people who live near government weapons production or testing sites may have higher exposure.

Plutonium particles in dust are the greatest concern, because they pose the greatest health risk. People living near government weapons facilities can track radiation monitoring data made available by site personnel. If radiation levels rise, they should follow the radiation protection instructions given by site personnel.

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### How do I know if I'm near plutonium?

You must have special equipment to detect the presence of plutonium.

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### What is EPA doing to protect us from plutonium?

EPA sets health-based limits on radiation in air, soil, and water. Federal government agencies are required to meet EPA standards the same as commercial industries. Using its authority under the [Safe Drinking Water Act](#), EPA limits the amount of radiation in community water systems by establishing maximum contaminant levels. Maximum Contaminant Levels limit the amount of activity from alpha emitters, like plutonium, to 15 picocuries per liter.

EPA also protects people against exposure from soil and ground water from sites that have been contaminated with plutonium. We set criteria that soil and ground water from the sites must meet before releasing the sites for public use.

Rather than limiting the concentration of plutonium itself, the criteria limit the cancer risk the sites pose. A person's added risk of developing cancer is limited to no more than about 1-in-10,000 and if possible to 1-in-1,000,000, or less. Under the [Clean Air Act](#), EPA limits the dose to humans from radionuclides to 10 millirem from emissions to air.

- [Radionuclides in Drinking Water](#)  
This site provides information about radionuclides in drinking water and guidance to help states and water systems comply with EPA's limits on radionuclides in drinking water.
- [RadNESHAPS](#)  
This site provides information on EPA's National Emission Standards for Hazardous Air Pollutants: Radionuclides.

EPA sets standards for radioactive waste storage and disposal facilities. We can't treat plutonium or other radioactive materials to get rid of their radioactivity. We can only isolate and store them until they decay. The extremely long half-lives of some plutonium radioisotopes make the

management of spent nuclear fuel, and wastes from nuclear weapons facilities a difficult problem.

One of EPA's responsibilities has been to develop public health and safety standards for the two major U.S. nuclear waste storage and disposal facilities. The Waste Isolation Pilot Plant in New Mexico stores transuranic wastes. They range from slightly contaminated clothing to barrels of waste so radioactive that it can only be handled with remote control equipment. The proposed Yucca Mountain repository is designed to store high-level radioactive waste and spent nuclear fuel.

EPA also responds to radiation emergencies. Additionally, EPA helps state and local governments during emergencies that involve radioactive materials. We provide guidance on ways to protect people from harmful exposure to radiation. We can also monitor radiation levels in the environment and assess the threat to public health. We also work with international radiation protection organizations to prepare for large scale foreign emergencies such as Chernobyl. EPA also works with law enforcement agencies to develop counter terrorism plans.

- [Yucca Mountain Standards](#)

This site provides information about EPA's public health and environmental radiation protection standards for the Department of Energy's proposed nuclear waste repository at Yucca Mountain Nevada.

- [Radiological Emergency Response](#)

This site provides information about EPA's work to prevent, prepare for, and respond to emergencies involving radioactive materials.

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