http://www.epa.gov/rpdweb00/radionuclides

Commonly Encountered Radionuclides
- Americium-241
- Cesium-137
- Cobalt-60
- Iodine-129 &-131
- Plutonium
- Radium
- Radon
- Strontium-90
- Technetium-99
- Tritium
- Thorium
- Uranium

Americium

Americium (chemical symbol Am) is a man-made radioactive metal, with Atomic Number 95. The most important isotope of Americium is Am-241.

Who discovered americium?
Americium (isotope Am-241) was discovered by nuclear chemist Glenn Seaborg and his colleagues at the University of Chicago in 1944.

Where does americium-241 come from?
Americium is a man-made metal produced when plutonium atoms absorb neutrons in nuclear reactors and in nuclear weapons detonations. Americium has several different isotopes, all of which are radioactive. The most important isotope is Am-241.

What are the properties of americium-241?
Americium is a silver-white, crystalline metal that is solid under normal conditions. All isotopes of americium are radioactive. Americium-241 primarily emits alpha particles, but also emits gamma rays. A mixture of americium-241 and beryllium emits neutrons. Americium-241 has a half-life of 432.7 years.

What is americium-241 used for?
By far the largest and most widespread use of americium-241 is as a component in household and industrial smoke detectors, where a small amount is used in an ionization chamber inside the detector.

Americium-241 is the only isotope of americium to have widespread commercial use. It is the radiation source for a number of applications:

* medical diagnostic devices
* research
* fluid-density gauges
* thickness gauges
* aircraft fuel gauges
* distance-sensing devices, all of which utilize its gamma radiation.

A mixture of americium-241 and beryllium provides a neutron source for industrial devices that monitor product quality. Two examples are devices for nondestructive testing of machinery and gauges for measuring the thickness of glass and other products.

Exposure to Americium and Americium-241
How does americium-241 get into the environment?
Most americium-241 in the environment originates from the atmospheric testing of nuclear weapons during the 1950's and 1960's. The exposure to an individual from americium-241, and other long-lived radionuclides is very, very small. Facilities that produce weapons and manufacture smoke detectors are minor sources of Americium-241 contamination. Americium-241 may also enter the environment if industrial americium sources (many of which are portable) are lost or stolen, and subsequently broken open, or melted in a steel mill. Also, when household smoke detectors are discarded, they go directly to municipal landfills.

How does americium-241 change in the environment?

Americium-241 is an unstable (radioactive) isotope with a half-life of 432.7 years. As it decays, it releases alpha and gamma radiation and changes into neptunium-237, which is also radioactive. The americium-241 decay chain ends with bismuth-209, a stable (non-radioactive) element.

How do people come in contact with americium-241?
Exposure to any significant amount of Am-241 is unlikely under normal circumstances.
People may be directly exposed to gamma radiation from americium-241 by walking on contaminated land. They may also be exposed to both alpha and gamma radiation by breathing in americium contaminated dust, or drinking contaminated water. Because americium-241 was widely dispersed globally during the testing of nuclear weapons, only very minute amounts of it are found in the soil, plants, and water. Living near a weapons testing or production facility may increase your chance of exposure to americium-241.
Smoke detectors containing Am-241 also provide some radiation exposure. However, the radiation exposure people receive from a smoke detector is very low. The health risk reduction from the fire protection vastly outweighs the health risk from the radiation. That said, you should still handle smoke detectors containing americium with care. To avoid exposure:

- never dismantle a smoke detector
- never burn a smoke detector in your fireplace

The Nuclear Regulatory Commission, which regulates the radioactive material in smoke detectors, permits their disposal as ordinary trash.

How does americium-241 get into the body?
People who live or work near a contaminated site, such as a former weapons production facility, may ingest americium-241 with food and water, or may inhale it as part of resuspended dust.

What does americium-241 do once it gets into the body?
Once in the body, americium-241 tends to concentrate in the bone, liver, and muscle. It can stay in the body for decades and continue to expose the surrounding tissues to radiation, and increase your risk of developing cancer.
When inhaled, some Am-241 remains in the lungs, depending upon the particle size and the chemical form of the americium compound. The chemical forms that dissolve easily may pass into the bloodstream from the lungs. The chemical forms that dissolve less easily tend to remain in the lungs, or are coughed up through the lung's natural defense system, and swallowed. From the stomach swallowed americium may dissolve and pass into the bloodstream. However, undissolved material passes from the body through the feces.

Health Effects of Americium-241
How can americium-241 affect people's health?
Americium-241 poses a significant risk if ingested (swallowed) or inhaled. It can stay in the body for decades and continue to expose the surrounding tissues to both alpha and gamma radiation, increasing the risk of developing cancer. Americium-241 also poses a cancer risk to all organs of the body from direct external exposure to its gamma radiation. One source of direct exposure would be contaminated soil. Exposure to any significant amount of Am-241 is unlikely under normal circumstances.

Is there a medical test to determine exposure to americium-241?
Yes. There are tests that reliably measure the amount of americium in a urine sample, even at very low levels. Using these measurements, scientists can estimate the total amount of Am-241 present in the body. Other tests can measure Am-241 in soft tissues (such as body organs) and in feces, bone, and milk. None of these tests are routinely available in a doctor's office because they require special laboratory equipment.

Protecting People From Americium
How do I know if I'm near americium-241?
You need specialized equipment to detect the presence of Am-241.

What can I do to protect myself and my family from americium-241?
Most Americans never get close to a significant amount of Am-241, except in their household smoke detectors. Ionizing chamber smoke detectors contain a small amount of Am-241. Smoke detectors pose very little risk if used according to manufacturers' instructions.

You can follow some precautions to protect yourself and your family:
- Never try to access or remove the Am-241 source in your smoke detector.
- Be aware that industrial instruments using Am-241 can be lost, stolen, or otherwise fall out of monitored control. These "orphan sources" present a significant risk to those who come in contact with them. EPA, other federal, state and industry organizations are working together to locate and retrieve orphan sources throughout the U.S.

The Nuclear Regulatory Commission regulates the radioactive materials in smoke detectors. Because the amount of americium in these devices is so small, NRC's regulations exempt individuals purchasing smoke detectors from licensing requirements including those related to disposal of radioactive materials. You can dispose of single, household smoke detectors as ordinary trash.

What is EPA doing about americium-241?
Americium-241 in drinking water is covered under the Safe Drinking Water Act. This law establishes Maximum Contaminant Levels, or MCLs, for radionuclides and other contaminants in drinking water. The MCL for alpha particle activity applies to Am-241. The limit is 15 pCi/l alpha particle activity in drinking water.

EPA standards under the Clean Air Act limit Am-241 in the air. In addition, the cleanup of contaminated sites to be released for public use, must meet EPA's risk-based criteria for soil and ground water. For sites with residual Am-241 on the ground, EPA's cleanup standards set the potential cancer risk as being no more than a 1-in-10,000 to a 1-in-1,000,000 increased chance of developing cancer.

Cesium

Cesium (chemical symbol Cs) is a metal that may be stable (nonradioactive) or unstable (radioactive). The most common radioactive form of cesium is cesium-137. Another fairly common radioisotope is cesium-134. Cesium-137 is much more significant as an environmental contaminant than cesium-134. It is also very useful in industry for its strong radioactivity.

Who discovered cesium and cesium-137?
In 1860, Gustav Kirchhoff and Robert Bunsen discovered nonradioactive cesium in mineral water in Germany. Radioactive cesium-137, and many other radionuclides that are used in nuclear medicine, was discovered in the late 1930s by Glenn T. Seaborg and his coworker, Margaret Melhase.

Where does cesium-137 come from?
Nonradioactive cesium occurs naturally in various minerals. Radioactive cesium-137 is produced when uranium and plutonium absorb neutrons and undergo fission. Examples of the uses of this process are nuclear reactors and nuclear weapons. The splitting of uranium and plutonium in fission creates numerous fission products. Cesium-137 is one of the more well-known fission products.

What are the properties of cesium-137?
Cesium, as well as cesium-137, is a soft, malleable, silvery white metal. Cesium is one of only three metals that is a liquid near room temperature (83 °F). The half-life of cesium-137 is 30 years. It decays by emission of a beta particle and gamma rays to barium-137m.

What is cesium-137 used for?
Cesium-137 is one of the most common radioisotopes used in industry. Thousands of devices use cesium-137:
   * moisture-density gauges, widely used in the construction industry
   * leveling gauges, used in industries to detect liquid flow in pipes and tanks
   * thickness gauges, for measuring thickness of sheet metal, paper, film and many other products
   * well-logging devices in the drilling industry to help characterize rock strata
Cesium-137 is also used in medical therapy to treat cancer.

Exposure to Cesium and Cesium-137

How does cesium-137 get into the environment?

Cesium-137 in the environment came from a variety of sources. The largest single source was fallout from atmospheric nuclear weapons tests in the 1950s and 1960s, which dispersed and deposited cesium-137 world-wide. However much of the cesium-137 from testing has now decayed.
Nuclear reactor waste and accidental releases such as the Chernobyl accident in the Ukraine release some cesium-137 to the environment. Spent nuclear fuel reprocessing plant wastes may introduce small amounts to the environment. However, the U.S. does not currently reprocess spent nuclear fuel.
Although hospitals and research laboratories generate wastes containing cesium-137, they usually do not enter the environment. Occasionally, industrial instruments containing cesium-137 are lost or stolen. Anyone who unwittingly handles them may be exposed. These devices are typically metal, and may be considered scrap metal and sold for recycling. If they find their way into a steel mill and are melted, they can cause significant environmental contamination. They may also be discarded and sent to a municipal landfill, or sold for other reasons. These devices should be considered dangerous.

How does cesium-137 change in the environment?

Cesium-137 undergoes radioactive decay with the emission of beta particles and relatively strong gamma radiation. Cesium-137 decays to barium-137m, a short-lived decay product, which in turn decays to a nonradioactive form of barium. The major dose from cesium-137 is from the barium-137. The half-life of cesium-137 is 30.17 years. Because of the chemical nature of cesium, it moves easily through the environment. This makes the cleanup of cesium-137 difficult.

How do people come in contact with cesium-137?
Everyone is exposed to very small amounts of cesium-137 in soil and water as a result of atmospheric fallout. In the Northern Hemisphere, the average annual dose from exposure to cesium-137 associated with atmospheric fallout is less than 1 mrem; this dose continues to diminish every year as cesium-137 decays.

People may also be exposed from contaminated sites:
* Walking on cesium-137 contaminated soil could result in external exposure to gamma radiation. Leaving the contaminated area would prevent additional exposure.
* Coming in contact with waste materials at contaminated sites could also result in external exposure to gamma radiation. Leaving the area would also end the exposure.
* If cesium-137 contaminated soil becomes air-borne as dust, breathing the dust would result in internal exposure. Because the radiation emitting material is then in the body, leaving the site would not end the exposure.
* Drinking cesium-137 contaminated water, would also place the cesium-137 inside the body, where it would expose living tissue to gamma and beta radiation.
People may also unknowingly handle a strong industrial source of cesium-137. For example, certain moisture gauges contain cesium-137 sources.

How do I know if I'm near cesium-137?
You need special equipment to detect the presence of any radionuclide. You cannot feel exposure to cesium-137, or taste or smell it.

How does cesium-137 get into the body?
People may ingest cesium-137 with food and water, or may inhale it as dust. If cesium-137 enters the body, it is distributed fairly uniformly throughout the body's soft tissues, resulting in exposure of those tissues. Slightly higher concentrations of the metal are found in muscle, while slightly lower concentrations are found in bone and fat. Compared to some other radionuclides, cesium-137 remains in the body for a relatively short time. It is eliminated through the urine. Exposure to cesium-137 may also be external (that is, exposure to its gamma radiation from outside the body).

Health Effects of Cesium-137
How can cesium-137 affect people's health?
Like all radionuclides, exposure to radiation from cesium-137 results in increased risk of cancer. Everyone is exposed to very small amounts of cesium-137 in soil and water as a result of atmospheric fallout. Exposure to waste materials, from contaminated sites, or from nuclear accidents can result in cancer risks much higher than typical environmental exposures.
If exposures are very high, serious burns, and even death, can result. Instances of such exposure are very rare. One example of a high-exposure situation would be the mishandling a strong industrial cesium-137 source. The magnitude of the health risk depends on exposure conditions. These include such factors as strength of the source, length of exposure, distance from the source, and whether there was shielding between you and the source (such as metal plating).

Is there a medical test to determine exposure to cesium-137?
Yes, there are several. However, they are not routinely available in a doctor's office, because they require special laboratory equipment. Some tests can measure the amount of radionuclides in urine, or in fecal samples, even at very low levels. A technique called "whole-body counting" can detect gamma radiation emitted by cesium-137 in the body. A variety of portable instruments can directly measure cesium-137 on the skin or hair. Other techniques include directly measuring the level of cesium-137 in soft tissues samples from organs or from blood, bones, and milk.

Protecting People from Cesium-137
What can I do to protect myself and my family from cesium-137?
Cesium-137 that is dispersed in the environment, like that from atmospheric testing, is impossible to avoid. However the exposure from cesium-137 in the environment is very small.
Serious exposure is unlikely. People most likely to accidentally encounter a cesium-137 source typically work in scrap metal sorting, sales and brokerage, metal melting and casting, and in municipal landfill operations. They may unwittingly encounter an industrial instrument containing a sealed cesium-137 radiation source.

What is EPA doing about Cesium-137?
Both EPA and the Nuclear Regulatory Commission regulate Cesium-137. The Nuclear Regulatory Commission licenses its use. EPA has several regulations that protect you from cesium-137 in the environment. These include standards for the maximum amount of cesium-137 that nuclear facilities may release to the air, and maximum levels for cesium-137 in drinking water. EPA also sets risk-based criteria for clean up of soil and groundwater at sites contaminated with cesium-137 that must be met before the site can be approved for public use.

Cobalt 60

Cobalt (chemical symbol Co) is a metal that may be stable (non radioactive, as found in nature), or unstable (radioactive, man-made). The most common radioactive isotope of cobalt is cobalt-60.

Who discovered cobalt and cobalt-60?
In 1735, a Swedish scientist, George Brandt, demonstrated that a blue color common in colored glass was caused by a new element, cobalt. Previously, people thought that bismuth, which occurs in nature with cobalt, was the cause. Radioactive cobalt-60 was discovered by Glenn T. Seaborg and John Livingood at the University of California - Berkeley in the late 1930's.

Where do cobalt and cobalt-60 come from?
Non radioactive cobalt occurs naturally in various minerals, and has been used for thousands of years to impart blue color to ceramic and glass. The radionuclide, cobalt-60, is produced for commercial use in linear accelerators. It is also produced as a by-product of nuclear reactor operations, when structural materials, such as steel, are exposed to neutron radiation.

What are the properties of cobalt-60?
Cobalt (including cobalt-60) is a hard, brittle, gray metal with a bluish tint. It is solid under normal conditions and is generally similar to iron and nickel in its properties. In particular, cobalt, like iron, can be magnetized.

What is cobalt-60 used for?
Cobalt-60 is used in many common industrial applications, such as in leveling devices and thickness gauges, and in radiotherapy in hospitals. Large sources of cobalt-60 are increasingly used for sterilization of spices and certain foods. The powerful gamma rays kill bacteria and other pathogens, without damaging the product. After the radiation ceases, the product is not left radioactive. This process is sometimes called "cold pasteurization."

Cobalt-60 is also used for industrial radiography, a process similar to an x-ray, to detect structural flaws in metal parts. One of its uses is in a medical device for the precise treatment of otherwise inoperable deformities of blood vessels and brain tumors. Radionuclides, such as cobalt-60, that are used in industry or medical treatment are encased in shielded metal containers or housings, and are referred to as radiation ‘sources.' The shielding keeps operators from being exposed to the strong radiation.

Exposure to Cobalt-60

How does cobalt-60 get into the environment?
Occasionally, medical or industrial radiation sources are lost or stolen. We call these "orphan sources." They pose a significant risk:
 * On a number of occasions, people have handled them, not knowing what they were, and have been exposed.
 * Sometimes sources find their way into municipal landfills, where it is illegal to dispose of them.
 * Because of their metallic housings, sources can get mixed in with scrap metal and pass undetected into scrap metal recycling facilities. If melted in a mill, they can contaminate the entire batch of metal and the larger facility, costing millions of dollars in lost productivity and cleanup costs. The scrap industry uses radiation detectors to screen incoming material. However, sources that are under large loads may be undetected initially.
Cobalt-60 can also be released to the environment through leaks or spills at nuclear power plants, and in solid waste originating from nuclear power plants. Nuclear Regulatory Commission regulations allow small amounts of cobalt-60 to be released into the air, or poured down drains as part of a liquid.

How does cobalt-60 change in the environment?
Cobalt-60 undergoes radioactive decay with the emission of beta particles and strong gamma radiation. It ultimately decays to non radioactive nickel. The half-life of cobalt-60 is 5.27 years. This is short enough to make isolation a useful treatment strategy for contaminated areas. In some cases, simply waiting 10 to 20 years allows for sufficient decay to make the site acceptable for use again.

How do people come in contact with cobalt-60?
Most exposure to cobalt-60 takes place intentionally during medical tests and treatments. Such exposures are carefully controlled to avoid the adverse health impacts and to maximize the benefits of medical care. Accidental exposures may occur as the result of loss or improper disposal of medical and industrial radiation sources. Though relatively rare, exposure has also occurred by accidental mishandling of a source at a metal recycling facility or steel mill.

How does cobalt-60 get into the body?
People may ingest cobalt-60 with food and water that has been contaminated, or may inhale it in contaminated dust. The major concern posed by cobalt-60, however, is external exposure to its strong gamma rays. This may occur if you are exposed to an orphaned source, or if you come in contact with waste from a nuclear reactor (though this is very unlikely).

What does cobalt do once it gets into the body?
Once in the body, some cobalt-60 is quickly eliminated in the feces. The rest is absorbed into the blood and tissues, mainly the liver, kidney, and bones. Absorbed cobalt leaves the body slowly, mainly in the urine.
Health Effects of Cobalt-60
How can cobalt-60 affect people's health?

All ionizing radiation, including that of cobalt-60, is known to cause cancer. Therefore, exposures to gamma radiation from cobalt-60 result in an increased risk of cancer.

Because it emits such strong gamma rays, external exposure to cobalt-60 is also considered a significant threat. The magnitude of the health risk depends on the quantity of cobalt-60 involved and on exposure conditions:

* length of exposure
* distance from the source (for external exposure)
* whether the cobalt-60 was ingested or inhaled.

Is there a medical test to determine exposure to cobalt-60?

Yes, there are several. However they are not routinely available in a doctor's office because they require special laboratory equipment. Some tests can measure the amount of cobalt-60 in urine, even at very low levels. Scientist can estimate the amount in the body from the amount measured in the urine. A technique called "whole-body counting" can detect gamma radiation emitted by cobalt-60 in the body. A variety of portable instruments can directly measure cobalt-60 on the skin or hair. Other techniques include measuring the level of cobalt-60 in soft tissues (such as organs) and in blood, bones, milk, or feces.

Protecting People from Cobalt-60

How do I know if I'm near cobalt-60?

You need special equipment to detect the presence of any radionuclide.

What can I do to protect myself and my family from cobalt-60?

You are unlikely to encounter cobalt-60 unless you undergo certain medical treatments. Thorough discussions with your doctor about the amount of exposure and potential alternatives allow you to make informed decisions about the relative risks. Although it is very unlikely, you may accidentally encounter a sealed radiation source containing cobalt-60 that has escaped proper control ("orphaned sources").

What is EPA doing about cobalt-60?

Cobalt-60 is regulated by both the EPA and the Nuclear Regulatory Commission. The Nuclear Regulatory Commission has jurisdiction over the licensing and use of cobalt-60 sources, and disposal of cobalt-60 sources.

EPA has several regulations that control cobalt-60 in the environment:

* standards for the maximum amount of cobalt-60 that nuclear facilities may release to the air
* maximum contaminant levels for cobalt-60 in drinking water
* risk-based criteria for soil and groundwater at sites previously contaminated with cobalt-60.

IODINE

Iodine (chemical symbol I) is a nonmetallic solid element. There are both radioactive and non-radioactive isotopes of iodine. Iodine-129 and -131 are the most important radioactive isotopes in the environment. Some isotopes of iodine, such as I-123 and I-124 are used in medical imaging and treatment, but are generally not a problem in the environment because they have very short half-lives.

Who discovered iodine and radioactive iodine?

In 1811, Bernard Courtois discovered natural iodine in water that was used to dissolve certain parts of seaweed ash for use. Radioactive iodine-131 was discovered by Glenn T. Seaborg and John Livingood at the University of California - Berkeley in the late 1930's.

Where do iodine-129 and iodine-131 come from?

Both iodine-129 and iodine-131 are produced by the fission of uranium atoms during operation of nuclear reactors and by plutonium (or uranium) in the detonation of nuclear weapons.

What are the properties of iodine-129 and iodine-131?

Radioactive iodines have the same physical properties as stable iodine. However, radioactive iodines decay with time. Iodine is a nonmetallic, purplish-black crystalline solid. It has the unusual property of ‘sublimation,' which means that it can go directly from a solid to a gas, without first becoming liquid. It sublimes to a deep violet vapor at room temperature. This vapor is irritating to the eyes, nose and throat. Iodine dissolves in alcohol and in water. It melts at 236 °F.

Iodine reacts easily with other chemicals, and isotopes of iodine are found as compounds rather than as a pure elemental nuclide. Thus, iodine-129 and -131 found in nuclear facilities and waste treatment plants quickly form compounds with the mixture of chemicals present. However, iodine released to the environment from nuclear power plants is usually a gas.

Iodine-129 has a half-life of 15.7 million years; iodine-131 has a half-life of about 8 days. Both emit beta particles upon radioactive decay.

What are iodine radioisotopes used for?

Iodines are among the most widely used radionuclides, mostly in the medical field. Because of its short half-life and useful beta emission, iodine-131 is used extensively in nuclear medicine.

- Its tendency to collect in the thyroid gland makes iodine especially useful for diagnosing and treating thyroid problems. Iodine-123 is widely used in medical imaging, and I-124 is useful in immunotherapy.
- Iodine's chemical properties make it easy to attach to molecules for imaging studies. It is useful in tracking the metabolism of drugs or compounds, or for viewing structural defects in various organs, such as the heart.
- A less common isotope, iodine-125, is sometimes used to treat cancerous tissue.

Iodine-129 has little practical use, but may be used to check some radioactivity counters in diagnostic testing laboratories.

Exposure to Iodine-129 and Iodine-131

How do iodine-129 and iodine-131 get into the environment?

Iodine-129 and iodine-131 are gaseous fission products that form within fuel rods as they fission. Unless reactor chemistry is carefully controlled, they can build up too fast, increasing pressure and causing corrosion in the rods. As the rods age, cracks or wholes may breach the rods.

Cracked rods can release radioactive iodine into the water that surrounds and cools the fuel rods. There, it circulates with the cooling water throughout the system, ending up in the airborne, liquid, and solid wastes from the reactor. From time to time, reactor gas capture systems release gases, including iodine, to the environment under applicable regulations.

Anywhere spent nuclear fuel is handled, there is a chance that iodine-129 and iodine-131 will escape into the environment. Nuclear fuel reprocessing plants dissolve the spent fuel rods in strong acids to recover plutonium and other valuable materials. In the process, they also release iodine-129 and -131 into the airborne, liquid, and solid waste processing systems. In the U.S., spent nuclear fuel is no longer reprocessed, because of concerns about nuclear weapons proliferation.

Currently, spent nuclear fuel remains in temporary storage at nuclear power plants around the country. If the nuclear waste repository at Yucca Mountain opens, it will provide permanent disposal for spent nuclear fuel and other high-level radioactive wastes. Wherever spent nuclear fuel is stored, the short-lived iodine-131 it contains will decay away quickly and completely. However, the long-lived iodine-129 will remain for millions of years. Keeping it from leaking into the environment, requires carefully designed, long-term safeguards.

The detonation of nuclear weapons also releases iodine-129 into the environment. Atmospheric testing in the 1950's and 60's released radioactive iodine to the atmosphere which has disseminated around the world, and is now found at very low levels in the environment. Most I-129 in the environment came from weapons testing.

How do iodine-129 and iodine-131 change in the environment?

Radioactive iodine can disperse rapidly in air and water, under the right conditions. However, it combines easily with organic materials in soil. This is known as ‘organic fixation' and slows iodine's movement in the environment. Some soil minerals also attach to, or adsorb, iodine, which also slows its movement.

The long half-life of iodine-129, 15.7 million years, means that it remains in the environment. However, iodine-131's short half-life of 8 days means that it will decay away completely in the environment in a matter of months. Both decay with the emission of a beta particle, accompanied by weak gamma radiation.

How do people come in contact with iodine-129 and iodine-131?

Radioactive iodine can be inhaled as a gas or ingested in food or water. It dissolves in water so it moves easily from the atmosphere into humans and other living organisms. People are exposed to I-129 from the past testing of nuclear weapons, and I-131 from nuclear power plant emissions. Some industrial facilities also emit radioactive iodine to the environment, as well as medical institutions. Radioactive iodine is usually emitted as a gas, but may contaminate liquids or solid materials as well. If a family member has been treated with I-131, you may have increased exposure to it through their body fluids.

How do iodine-129 and iodine-131 get into the body?

Radioactive iodine can enter the body by ingestion or inhalation. It dissolves in water so it moves easily from the atmosphere into humans and other living organisms. For example, I-129 and -131 can settle on grass where cows can eat it and pass it to humans through their milk. It may settle on leafy vegetables and be ingested by humans. Iodine isotopes also concentrate in marine and freshwater fish, which people may then eat.

Also, doctors may give thyroid patients radioactive iodine, usually iodine-131, to treat or help diagnose certain thyroid problems. The tendency of iodine to collect in the thyroid makes it very useful for highlighting parts of its structure in diagnostic images.

- Exposure from Iodine 131 (Centers for Disease Control)

What do iodine-129 and iodine-131 do once they get into the body?

When I-129 or I-131 is ingested, some of it concentrates in the thyroid gland. The rest passes from the body in urine.

Airborne I-129 and I-131 can be inhaled. In the lung, radioactive iodine is absorbed, passes into the blood stream, and collects in the thyroid. Any remaining iodine passes from the body with urine.

In the body, iodine has a biological half-life of about 100 days for the body as a whole. It has different biological half-lives for various organs: thyroid - 100 days, bone - 14 days, and kidney, spleen, and reproductive organs - 7 days.

Health Effects of Iodine-129 and Iodine-131

How can iodine-129 and iodine-131affect people's health?

Radioactive iodine can cause thyroid problems, and help diagnose and treat thyroid problems. Long-term (chronic) exposure to radioactive iodine can cause nodules, or cancer of the thyroid. However, once thyroid cancer occurs, treatment with high doses of I-131 may be used to treat it. Doctors also use lower doses of I-131 to treat overactive thyroids.

Low doses can reduce activity of the thyroid gland, lowering hormone production in the gland. Doctors must maintain the fine balance between the risks and benefits of using radioactive iodine. On one hand, this small, additional exposure may tip the balance in favor of cancer formation. On the other, this small additional exposure can restore health by slowing an overactive thyroid and improve health conditions.

Is there a medical test to determine exposure to iodine-129 and iodine-131?
Since iodine is concentrated in the thyroid gland, a radioassay of the thyroid can determine the level of exposure to many of its isotopes. However, I-129 has very low activity and emits extremely low energy beta particles, making a radioassay much more difficult. Tests for I-131 in the body should be available through most major medical centers.

Protecting People from Iodine-129
How do I know if I'm near radioactive iodine?
Living near a nuclear power plant may slightly increase your annual exposure to I-131. Detecting radioactive iodine in the environment requires specialized equipment. Most major medical centers can test for isotopes of iodine in your body.

What can I do to protect myself and my family from iodine-129 and iodine-131?
The thyroid cannot tell the difference between radioactive and non-radioactive iodine. It will take up radioactive iodine in whatever proportion it is available in the environment.
If large amounts of radioactive iodine are released during an nuclear accident, large doses of stable iodine may be distributed by government agencies to keep your thyroid gland from absorbing too much radioactive iodine: Raising the concentration of stable iodine in the blood, increases the likelihood that the thyroid will absorb it instead of radioactive iodine. (Note: Large doses of stable iodine can be a health hazard and should not be taken except in an emergency. However iodized table salt is an important means of acquiring essential non-radioactive iodine to maintain health).

"What is EPA doing about iodine-129 and iodine-131?
EPA has issued a variety of regulations that limit the release of radionuclides, including I-129 and I-131, to the environment. These regulations address airborne and liquid releases from nuclear reactors, airborne emissions from a variety of industrial and governmental facilities, and allowable radioactive releases from radioactive waste disposal systems.
EPA has established Maximum Contaminant Levels that limit the concentration of radioactive iodine and other radionuclides in drinking water from public water suppliers.
Recently, EPA issued its environmental standards for the potential waste repository at Yucca Mountain, Nevada. Iodine-129 is one of the more important radionuclides of concern in the large inventory of spent reactor fuel and defense high-level waste. This standard limits the radiation exposure of individuals, and radionuclide concentrations in ground water from the release of I-129 and other radionuclides in the vicinity of Yucca Mountain.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

How do I know if I'm near plutonium?
You must have special equipment to detect the presence of plutonium.

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.

Radium
Radium (chemical symbol Ra) is a naturally-occurring radioactive metal. Its most common isotopes are radium-226, radium 224, and radium-228. Radium is a radionuclide formed by the decay of uranium and thorium in the environment. It occurs at low levels in virtually all rock, soil, water, plants, and animals.

Who discovered radium?
Radium was discovered in 1898 by French physicist and Nobel laureate Marie Curie in pitchblende (a uranium and radium-bearing mineral). There is about 1 gram of radium in 7 tons of pitchblende. Elemental radium was isolated by Mme. Curie in 1911.

Where does radium come from?
Radium forms when isotopes of uranium or thorium decay in the environment. Most radium (radium-226) originates from the decay of the plentiful uranium-238.

In the natural environment, radium occurs at very low levels in virtually all rock, soil, water, plants, and animals. When uranium (or thorium) occurs in high levels in rock, radium is often also found in high levels.

What are the properties of radium?

Radium is a naturally radioactive, silvery-white metal when freshly cut. It blackens on exposure to air.

Purified radium and some radium compounds glow in the dark (luminesce). The radiation emitted by radium can also cause certain materials, called "phosphors" to emit light. Mixtures of radium salts and appropriate phosphors were widely used for clock dials and gauges before the risks of radium exposure were understood.

Metallic radium is highly chemically reactive. It forms compounds that are very similar to barium compounds, making separation of the two elements difficult.

The various isotopes of radium originate from the radioactive decay of uranium or thorium. Radium-226 is found in the uranium-238 decay series, and radium-228 and -224 are found in the thorium-232 decay series.

Radium-226, the most common isotope, is an alpha emitter, with accompanying gamma radiation, and has a half-life of about 1600 years. Radium-228, is principally a beta emitter and has a half-life of 5.76 years. Radium-224, an alpha emitter, has a half life of 3.66 days. Radium decays to form isotopes of the radioactive gas radon, which is not chemically reactive. Stable lead is the final product of this lengthy radioactive decay series.

What is radium used for?

In the early 1900's, when it was newly discovered, no one understood the dangers of radium. People were fascinated with its mysterious properties, especially the luminescence produced when it is mixed with a phosphor. Industries sprang up to manufacture hundreds of consumer products containing radium. Advertisements proclaimed its special powers and unique effects in such products such as hair tonic, toothpaste, ointments, and elixirs. Glow in the dark watch and clock faces were immensely popular.

Most of its original uses have been halted for health and safety reasons, but its wide use in luminescent paints continued through World War II, because the soft glow of radium's luminescence made aircraft dials, gauges and other instruments visible to their operators at night. Radium was also an early radiation source for cancer treatment. Small seeds were implanted in tumors to kill cancerous cells. Safer, more effective radiation sources, such as cobalt-60 have mostly replaced it.

Radium is a radiation source in some industrial radiography devices, a technology similar to x-ray imaging used in industry to inspect for flaws in metal parts. When radium is mixed with beryllium it becomes a good source of neutrons, useful in well logging devices and research. Radium also has been added to the tips of lightening rods, improving their effectiveness by ionizing the air around it.

Exposure to Radium

How does radium get into the environment?

Radium occurs naturally in the environment. As a decay product of uranium and thorium, it is common in virtually all rock, soil, and water. Usually concentrations are very low. However, geologic processes can form concentrations of naturally radioactive elements, especially uranium and radium. Radium and its salts are soluble in water. As a result, groundwater in areas where concentrations of radium are high in surrounding bedrock typically has relatively high radium content.

How does radium change in the environment?

All isotopes of radium are radioactive. As they decay, they emit radiation and form new radioactive elements, until they reach stable lead. Isotopes of radium decay to form different isotopes of radon. For example, radium-226 decays to radon-222, and radium-228 goes through several decays to radium-224 before forming radon-220.

How do people come in contact with radium?

Since radium is present at low levels in the natural environment, everyone has some minor exposure to it. However, individuals may be exposed to higher levels of radium if they live in an area where there is an elevated level of radium in the surrounding rock and soil. Private well water in such areas can also be an added source of radium.

The concentration of radium in drinking water is generally low, but there are specific geographic regions in the United States where higher concentrations of radium occur in water due to geologic sources. Limited information is available about the amounts of radium that are typically present in food and air, but they are very low.

People can also be exposed to radium if it is released into the air from the burning of coal or other fuels. Certain occupations can also lead to high exposures to radium, such as working in a uranium mine or in a plant that processes ores. Phosphate rocks typically contain relatively high levels of both uranium and radium and can be a potential source of exposure in areas where phosphate is mined.

In some parts of the country, former radium processing plants exist that were highly contaminated with radium. However, most of these have been cleaned up and do not pose a serious health threat any longer.

Radium emits several different kinds of radiation, in particular, alpha and gamma radiation. Alpha radiation is only a concern if radium is taken into the body through inhalation or ingestion. Gamma radiation, or rays, can expose individual even at a distance. As a result, radium on the ground, for example, can expose individuals externally to gamma rays or be inhaled or ingested with contaminated food or water. The greatest health risk from radium in the environment, however, is actually its decay product radon, which can collect in buildings.

How does radium get into the body?

People may swallow radium with food and water, or may inhale it as part of dust in the air. Radium can also be produced in the body from "parent" radionuclides (uranium and thorium) that have been inhaled or swallowed, but this is not a significant source.

What does radium do once it gets into the body?
Most radium that is swallowed (about 80%) promptly leaves the body through the feces. The other 20% enters the bloodstream and accumulates preferentially in the bones. Some of this radium is excreted through the feces and urine over a long time. However, a portion will remain in the bones throughout the person's lifetime.

Health Effects of Radium
How can radium affect people's health?
Radium emits several different kinds of radiation, in particular, alpha particles and gamma rays. Alpha particles are generally only harmful if emitted inside the body. However, both internal and external exposure to gamma radiation is harmful. Gamma rays can penetrate the body, so gamma emitters like radium can result in exposures even when the source is a distance away.
Long-term exposure to radium increases the risk of developing several diseases. Inhaled or ingested radium increases the risk of developing such diseases as lymphoma, bone cancer, and diseases that affect the formation of blood, such as leukemia and aplastic anemia. These effects usually take years to develop. External exposure to radium's gamma radiation increases the risk of cancer to varying degrees in all tissues and organs.
However, the greatest health risk from radium is from exposure to its radioactive decay product radon. It is common in many soils and can collect in homes and other buildings.
 * Radon
 This fact sheet describes the basic properties and uses, and the hazards associated with this radionuclide. It also discusses radiation protection related to it.
 * Radon Home Page
 This site provides information about the hazards and management of radon.

Is there a medical test to determine exposure to radium?
There are tests that can determine exposure to radium or other radioactive substances. For example, a whole body count can measure the total amount of radioactivity in the body, and urine and feces can be tested for the presence of radionuclides.
These tests are not routinely performed in a doctor's office because it requires special laboratory equipment. There is no test that can detect external exposure to radium's gamma radiation, unless the doses were very high, and cellular damage is detectable.

Protecting People from Radium
How do I know radium if I'm near radium?
You need special equipment to detect the presence of radium. However, you can buy radon detection kits at most hardware stores.

What can I do to protect myself and my family from radium?
The most effective way to protect yourself and your family is to test your home for radium's decay product, radon.
 * Radon Home Page
 This site provides information about the hazards and management of radon.

What is EPA doing about radium?
The U.S. Congress passes laws that authorize EPA and other federal agencies, to protect public health and the environment from radium and other radioactive materials. EPA has issued a variety of regulations that limit the release of radium and other radionuclides to the environment. For example, Congress passed the Uranium Mill Tailings Radiation Control Act (UMTRCA). EPA has established standards for cleaning up and managing leftover uranium ore at inactive ore-processing plants under the authority of UMTRCA. The U.S. Department of Energy is responsible for conducting the cleanups, and the U.S. Nuclear Regulatory Commission oversees and manages them.
 * UMTRCA
 This page provides a summary and link to the full statute.
Complementing these efforts, EPA's Superfund program identifies abandoned industrial sites contaminated with radium and other radionuclides and chemicals. It then assesses the health and environmental risks the sites pose, and assigns priorities for cleaning them up based on those risks. Superfund regulations require sites to be cleaned up to the point that people living on the sites after cleanup would have no more than a 1-in-10,000 to a 1-in-1,000,000 increased risk of developing cancer from exposure to contaminants.
 * CERCLA
 This page provides a summary and a link to the complete statute.
 * Superfund
 This site contains information about individual Superfund sites.
Other laws passed by Congress address specific environmental media. The Clean Air Act authorizes EPA to establish annual limits, known as National Emission Standards for Hazardous Air Pollutants, for the maximum amount of radium and other radionuclides that may be released to the air. For radium the "NESHAP" is 10 millirem. The Safe Drinking Water Act authorizes EPA to limit the Maximum Contaminant Levels of radium and other radionuclides in publicly supplied drinking water. For 226 and 228 radium, the MCL is 5 picocuries per liter and for 224 radium it is 15pCi/l. Both the air and water standards limit the increased lifetime cancer risk to about 2 in 10,000.

- Clean Air Act
  This page provides a summary and a link to the complete act.
- Safe Drinking Water Act
  This page provides a summary and a link to the complete act.

Radon

Radon (chemical symbol Rn) is a naturally occurring radioactive gas found in soils, rock, and water throughout the U.S. It has numerous different isotopes, but radon-220, and -222 are the most common. Radon causes lung cancer, and is a threat to health because it tends to collect in homes, sometimes to very high concentrations. As a result, radon is the largest source of exposure to naturally occurring radiation.

Who Discovered Radon?

The German chemist Friedrich E. Dorn discovered radon-222 in 1900, and called it radium emanation. However, a scarcer isotope, radon-220, was actually observed first, in 1899, by the British scientist, R.B. Owens, and the New Zealand scientist, Ernest Rutherford. The medical community nationwide became aware of the possible extent of a radon problem in 1984. That year a nuclear plant worker in Pennsylvania discovered radioactivity on his clothing while exiting his place of work through the radiation detectors. The source of the radiation was determined to be radon decay products on his clothing originating from his home.

Where does radon come from?

Radon-222 is the decay product of radium-226. Radon-222 and its parent, radium-226, are part of the long decay chain for uranium-238. Since uranium is essentially ubiquitous in the earth's crust, radium-226 and radon-222 are present in almost all rock and all soil and water.

- Decay Chains - Uranium Decay
  This links provides an illustration of uranium-238 decays through a series of steps to become a stable form of lead.
- Uranium
  This fact sheet describes the basic properties and uses, and the hazards associated with this radionuclide. It also discusses radiation protection related to it.

What are the properties of radon?

Radon is a noble gas, which means it is essentially inert, and does not combine with other chemicals. Radon is a heavy gas, which accounts for its tendency to collect in basements or other low places in housing. It has no color, odor, or taste. Radon-222 is produced by the decay of radium, has a half-life of 3.8 days, and emits an alpha particle as it decays to polonium-218, and eventually to stable lead. Radon-220, is the decay product of thorium – it is sometimes called thoron, has a half-life of 54.5 seconds and emits an alpha particle in its decay to polonium-216.

Does radon have any practical uses?

Radon has little practical use. Some medical treatments have employed radon in small sealed glass tubes, called seeds, that are specially manufactured to contain the exact amount of radioactivity needed for the application. Radon spas are used extensively in Russia and Central Europe to treat a number of conditions.

Exposure to Radon

How does radon get into the environment?

Radon-222 is the radioactive decay product of radium-226, which is found at low concentrations in almost all rock and soil. Radon is generated in rock and soil, and it creeps through cracks or spaces between particles up to the outside air. Although outdoor concentrations of radon are typically low, about 0.4 picocuries per liter (pCi/l) of air, it can seep into buildings through foundation cracks or openings and build up to much higher concentrations indoors, if the sources are large enough.

The average indoor radon concentration is about 1.3 pCi/l of air. It is not uncommon, though, for indoor radon levels to be found in the range of 5 - 50 pCi/l, and they have been found as high as 2,000 pCi/l. The concentration of radon measured in a house depends on many factors, including the design of the house, local geology and soil conditions, and the weather. Radon's decay products are all metallic solids, and when radon decay occurs in air, the decay products can cling to aerosols and dust, which makes them available for inhalation into the lungs.

Radon easily dissolves in water. In areas of the country that have high radium content in soils and rocks, local ground water may contain high concentrations of radon. For example, underlying rock such as granite, or phosphate rock, typically have increased uranium and radium, and therefore radon. While radon easily dissolves into water, it also easily escapes from water when exposed to the atmosphere, especially if it is stirred or agitated. Consequently, radon concentrations are very low in rivers and lakes, but could still be high in water pumped from the ground. Some natural springs, such as those at Hot Springs, Arkansas, contain radon, and were once considered healthful.

- Radon in Water
  This site provides informatiom Public Health Standards for Radon in Drinking Water
- Radon Home Page
  This site provides information about the hazards and management of radon.
- EPA Map of Radon Zones

The purpose of this map is to assist National, State, and local organizations to target their resources and to implement radon-resistant building codes.

How does radon change in the environment?

Because radon is a chemically inert (unreactive) gas, it can move easily through rock and soil and arrive at the surface. The half-life of radon-222 is 3.8 days. As it undergoes radioactive decay, radon-222 releases alpha radiation and changes to polonium-218, a short-lived radioactive solid. After several more decay transformations, the series ends at lead-206, which is stable.

Radon dissolves in water, and easily leaves water that is exposed to the atmosphere, especially if the water is agitated. Consequently, radon levels are very low in rivers and lakes, but water drawn from underground can have elevated radon concentrations. Radon that decays in water, leaves only solid decay products which will remain in the water as they decay to stable lead.

How are people exposed to radon?

Most of the public's exposure to natural radiation comes from radon which can be found in homes, schools, and office buildings. EPA estimates that the national average indoor radon level in homes is about 1.3 pCi/l of air. We also estimate that about 1 in 15 homes nationwide have levels at or above the level of 4 pCi/l, the level at which EPA recommends taking action to reduce concentrations. Levels greater than 2,000 pCi/l of air have been measured in some homes.

Radon is also found in the water in homes, in particular, homes that have their own well rather than municipal water. When the water is agitated, as when showering or washing dishes, radon escapes into the air. However, radon from domestic water generally contributes only a small proportion (less than 1%) of the total radon in indoor air in most housing. Municipal water systems hold and treat water, which helps to release radon, so that levels are very low by the time the water reaches our homes. But, people who have private wells, particularly in areas of high radium soil content, may be exposed to higher levels of radon.

* Radon in Water

This site provides informatiom Public Health Standards for Radon in Drinking Water

* Radon Home Page

This site provides information about the hazards and management of radon.

How does radon get into the body?

People may ingest trace amounts of radon with food and water, However, inhalation is the main route of entry into the body for radon and its decay products. Radon decay products may attach to particulates and aerosols in the air we breathe (for example, cooking oil vapors). When they are inhaled, some of these particles are retained in the lungs. Radon decay products also cling to tobacco leaves, which are sticky, during the growing season, and enter the lungs when tobacco is smoked. Smoke in indoor environments also is very effective at picking up radon decay products from the air and making them available for inhalation. It is likely that radon decay products contribute significantly to the risk of lung cancer from cigarette smoke.

What does radon do once it gets into the body?

Most of the radon gas that you inhale is also exhaled. However, some of radon's decay products attach to dusts and aerosols in the air and are then readily deposited in the lungs. Some of these are cleared by the lung's natural defense system, and swallowed or coughed out. Those particles that are retained long enough release radiation damaging surrounding lung tissues. A small amount of radon decay products in the lung are absorbed into the blood.

Most of the radon ingested in water is exhaled in hours. There is some risk from drinking water with elevated radon, because radioactive decay can occur within the body where tissues, such as the stomach lining, would be exposed. However, alpha particles emitted by radon and its decay product in water prior to drinking quickly lose their energy and are taken up by other compounds in water, and do not themselves pose a health concern.

Health Effects of Radon

How can radon affect people's health?

Almost all risk from radon comes from breathing air with radon and its decay products. Radon decay products cause lung cancer. The health risk of ingesting radon, in water for example, is dwarfed by the risk of inhaling radon and its decay products. They occur in indoor air or with tobacco smoke. Alpha radiation directly causes damage to sensitive lung tissue. Most of the radiation dose is not actually from radon itself, though, which is mostly exhaled. It comes from radon's chain of short-lived solid decay products that are inhaled on dust particles and lodge in the airways of the lungs. These radionuclides decay quickly, producing other radionuclides that continue damaging the lung tissue.

There is no safe level of radon--any exposure poses some risk of cancer. In two 1999 reports, the National Academy of Sciences (NAS) concluded after an exhaustive review that radon in indoor air is the second leading cause of lung cancer in the U.S. after cigarette smoking. The NAS estimated that 15,000-22,000 Americans die every year from radon-related lung cancer.

When people who smoke are exposed to radon as well, the risk of developing lung cancer is significantly higher than the risk of smoking alone.

The NAS also estimated that radon in drinking water causes an additional 180 cancer deaths annually. However almost 90% of those projected deaths were from lung cancer from the inhalation of radon released to the indoor air from water, and only about 10% were from cancers of internal organs, mostly stomach cancers, from ingestion of radon in water.

Is there a medical test to determine exposure to radon?

Several decay products can be detected in urine, blood, and lung and bone tissue. However, these tests are not generally available through typical medical facilities. Also, they cannot be used to determine accurate exposure levels, since most radon decay products deliver their dose and decay within a few hours.

The best way to assess exposure to radon is by measuring concentrations of radon (or radon decay products) in the air you breathe at home.

Protecting People from Radon

How do I know if there is radon in my home?

You cannot see, feel, smell, or taste radon. Testing your home is the only way to know if you and your family are at risk from radon. EPA and the Surgeon General recommend testing for radon in all rooms below the third floor. EPA also recommends testing in schools.

The EPA Citizen's Guide to Radon describes commonly available tests for measuring radon concentrations in the home. (See "What is EPA Doing About Radon?".)

Radon testing is inexpensive and easy--it should only take a few minutes of your time. Millions of Americans have already tested their homes for radon. Various low-cost, do-it-yourself test kits are available through the mail and in hardware stores and other retail outlets. You can also hire a trained contractor to do the testing for you.

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

The first step is to test your home for radon, and have it fixed if it is at or above EPA's Action Level of 4 picocuries per liter. You may want to take action if the levels are in the range of 2-4 picocuries per liter. Generally, levels can be brought below 2 pCi/l fairly simply.

The best method for reducing radon in your home will depend on how radon enters your home and the design of your home. For example, sealing cracks in floors and walls may help to reduce radon. There are also systems that remove radon from the crawl space or from beneath the concrete floor or basement slab that are effective at keeping radon from entering your home. These systems are simple and don't require major changes to your home. Other methods may be necessary.

People who have private wells should test their well water to ensure that radon levels meet EPA's newly proposed standard.

* Radon in Drinking Water
  This page provides information on regulations, studies, and state contacts related to radon in drinking water.
* Radon
  This page provides access to a wide variety of information and publications on radon and preventing exposure to radon.
* National Radon Hotline:
  800.767-7236

What recommendations has the federal government made to protect human health from radon?

In 1988, EPA and the U.S. Surgeon General issued a Health Advisory recommending that all homes be tested below the third floor for radon. They also recommended fixing homes with radon levels at or above 4 picocuries per liter (pCi/L), EPA's National Voluntary Action Level. EPA and the Surgeon General also recommend that schools nationwide be tested for radon.

* EPA Radon Publications, including:
    o EPA's "A Citizen's Guide to Radon
    o "Consumer's Guide to Radon Reduction

What is EPA doing about radon?

EPA has established a voluntary program to promote radon awareness, testing, and reduction. The program sets an ‘Action Level' of 4 picocuries per liter (pCi/l) of air for indoor radon. The action level is not the maximum safe level for radon in the home. Instead it is the point at which the cost to the homeowner for fixing the problem (taking action) is warranted by the risk from the radon. However, the lower the level of radon, the better. Generally, levels can be brought below 2 pCi/l fairly simply.

In addition to working with homeowners, EPA is working with home builders and building code organizations. The goals are to help newly constructed homes be more radon resistant and to encourage radon testing when existing homes are sold.

* Radon Resistant New Construction
  This page provides information on radon resistant homes.
* Radon and Real Estate
  You will find a number of tools and resources use by the real estate community that EPA and its radon partners has developed.

The 1988 Indoor Radon Abatement Act authorizes EPA to provide grants to states to support testing and reducing radon in homes.

With various non-governmental and public health organizations, EPA promotes awareness and reduction of indoor radon. Partners include the American Lung Association, the National Environmental Health Association, the American Society of Home Inspectors, and the National Safety Council. The Radon Publications page provides a list of EPA-sponsored publications in English and Spanish.

EPA has also proposed a standard for the maximum amount of radon that may be found in drinking from community water systems using ground water.

* Proposed Radon Rule
  to set maximum contaminant levels in drinking water.

Strontium

Strontium (chemical symbol Sr) is a silvery metal that rapidly turns yellowish in air. Strontium is found naturally as a non-radioactive element. Strontium has 16 known isotopes. Naturally occurring strontium is found as four stable isotopes Sr-84, -86, -87, and -88. Twelve other isotopes are radioactive. Strontium-90 is the most important radioactive isotope in the environment, although strontium-89 can be found around reactors, and strontium-85 is used in industry and medicine.

Who discovered strontium?

In 1790 Adair Crawford and William Cruikshank first detected non-radioactive strontium in the mineral strontianite in Scotland. Metallic strontium was isolated in 1808 by Sir Humphry Davy.

Radioactive Sr-90, like many other radionuclides, was discovered in the 1940s in nuclear experiments connected to the development of the atomic bomb.

Where does strontium-90 come from?

Strontium-90 is a by-product of the fission of uranium and plutonium in nuclear reactors, and in nuclear weapons. Strontium-90 is found in waste from nuclear reactors. It can also contaminate reactor parts and fluids. Large amounts of Sr-90 were produced during atmospheric nuclear weapons tests conducted in the 1950s and 1960s and dispersed worldwide.

What are the properties of strontium-90?

Non-radioactive strontium and its radioactive isotopes have the same physical properties. Strontium is a soft metal similar to lead. Strontium is chemically very reactive, and is only found in compounds in nature.

When freshly cut, it has a silvery luster, but rapidly reacts with air and turns yellow. Finely cut strontium will burst into flame in air. Because of these qualities, it is generally stored in kerosene.

Strontium-90 emits a beta particle with, no gamma radiation, as it decays to yttrium-90 (also a beta-emitter). Strontium-90 has a half-life of 29.1 years. It behaves chemically much like calcium, and therefore tends to concentrate in the bones and teeth.

What is strontium-90 used for?

Strontium-90 is used as a radioactive tracer in medical and agricultural studies. The heat generated by strontium-90's radioactive decay can be converted to electricity for long-lived, portable power supplies. These are often used in remote locations, such as in navigational beacons, weather stations, and space vehicles.

Strontium-90 is also used in electron tubes, as a radiation source in industrial thickness gauges, and for the treatment of eye diseases. Controlled amounts of strontium-90 have been used as a treatment for bone cancer.

Exposure to Strontium-90

How does strontium-90 get into the environment?

Strontium-90 was widely dispersed in the 1950s and 1960s in fall out from atmospheric testing of nuclear weapons. It has been slowly decaying since then so that current levels from these tests are very low.

Strontium-90 is also found in waste from nuclear reactors. It is considered one of the more hazardous constituents of nuclear wastes. The accident at the Chernobyl nuclear power plant also introduced a large amount of Sr-90 into the environment. A large part of the Sr-90 was deposited in the Soviet Republics. The rest was dispersed as fallout over Northern Europe and worldwide. No significant amount of stronium-90 reached the U.S.

How does strontium-90 change in the environment?

As strontium-90 decays, it releases radiation and forms yttrium-90 (Y-90), which in turn decays to stable zirconium. The half-life of Sr-90 is 29.1 years, and that of Yttrium-90 is 64 hours. Sr-90 emits moderate energy beta particles, and Y-90 emits very strong (energetic) beta particles. Strontium-90 can form many chemical compounds, including halides, oxides, and sulfides, and moves easily through the environment.

How do people come in contact with strontium-90?

Everyone is exposed to small amounts of strontium-90, since it is widely dispersed in the environment and the food chain. Dietary intake of Sr-90, however, has steadily fallen over the last 30 years with the suspension of nuclear weapons testing. People who live near or work in nuclear facilities may have increased exposure to Sr-90. The greatest concern would be the exposures from an accident at a nuclear reactor, or an accident involving high-level wastes.

How does strontium-90 get into the body?

People may inhale trace amounts of strontium-90 as a contaminant in dust. But, swallowing Sr-90 with food or water is the primary pathway of intake.

What does strontium-90 do once it gets into the body?

When people ingest Sr-90, about 70-80% of it passes through the body. Virtually all of the remaining 20-30% that is absorbed is deposited in the bone. About 1% is distributed among the blood volume, extracellular fluid, soft tissue, and surface of the bone, where it may stay and decay or be excreted.

Health Effects of Strontium-90

How can strontium-90 affect people's health?

Strontium-90 is chemically similar to calcium, and tends to deposit in bone and blood-forming tissue (bone marrow). Thus, strontium-90 is referred to as a "bone seeker." Internal exposure to Sr-90 is linked to bone cancer, cancer of the soft tissue near the bone, and leukemia.
Risk of cancer increases with increased exposure to Sr-90. The risk depends on the concentration of Sr-90 in the environment, and on the exposure conditions.

Is there a medical test to determine exposure to strontium-90?
The most common test for exposure to strontium-90 is a bioassay, usually by urinalysis. As with most cases of internal contamination, the sooner the test is taken after ingesting or inhaling the contaminant, the more accurate the results will be. Most major medical centers should be capable of performing this test.

Protecting People from Strontium-90
How do I know strontium if I'm near strontium-90?
Although you are exposed to tiny amounts of strontium-90 from past accidents and weapons testing, you cannot sense its presence. You need specialized equipment to detect Sr-90.

What can I do to protect myself and my family from strontium-90?
Strontium-90 dispersed in the environment, like that from atmospheric weapons testing, is almost impossible to avoid. You may also be exposed to tiny amounts from nuclear power reactors and certain government facilities. The more serious risk to you (though it is unlikely), is that you may unwittingly encounter an industrial instrument containing a Sr-90 radiation source. This is more likely if you work in specific industries:
 * scrap metal sorting, sales and brokerage
 * metal melting and casting
 * municipal landfill operations.
 * Radioactive Source Reduction and Management
 This site describes EPA's activities to reduce the use of radioactive sources in industry, track exisitng sources and recover orphan sources.

What is EPA doing about strontium-90?
EPA protects people and the environment from Sr-90 by establishing standards for the clean-up of contaminated sites, by setting limits on the amount of Sr-90 (and other radionuclides) that may be released to the air, and by setting limits on the amount of strontium-90 (and other radionuclides) that may be present in public drinking water.
EPA uses its authority under the Comprehensive Environmental Response, Compensation, and Liability Act (commonly known as "Superfund") to set standards for the clean-up of existing contaminated sites. Cleanups must meet all environmental requirements that are relevant or applicable, including state regulations and regulations issued in connection with other federal environmental laws.
When these types of regulations are unavailable, or not protective enough, EPA sets site-specific cleanup levels. Site-specific standards limit the chance of developing cancer because of exposure to a site-related carcinogen (such as strontium-90) to between one in 10,000 and one in 1,000,000.
 * Superfund: EPA Radiation Guidances and Reports
 This site provides information on radionuclides at Superfund sites.
 * EPA's Superfund Hotline: 1-800-424-9346 or 1-800-535-0202
EPA uses its Clean Air Act authority to set limits on the amount of radionuclides, such as Sr-90, that may be released to the air.
 * RadNESHAPS
 This site provides information on EPA's National Emission Standards for Hazardous Air Pollutants: Radionuclides.
EPA uses its Safe Drinking Water Act authority to establish maximum contaminant levels (MCLs) for beta emitters, such as strontium-90, in public drinking water. The MCL for beta emitters is 4 millirem per year or 8 picoCuries per liter of water.

Technetium-99
All isotopes of technetium are radioactive. Technetium-99, chemical symbol Tc-99, is a silver-gray, radioactive metal. It occurs naturally in minute amounts in the earth's crust, but is primarily man-made. The most commonly available isotope is Tc-99m (called metastable Tc-99) and is the shorter-lived parent of Tc-99.

Who discovered technetium-99?
In 1925, Ida Noddack-Tacke, Walter Noddack, and Otto Berg published an article in which they reported the discovery of element 43, which they named "masurium," in samples from uranium-rich ores. Because they were unable to concentrate masurium, the International Union of Pure and Applied Chemistry eventually rejected their discovery. Discovery of technetium in 1937 in the form of technetium-97 has been credited to Emilio Segré and Carlo Perrier at the University of California - Berkeley. Technetium-99m, one of the most common isotopes used in modern medicine, was developed by Glenn T. Seaborg and Emilio Segré.

Where does Technetium-99 come from?
Technetium-99 is produced in commercial quantities mainly as a byproduct from the operation of nuclear reactors. Most of the Tc-99 produced in a nuclear reactor originates from the fission of uranium-235. The Tc-99 produced in the reactor may become part of

its airborne, liquid, or solid wastes. In addition to being produced in nuclear reactors, Tc-99 is produced in the detonation of nuclear weapons.

Medical and academic institutions use molybdenum/technetium generators as a source of Tc-99m for diagnostic tests or research. In this case, the nuclear reactor provides the radioactive parent, molybdenum-99, for the technetium generator. Molybdenum-99 has a short (66 hour) half-life, and decays to the even shorter-lived (6 hrs) Tc-99m.

What are the properties of technetium-99?

Technetium-99 is silver-gray, radioactive metal. It occurs naturally only in very small amounts. Its melting point is 3,942 °F and its boiling point is 8,811 °F. It is also a very dense material--at room temperature, a mass of technetium-99 weighs 11.5 times as much as an equal volume of water.

Technetium-99 has a radioactive half-life of 212,000 years. Technetium-99m (called metastable Tc-99) has a half-life of only about 6 hours and decays to Tc-99 primarily by gamma emission. Technetium-99 decays to form ruthenium-99, which is stable, by emitting beta and gamma radiation.

Technetium exhibits the complex chemistry of a transition metal. It dissolves in nitric acid, aqua regia, and hot concentrated sulfuric acid, but is insoluble in hydrochloric acid.

What is technetium-99 used for?

Technetium-99 has no significant industrial use. Technetium-99 is found in the radioactive wastes from defense-related government facilities, nuclear reactor and fuel cycle facilities, academic institutions, hospitals, and research establishments.

Its short-lived parent, Tc-99m, however, is the most widely used radioactive isotope for medical diagnostic studies. Technetium-99m is used for medical and research purposes, including evaluating the medical condition of the heart, kidneys, lungs, liver, spleen, and bone, among others, and also for blood flow studies.

Exposure to Technetium-99

How does technetium-99 get into the environment?

Most Tc-99 in the environment comes from a few sources:

* the detonation of nuclear weapons (especially atmospheric weapons tests)
* nuclear reactor airborne emissions
* nuclear fuel reprocessing plant airborne emissions
* facilities that treat or store radioactive waste.

Extremely small amounts of Tc-99 have entered the environment near a few radioactive waste disposal sites.

How does technetium-99 change in the environment?

Given its long half-life, 212,000 years, Tc-99 remains in the environment. Air, sea water, soils, plants, and animals contain very low concentrations of Tc-99. Organic matter in soils and sediments slows the transport of Tc-99.

In the presence of oxygen, plants readily take up technetium compounds from the soils. Some plants such as brown algae living in seawater are able to concentrate Tc-99. Technetium-99 can also transfer from seawater to animals.

How are people exposed to technetium-99?

Tiny amounts of Tc-99 are part of the environment, and are therefore found in food and water. Higher amounts may be found close to contaminated facilities such as federal weapons facilities or nuclear fuel cycle facilities. Exposure to technetium from the environment is unlikely. Most human exposure to technetium comes from the use of Tc-99m in nuclear medicine.

How does technetium-99 get into the body?

Ingestion is the primary entry route for Tc-99 into the body. This may occur by eating food or drinking water contaminated with Tc-99.

What does Technetium-99 do once it gets into the body?

Once in the human body, Tc-99 concentrates in the thyroid gland and the gastrointestinal tract. The body, however, excretes half of the ingested Tc-99 within 60 hours. It continues to excrete half of the remaining Tc-99 every 60 hours that follow. After 120 hours, only one-fourth of the ingested Tc-99 remains in the body. Nearly all of ingested technetium will be excreted from the body within a month.

Health Effects of Technetium-99

How can technetium-99 affect people's health?

As with any radioactive material, there is an increased chance that cancer or other adverse health effects can result from exposure to radioactivity.

Is there a medical test to determine exposure to technetium-99?

Special tests that measure the level of radioactivity from Tc-99 or other technetium isotopes in the urine, feces, and exhaled air can determine if a person has been exposed to technetium. These tests are better done soon after exposure as the body constantly excretes Tc-99 once ingested. However, hair retains Tc-99 for long periods and can be an indicator of Tc-99 contamination. The tests require special equipment and cannot be done in a doctor's office.

Protecting People from Technetium-99

What are EPA and other government agencies doing about technetium-99?

EPA has issued a variety of regulations that limit the release of radionuclides, including Tc-99, to the environment. These regulations address the following potential sources:

- airborne and liquid releases from the nuclear fuel cycle
- airborne emissions from a variety of industrial and governmental facilities
- allowable radioactive releases from radioactive waste disposal systems.

Most recently, EPA finalized public health and environmental radiation protection standards for the potential high level waste repository at Yucca Mountain, Nevada. Because of the large quantity of spent nuclear fuel and defense high-level waste, Tc-99 is one of the more important radionuclides considered. The standards limit the radiation exposures of individuals and concentrations in ground water from the release of Tc-99 and other radionuclides in the vicinity of Yucca Mountain.

- Yucca Mountain Standards
  describes EPA's role in the repository
- The Department of Energy's Yucca Mountain Project
  describes DOE's role in building and licensing this DOE facility

EPA has established specific Maximum Contaminant Levels (MCLs) that limit the concentration of Tc-99 and other radionuclides in drinking water from public water supplies.

Tritium

Tritium (chemical symbol H-3) is a radioactive isotope of the element hydrogen (chemical symbol H).

Who discovered tritium?

Tritium was discovered by physicists Ernest Rutherford, M. L. Oliphant, and Paul Harteck, in 1934, when they bombarded deuterium (a hydrogen isotope with mass number 2) with high-energy deuterons (nuclei of deuterium atoms).

Where does tritium come from?

Tritium is produced naturally in the upper atmosphere when cosmic rays strike nitrogen molecules in the air. Tritium is also produced during nuclear weapons explosions, as a byproduct in reactors producing electricity, and in special production reactors, where the isotope lithium-6 is bombarded to produce tritium.

What are the properties of tritium?

Tritium is a hydrogen atom that has two neutrons in the nucleus, in addition to its single proton, giving it an atomic weight near three. Although tritium can be a gas, its most common form is in water, because, like non-radioactive hydrogen, radioactive tritium reacts with oxygen to form water. Tritium replaces one of the stable hydrogens in the water molecule, H2O, and is called tritiated water (HTO). Like H2O, tritiated water is colorless and odorless. Tritium has a half-life of 12.3 years and emits a very weak beta particle.

What is tritium used for?

Tritium has several important uses. Its most significant use is as a component in the triggering mechanism in thermonuclear (fusion) weapons. Very large quantities of tritium are required for the maintenance of our nation's nuclear weapons capabilities.

Tritium is also produced commercially in reactors. It is used in various self-luminescent devices, such as exit signs in buildings, aircraft dials, gauges, luminous paints, and wristwatches. Tritium is also used in life science research, and in studies investigating the metabolism of potential new drugs.

Exposure to Tritium

How does tritium get into the environment?

Tritium occurs naturally in the environment in very low concentrations. Most tritium in the environment is in the form of tritiated water, which easily disburses in the atmosphere, water bodies, soil, and rock.

In the mid-1950s and early 1960s, tritium was widely dispersed during the above-ground testing of nuclear weapons. The quantity of tritium in the atmosphere from weapons testing peaked in 1963 and has been decreasing ever since.

Today, sources of tritium include commercial nuclear reactors and research reactors, and government weapons production plants. Tritium may be released as steam from these facilities or may leak into the underlying soil and ground water. However, such releases are usually small and are required not to exceed federal environmental limits.

A recently documented source of tritium in the environment is tritium exit signs that have been illegally disposed of in municipal landfills. Water, which seeps through the landfill, is contaminated with tritium from broken signs and can pass into water ways, carrying the tritium with it.

How does tritium change in the environment?

Tritium readily forms water when exposed to oxygen. As it undergoes radioactive decay, tritium emits a very low energy beta particle and transforms to stable, nonradioactive helium. Tritium has a half-life of 12.3 years.

Current treatment of landfill leachates do not remove tritium.

How are people exposed to tritium?

People are exposed to small amounts of tritium every day, since it is widely dispersed in the environment and in the food chain. People who live near or work in federal weapons facilities or nuclear fuel cycle facilities may have increased exposure. People working in research laboratories may also come in contact with tritium.

How does tritium get into the body?
Tritium primarily enters the body when people swallow tritiated water. People may also inhale tritium as a gas in the air, and absorb it through their skin.

What does tritium do once it gets into the body?
Tritium is almost always found as water, or "tritiated" water. Once tritium enters the body, it disperses quickly and is uniformly distributed throughout the body. Tritium is excreted through the urine within a month or so after ingestion. Organically bound tritium (tritium that is incorporated in organic compounds) can remain in the body for a longer period.
Tritium atoms can exchange with any hydrogen atoms. If the hydrogen atom is part of an organic molecule, the tritium becomes 'organically bound' and is transported with the molecule rather than moving freely like water.

Health Effects of Tritium
How does tritium affect people's health?

As with all ionizing radiation, exposure to tritium increases the risk of developing cancer. However, because it emits very low energy radiation and leaves the body relatively quickly, for a given amount of activity ingested, tritium is one of the least dangerous radionuclides. Since tritium is almost always found as water, it goes directly into soft tissues and organs. The associated dose to these tissues are generally uniform and dependent on the tissues' water content.

Is there a medical test to determine exposure to tritium?
Urinalysis is the easiest bioassay method for determining exposure to tritium. Liquid scintillation counting is a quick and relatively inexpensive method for assessing the concentration of tritium in urine. Because tritium is found naturally in most water supplies at very low concentrations, levels in drinking water would be measured to determine whether the tritium levels exceed the levels present in the body.

Protecting People from Tritium
How do I know if I'm near tritium?
You have to have specialized equipment to detect tritium.

What can I do to protect myself and my family from tritium?
Everyone is exposed to tiny amounts of tritium, much of it produced naturally. If you live near, or work at, a nuclear research facility, a commercial reactor, or a government weapons facility, you should be aware that your tritium exposure may be elevated. Also, be careful not to break open an exit sign, or other device that may contain tritium as an illuminating agent.

What is EPA doing about tritium?
EPA has established standards for the maximum amount of tritium that may be released by nuclear facilities, and that may be found in drinking water. In addition, before being approved for public use, sites previously contaminated with tritium must meet EPA's risk-based criteria for soil and ground water. These criteria set a person's increased risk of developing cancer from exposure to tritium at a cleaned-up site as being no more than a 1-in-10,000 to a 1-in-1,000,000 chance.

Thorium
Thorium (chemical symbol Th) is a naturally-occurring radioactive metal found at very low levels in soil, rocks, and water. It has several different isotopes, both natural and man-made, all of which are radioactive. The most common form of thorium is thorium-232, found naturally.

Who discovered thorium?
Thorium was discovered in 1828 by the Swedish chemist Jons Jakob Berzelius. After determining that it was a new element, Berzelius named his discovery after the Norse god of thunder and weather, Thor. Thorium was discovered to be radioactive independently in 1898 by Gerhard Carl Schmidt and by Marie Curie.

Where does thorium come from?
Almost all thorium is natural, but, thorium isotopes can be artificially produced. Thorium occurs at very low levels in virtually all rock, soil, and water, and therefore is found in plants and animals as well. Minerals such as monazite, thorite and thorianite are rich in thorium and may be mined for the metal. Generally, artificial isotopes come from decay of other man-made radionuclides, or absorption in nuclear reactions.

What are the properties of thorium?
Thorium is a soft, silvery white metal. Pure thorium will remain shiny for months in air, but if it contains impurities it tarnishes to black when exposed to air. When heated, thorium oxide glows bright white, a property that makes it useful in lantern mantles. It dissolves slowly in water. Thorium-232 has a half-life of 14 billion (14x109) years, and decays by alpha emission, with

accompanying gamma radiation. Thorium-232 is the top of a long decay series that contains key radionuclides such as radium-228, its direct decay product, and radon-220. Two other isotopes of thorium, which can be significant in the environment, are thorium-230 and thorium-228. Both belong to other decay series. They also decay by alpha emission, with accompanying gamma radiation, and have half-lives of 75,400 years and 1.9 years, respectively.

What is thorium used for?
Thorium has coloring properties that has made it useful in ceramic glazes. But, it has been most widely used in lantern mantles for the brightness it imparts (though alternatives are replacing it), and in welding rods, which burn better with small amounts of added thorium. Thorium improves the properties of ophthalmic lenses, and is an alloying agent in certain metals used in the aerospace industry. More than 30 years ago, thorium oxides were used in hospitals to make certain kinds of diagnostic X-ray photographs. But, this practice has been discontinued.

Exposure to Thorium

How does thorium get into the environment?
Natural thorium is present in very small quantities in virtually all rock, soil, water, plants and animals. Where high concentrations occur in rock, thorium may be mined and refined, producing waste products such as mill tailings. If not properly controlled, wind and water can introduce the tailings into the wider environment. Commercial and federal facilities that have processed thorium may also have released thorium to the air, water, or soil. Man-made thorium isotopes are rare, and almost never enter the environment.

How does thorium change in the environment?
As thorium-232 undergoes radioactive decay, it emits an alpha particle, with accompanying gamma radiation, and forms radium-228. This process of releasing radiation and forming a new radionuclide continues until stable lead-208 is formed. The half-life of thorium-232 is about 14 billion years. Two other isotopes of thorium, which can be significant in the environment, are thorium-230 and thorium-228. Both decay by alpha emission, with accompanying gamma radiation, in 75,400 years and 1.9 years, respectively.

How are people exposed to thorium?
Since thorium is naturally present in the environment, people are exposed to tiny amounts in air, food and water. The amounts are usually very small and pose little health hazard. Thorium is also present in many consumer products such as ceramic glazes, lantern mantles, and welding rods.
People who live near a facility that mines or mills thorium, or manufactures products with thorium, may receive higher exposures. Also, people who work with thorium in various industries may receive higher exposures.

How does thorium get into the body?
People may inhale contaminated dust, or swallow thorium with food or water. Living near a thorium contaminated site, or working in an industry where thorium is used, increases your chance of exposure to thorium.

What does thorium do once it gets into the body?
If inhaled as dust, some thorium may remain in the lungs for long periods of time, depending on the chemical form. If ingested, thorium typically leaves the body through feces and urine within several days. The small amount of thorium left in the body will enter the bloodstream and be deposited in the bones where it may remain for many years. There is some evidence that the body may absorb thorium through the skin, but that would not likely be the primary means of entry.

Health Effects of Thorium

How can thorium affect people's health?
The principal concern from low to moderate level exposure to ionizing radiation is increased risk of cancer. Studies have shown that inhaling thorium dust causes an increased risk of developing lung cancer, and cancer of the pancreas. Bone cancer risk is also increased because thorium may be stored in bone.

Is there a medical test to determine exposure to thorium?
There are special tests that measure the level of thorium in the urine, feces, and also via exhaled air that can determine if a person has been exposed to thorium. These tests are useful only if taken within a week after exposure. You need special equipment to detect thorium not available in doctors offices or most hospitals. Some federal facilities and specialized laboratories have this capability.

Protecting People from Thorium

How do I know thorium if I'm near thorium?
You need special equipment to detect thorium, and special training. Health physicists and radiation safety officers are trained to measure thorium.

What can I do to protect myself and my family from thorium?
Most people are not exposed to dangerous levels of thorium. However, people who live near thorium mining areas, or near certain government or industrial facilities may have increased exposure to thorium, especially if their water is from a private well. Analytical laboratories can test water for thorium content. Occasionally, household items may be found with thorium in them, such as some older ceramic wares in which uranium was used in the glaze, or gas lantern mantles. These generally do not pose serious

health risks, but may nevertheless be retired from use as a prudent avoidance measure. A radiation counter is required to confirm if ceramics contain thorium.

What is EPA doing about thorium?
EPA protects people and the environment from thorium by establishing standards for the clean-up of contaminated sites, and by setting limits on the amount of thorium (and other radionuclides) that may be released to the air from specific sources, or found in public drinking water.
The standards for the clean-up of existing contaminated sites generally fall under the Comprehensive Environmental Response, Compensation, and Liability Act, commonly called Superfund. Clean ups must meet all requirements that are relevant or applicable, such as state regulations and regulations issued in connection with other environmental laws. When these types of regulations are not applicable, or not protective enough, EPA sets site-specific cleanup levels that limit the chance of developing cancer due to exposure to a site-related carcinogen (such as thorium) to between one in 10,000 and one in 1,000,000.
EPA issued special regulations for cleaning up uranium and thorium mill tailing sites under the "Uranium Mill Tailings Radiation Control Act" (federal regulations are found in 40CFR192, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings"). These mills are found mostly in the western states of Colorado, Utah, Arizona and New Mexico.
* Superfund: EPA Radiation Guidances and Reports
This site provides information on radionuclides at Superfund sites.
EPA's Superfund Hotline: 1-800-424-9346 or 1-800-535-0202
* Clean Air Act
EPA uses this authority to set limits on the emissions of hazardous air pollutants from specific sources. Hazardous air pollutants include both chemicals and radionuclides that are known or suspected to cause serious health problems. While no air emissions standards list thorium specifically, radionuclides are limited as a group.
RadNESHAPS
This site provides information on EPA's National Emission Standards for Hazardous Air Pollutants: Radionuclides.
* Radionuclides in Drinking Water
This site provides information about radionuclides in drinking water and guidance to help states and water systems comply with the standard. EPA uses its Safe Drinking Water Act authority to establish maximum contaminant levels (MCLs) for beta emitters such as thorium in public drinking water. For example the MCL for beta emitters is 4 millirem per year or 8 picoCuries per liter of water.

Thorium is a naturally occurring, slightly radioactive metal. It is estimated to be about three to four times more abundant than uranium in the Earth's crust. It has been considered a waste product in mining rare earths, so its abundance is high and cost low. Thorium was successfully used as a breeding (fertile) source for nuclear fuel – uranium (233) in the molten-salt reactor experiment (MSR) from 1964 to 1969 (producing thermal energy for heat exchange to air or liquids), as well as in several light water reactors using solid fuel composed of a mixture of 232Th and 233U, including the Shippingport Atomic Power Station (operation commenced 1957, decommissioned in 1982), but a thorium-uranium mix was only used at end of life to demonstrate Th-to-U breeding. Currently, the Japanese Fuji project and officials in India are advocating a thorium-based nuclear program, and a seed-and-blanket fuel utilizing thorium is undergoing irradiation testing at the Kurchatov Institute in Moscow.[2][3] Advocates of the use of thorium as the fuel source for nuclear reactors state that they can be built to operate significantly cleaner than uranium-based power plants as the waste products are much easier to handle.[4]
When used in molten-salt reactors, thorium bred to 233U removes weaponization dangers, because no uranium exists in solid form and the reactor runs continuously, with no shutdown for refuelling—all thorium and fissile uranium is consumed and any undesired gasses and uranium/plutonium isotopes are flushed out as gasses (e.g., as uranium hexafluoride) as the hot, liquid salt is pumped around the reactor/exchanger system.

Uranium
Uranium (chemical symbol U) is a naturally-occurring radioactive element, with atomic number 92. Uranium is commonly found in very small amounts in rocks, soil, water, plants, and animals (including humans). Uranium is weakly radioactive and contributes to low levels of natural background radiation in the environment.

Who discovered uranium?
The use of uranium, in its natural oxide form, dates back to at least 79 A.D., when it was used to add color to ceramic glazes. The German chemist Martin Klaproth is credited with discovering uranium in samples of the mineral pitchblende in 1789. It was first isolated as a metal in 1841 by Eugene-Melchior Peligot. Uranium was discovered to be radioactive in 1896 by French physicist Henri Becquerel. Through his work with uranium metals, he was the first to discover the process of radioactivity.

Where does uranium come from?
Uranium is a naturally-occurring element found at low levels in virtually all rock, soil, and water. Significant concentrations of uranium occur in some substances such as phosphate rock deposits, and minerals such as uraninite in uranium-rich ores. Because uranium has such a long radioactive half-life (4.47x109 years for U-238), the total amount of it on earth stays almost the same.

What are the properties of uranium?
When refined, uranium is a silvery white, weakly radioactive metal. Uranium metal has very high density, 65% more dense than lead. Uranium in ores can be extracted and chemically converted into uranium dioxide or other chemical forms usable in industry.

Uranium found naturally has 3 different isotopes, U-238, U-235, and U-234. Other isotopes can be synthesized. All uranium isotopes are radioactive. The table below shows the percentage of natural abundance of each natural uranium isotope, and their respective half-lives.

Relative Abundance of Uranium Isotopes Isotope	U-238	U-235	U-234
Natural Abundance (%)	99.27	0.72	0.0055
Half-life (years)	4.47 billion	700 million	246,000

Uranium isotopes can be separated to increase the concentration of one isotope relative to another. This process is called "enrichment." The enriched fraction has increased U-235. Uranium-235 is better for nuclear power reactors, and for making nuclear weapons. The process produces huge quantities of uranium that are depleted in U-235, but are almost pure U-238, called depleted uranium, or DU.

What is uranium used for?

Uranium metal is very dense and heavy. When it is depleted (DU), uranium is used by the military as shielding to protect Army tanks, and also in parts of bullets and missiles. The military also uses enriched uranium to power nuclear propelled Navy ships and submarines, and in nuclear weapons. Fuel used for Naval reactors is typically highly enriched in U-235 (the exact values are classified information). In nuclear weapons uranium is also highly enriched, usually over 90% (again, the exact values are classified information).

The main use of uranium in the civilian sector is to fuel commercial nuclear power plants, where fuel is typically enriched in U-235 to 2-3%. Depleted uranium is used in helicopters and airplanes as counter weights on certain wing parts. Other uses include ceramic glazes where small amounts of natural uranium (that is, not having gone through the enrichment process) may be added for color. Some lighting fixtures utilize uranium, as do some photographic chemicals. Phosphate fertilizers often contain high amounts of natural uranium, because the mineral material from which they are made is typically high in uranium. Also, people who collect rocks and minerals may have specimens of uranium minerals in their collection such as pitchblende, uraninite, autunite, uranophane, or coffinite.

Exposure to Uranium

How does uranium get into the environment?

Uranium is present naturally in virtually all soil, rock and water. Uranium in soil and rocks is distributed throughout the environment by wind, rain and geologic processes. Rocks weather and break down to form soil, and soil can be washed by water and blown by wind, moving uranium into streams and lakes, and ultimately settling out and reforming as rock. Uranium can also be removed and concentrated by people through mining and refining. These mining and refining processes produce wastes such as mill tailings which may be introduced back into the environment by wind and water if they are not properly controlled. Manufacturing of nuclear fuel, and other human activities also release uranium to the environment.

How does uranium change in the environment?

All uranium isotopes are radioactive. The three natural uranium isotopes found in the environment, U-234, U-235, and U-238, undergo radioactive decay by emission of an alpha particle accompanied by weak gamma radiation. The dominant isotope, U-238, forms a long series of decay products that includes the key radionuclides radium-226, and radon-222. The decay process continues until a stable, non-radioactive decay product is formed (see uranium decay series). The release of radiation during the decay process raises health concerns.

How are people exposed to uranium?

A person can be exposed to uranium by inhaling dust in air, or ingesting water and food. The general population is exposed to uranium primarily through food and water. The average daily intake of uranium from food ranges from 0.07 to 1.1 micrograms per day. The amount of uranium in air is usually very small. People who live near federal government facilities that made or tested nuclear weapons, or facilities that mine or process uranium ore or enrich uranium for reactor fuel, may have increased exposure to uranium.

How does uranium get into the body?

Uranium can enter the body when it is inhaled or swallowed, or under rare circumstances it may enter through cuts in the skin. Uranium does not absorb through the skin, and alpha particles released by uranium cannot penetrate the skin, so uranium that is outside the body is much less harmful than it would be if it where inhaled or swallowed. When uranium gets inside the body it can lead to cancer or kidney damage.

What does uranium do once it gets into the body?

About 99 percent of the uranium ingested in food or water will leave a person's body in the feces, and the remainder will enter the blood. Most of this absorbed uranium will be removed by the kidneys and excreted in the urine within a few days. A small amount of the uranium in the bloodstream will deposit in a person's bones, where it will remain for years.

Health Effects of Uranium

How can uranium affect people's health?

The greatest health risk from large intakes of uranium is toxic damage to the kidneys, because, in addition to being weakly radioactive, uranium is a toxic metal. Uranium exposure also increases your risk of getting cancer due to its radioactivity. Since uranium tends to concentrate in specific locations in the body, risk of cancer of the bone, liver cancer, and blood diseases (such as leukemia) are increased. Inhaled uranium increases the risk of lung cancer.

Is there a medical test to determine exposure to uranium?
Tests are available to measure the amount of uranium in a urine or stool sample. Hospitals do not perform these tests routinely. These tests are useful if a person is exposed to a large amount of uranium, because most uranium leaves the body in the feces within a few days after ingestion. Uranium can be found in the urine for up to several months after exposure. However, the amount of uranium in the urine and feces does not always accurately show the level of uranium to which you may have been exposed. Since uranium is known to cause kidney damage, special urine tests are often used to determine whether kidney damage has occurred.

Protecting People from Uranium
How do I know I'm near uranium?
You need specialized equipment and training to detect uranium in the environment.

What can I do to protect myself and my family from uranium?
Most people are not exposed to dangerous levels of uranium. However, people who live near uranium mining areas, or near government weapons facilities or certain industrial facilities may have increased exposure to uranium, especially if their water is from a private well. Analytical laboratories can test water for uranium content. Occasionally, household wares may be found with uranium in them, such as some older ceramic dishes or plates in which uranium was used in the glaze. These generally do not pose serious health risks, but may nevertheless be retired from use as a prudent avoidance measure. A radiation counter is required to confirm if ceramics contain uranium.

What is EPA doing about uranium?
EPA standards under the Clean Air Act limit uranium in the air. The maximum dose to an individual from uranium in the air is 10 millirem. The cleanup of contaminated sites to be released for public use, must meet EPA's risk-based criteria for soil and ground water. EPA's site cleanup standards limit a person's increased chance of developing cancer to between 1 in 10,000 to 1 in 1,000,000 from residual uranium on the ground. Site-specific factors, cost, and community concerns are weighed in establishing the actual clean up value.

Uranium in drinking water is covered under the Safe Drinking Water Act. This law establishes Maximum Contaminant Levels, or MCLs, for radionuclides and other contaminants in drinking water. The uranium limit is 30 µg/l (micrograms per liter) in drinking water.

EPA has issued special regulations for cleaning up uranium mill tailing sites under the "Uranium Mill Tailings Radiation Control Act." The regulations are found in 40CFR192, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings."

Title 40: Protection of Environment
PART 61—NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS

[http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=e7251b5fade04e4ed83a3fdba34f721e&rgn=div6&view=text&node=40:8.0.1.1.1.9&idno=40]

[54 FR 51697, Dec. 15, 1989, as amended at 61 FR 68981, Dec. 30, 1996]

§ 61.102   Standard.

(a) Emissions of radionuclides, including iodine, to the ambient air from a facility regulated under this subpart shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr (=0.1mSv/yr).

(b) Emissions of iodine to the ambient air from a facility regulated under this subpart shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 3 mrem/yr (=0.03 mSv/yr).

1 Sv is equal to 100 rem, for a quality factor Q=1. 1mSv = 0.1 rem = 100 mrem

The sievert (symbol: Sv) is the SI derived unit of dose equivalent. It attempts to reflect the biological effects of radiation as opposed to the physical aspects, which are characterized by the absorbed dose, measured in gray. It is named after Rolf Sievert, a Swedish medical physicist famous for work on radiation dosage measurement and research into the biological effects of radiation.

The equivalent dose to a tissue is found by multiplying the absorbed dose, in gray, by a dimensionless "quality factor" Q, dependent upon radiation type, and by another dimensionless factor N, dependent on all other pertinent factors.

N depends upon the part of the body irradiated, the time and volume over which the dose was spread, even the species of the subject. Together, Q and N constitute the radiation weighting factor, WR . Q is the same thing as the Relative Biological Effectiveness (RBE). For an organism composed of multiple tissue types a weighted sum or integral is often used. (In 2002, the CIPM decided that the distinction between Q and N causes too much confusion and therefore deleted the factor N from the definition of absorbed dose in the SI brochure. [1].)

In terms of SI base units:

1 Sv = 1 J/kg = 1 m2/s2 = 1 m2•s–2

Radioactivity is measured in Becquerel (Bq) per second. 1 Bq means one disintegration per second. It is also measured in Curie (Ci), named for Madam Curie, who shared Nobel Prize with her husband. 1 Curie = 3.7 x 1010 Bq or disintegrations per second. The radiation absorbed dose is measured in Gray, rad, rem and Sievert (Sv).

In the United States, absorbed dose is commonly given in rad or Gray and other protection quantities, such as equivalent dose and effective dose, are given in rem. The following table is provided to help avoid confusion among persons not familiar with these quantities. The use of the newer system of units would be particularly useful during radiological incidents involving international responders.

Conversions for Effective Dose, Equivalent Dose, Dose Equivalent, and ambient dose equivalent
0.001 rem = 1 mrem = 0.01 mSv
0.01 rem = 10 mrem = 0.1 mSv
0.1 rem = 100 mrem = 1 mSv = 0.001 Sv
1 rem = 1000 mrem = 10 mSv = 0.01 Sv
10 rem = 100 mSv = 0.1 Sv
100 rem = 1000 mSv = 1 Sv (Sievert)
1000 rem = 10 Sv

Conversions for Absorbed Dose
0.001 rad = 1 mrad = 0.01 mGy
0.01 rad = 10 mrad = 0.1 mGy
0.1 rad = 100 mrad = 1 mGy = 0.001 Gy
1 rad = 1000 mrad = 10 mGy = 0.01 Gy = 1 cGy
10 rad = 100 mGy = 0.1 Gy
100 rad = 1000 mGy = 1 Gy (Gray)
1000 rad = 10 Gy

Measured Dose (Temporary Measurements) – gamma radiation or X-rays
1 R (roentgen) = 0.01 Gy = 0.01 Sv

Although the sievert has the same dimensions as the gray (i.e. joules per kilogram), it measures a different quantity. To avoid any risk of confusion between the absorbed dose and the equivalent dose, the corresponding special units, namely the gray instead of the joule per kilogram for absorbed dose and the sievert instead of the joule per kilogram for the dose equivalent, should be used. For a given amount of radiation (measured in gray - the plural of gray is gray), the biological effect (measured in sievert) can vary considerably as a result of the radiation weighting factor WR. This variation in effect is attributed to the Linear Energy Transfer [LET] of the type of radiation, creating a different relative biological effectiveness for each type of radiation under consideration. Per most government regulations, the RBE [Q] for electron and photon radiation is 1, for neutron radiation it is 10, and for alpha radiation it is 20. There is some controversy that the Q or RBE for alpha radiation is underestimated due to mistaken assumptions in the original work in the 1950s that developed those values. That original work neglected the component of the nucleus recoil radiation for alpha emitters.
[edit] SI multiples and conversions

Frequently used SI multiples are the millisievert (1 mSv = 10−3 Sv) and microsievert (1 μSv = 10−6 Sv).

An older unit of the equivalent dose is the rem (Röntgen equivalent man); 1 Sv is equal to 100 rem, for a quality factor Q=1. In some fields and countries, rem and mrem continue to be used along with Sv and mSv, causing confusion.

Explanation: Various terms are used with this unit:

* Dose equivalent
* Ambient dose equivalent

- Directional dose equivalent
- Personal dose equivalent
- Organ equivalent dose

The millisievert is commonly used to measure the effective dose in diagnostic medical procedures (e.g., X-rays, nuclear medicine, positron emission tomography, and computed tomography). The natural background effective dose rate varies considerably from place to place, but typically is around 2.4 mSv/year [2] (pdf).

For acute (that is, received in a relatively short time, up to about one hour) full body equivalent dose, 1 Sv causes nausea, 2-5 Sv causes epilation or hair loss, hemorrhage and will cause death in many cases. More than 3 Sv will lead to LD 50/30 or death in 50% of cases within 30 days, and over 6 Sv survival is unlikely. (For more details, see radiation poisoning.)

For first responders undertaking rescue operations that involve saving life, no dose restrictions are recommended in principle if, and only if, the benefit to others clearly outweighs the risk to the rescuer. Otherwise, for rescue operations involving the prevention of serious injury or the development of catastrophic conditions, every effort should be made to avoid serious tissue injuries by keeping doses below about 1000 mSv and, ideally, to avoid other tissue injuries by keeping doses below 100 mSv, the commission's maximum value for a constraint.
- For first responders undertaking other immediate and urgent rescue actions to prevent injuries or large doses to many people, all reasonable efforts should be made to keep doses below 100 mSv.
- For actions taken by workers engaged in recovery operations, the doses received should be treated as part of normal occupational exposure and the normal occupational dose limits would apply. Recovery operations should be planned exposure situations.]

Given the linear no-threshold model of radiation response, the collective dose that a population is exposed to is measured in "man-sievert" (man•Sv).
Q values: Here are some quality factor values:[1]

- Photons, all energies : Q = 1
- Electrons and muons, all energies : Q = 1
- Neutrons,
  - energy < 10 keV : Q = 5
  - 10 keV < energy < 100 keV : Q = 10
  - 100 keV < energy < 2 MeV : Q = 20
  - 2 MeV < energy < 20 MeV : Q = 10
  - energy > 20 MeV : Q = 5
- Protons, energy > 2 MeV : Q = 5
- Alpha particles and other atomic nuclei : Q = 20

N values: Here are some N values for organs and tissues:[2]
- Gonads: N = 0.08
- Bone marrow, colon, lung, breast, stomach: N = 0.12
- Bladder, brain, salivary glands, kidney, liver, muscles, oesophagus, pancreas, small intestine, spleen, thyroid, uterus: N = 0.05
- Bone surface, skin: N = 0.01

And for other organisms, relative to humans:
- Viruses, bacteria, protozoans: N ≈ 0.03 – 0.0003
- Insects: N ≈ 0.1 – 0.002
- Molluscs: N ≈ 0.06 – 0.006
- Plants: N ≈ 2 – 0.02
- Fish: N ≈ 0.75 – 0.03
- Amphibians: N ≈ 0.4 – 0.14
- Reptiles: N ≈ 1 – 0.075
- Birds: N ≈ 0.6 – 0.15
- Humans: N = 1

—Based on The International System of Units, section 5.2.

{ICRP Publ. 60}
Band of Projected Effective Dose –Acute or Annual (20-100 mSv):
Characteristics of the Situation - Individuals exposed by sources that are either not controllable or where actions to reduce doses would be disruptive. Exposures are usually controlled by action on the exposure pathways. Individuals may or may not receive benefit from the exposure situations.

Radiological Protection Requirements - Consideration should be given to reducing doses. Increasing efforts should be made to reduce doses as they approach 100 mSv. Individuals should receive information on radiation risk and on the actions to reduce doses. Assessment of individual doses should be undertaken.
Examples - Constraint for evacuation in a radiological emergency.

Band of Projected Effective Dose –Acute or Annual (1-20 mSv):
Characteristics of the Situation - Individuals will usually receive direct benefit from the exposure situation but not necessarily from the exposure itself. Exposures may be controlled at source or, alternatively, by action in the exposure pathways.
Radiological Protection Requirements - Where possible, general information should be made available to enable individuals to reduce their doses. For planned situations, individual monitoring and training should take place.
Examples - Constraints set for occupational exposure in planned situations. Dose constraint for radon in dwellings.

Band of Projected Effective Dose –Acute or Annual (<1 mSv):
Characteristics of the Situation - Individuals are exposed to a source that gives them no direct benefit but benefits society in general. Exposures are usually controlled by action taken directly on the source for which radiological protection requirements can be planned in advance.
Radiological Protection Requirements - General information on the level of exposure should be made available. Periodic checks should be made on the exposure pathways as to the level of exposure.
Examples - Constraints set for public exposure in planned situations.

[http://www.nea.fr/rp/prague/EGIR_Draft_Recommendations_track_changes.pdf]
(281) There are many sources of exposure to natural radiation and each can vary significantly with geography, geology and lifestyle. Natural radiation exposures are broadly grouped as cosmic radiation and terrestrial radionuclides, which can result in external exposures (both indoors and outdoors) or internal exposures due to inhalation or ingestion. (282) The development of human society has changed and this change has resulted in increased exposure to radionuclides in the thorium and uranium decay chains. Siting of dwellings in high background areas, house construction materials rich in some radionuclides in the thorium and uranium decay chains, developments in eating and drinking habits that include the use of man-made fertilizers and water from mineral sources, have all typically increased the prolonged exposure of people. The radioactive progeny of radon-222 cause widespread exposure in many dwellings, where they are often the predominant source of prolonged exposure. In recent years, industrial development has further increased natural exposures to radionuclides in the thorium and uranium decay chains. Some industries have modified human habitats, making available naturally occurring radioactive materials (usually termed NORMs). Industries producing NORMs include: extractive industries for energy production; use of phosphate rock; and mining and milling of
mineral sands. (283) Living in areas with high concentrations of primordial radionuclides is a common cause of typically elevated exposures. Many situations of typically elevated exposure are created by the presence of high concentrations of the gas radon in dwellings. Others, however, are caused by elevated concentrations of other natural radionuclides in the environment. The vast majority of the world population incur doses around the average global exposure of 2.4 mSv per year; more than about 98% of the population incur doses lower than about 5 mSv per year, and about 99% doses lower than 7 mSv per year. However, there are inhabited areas of the world where the annual doses from natural sources are much higher than 10 mSv (UNSCEAR 2000). (284) Doses from cosmic radiation at ground level (0.4 mSv per year = 40 mrem) vary within a small range for the overwhelming majority of the population. Two thirds of the population live below 500 m and only 2 % live above 3000 m. The dose at 2000 m is approximately 2.5 times that at sea level and at 3000 m 4.4 times (UNSCEAR 2000). (285) External exposure rates from terrestrial radiations are generated by potassium, uranium and thorium in soils and in building materials. The worldwide average dose rate is estimated to be 0.5 mSv per year, with most countries within the range of 0.3 – 0.6 mGy per year (UNSCEAR 2000). Outdoor exposure to these

radiations is not amenable to control without avoiding certain locations. Indoor exposures are sometimes elevated due to the use of building materials with high natural radioactive content or from using building materials that have had their radioactive content inadvertently enhanced due to human activity. These indoor exposures can generally be reduced. (286) Doses from ingestion of naturally occurring radionuclides commonly vary within a range of about a factor of two. The overall contribution of 40K is substantial but is fairly constant and is limited by the body's uptake of potassium and not by the amount of potassium in the diet. Intakes of radionuclides in the thorium and uranium decay series are more amenable to control. The average dose to individuals from this source is approximately 0.3 mSv per year with two thirds of this coming from 40K. (287) Radon exposure is dependent not only on geography and geology but also on lifestyle and building construction practices. While there can be large variations within a country there are also large variations between countries. The mean indoor radon concentration has been estimated to be 40 Bq m-3 with the mean for several countries below 20 Bq m-3 and others above 100 Bq m-3 (UNSCEAR 2000). Within a country much larger variations can occur with some homes over one hundred times the average level making radon the most commonly variable source of natural exposure.

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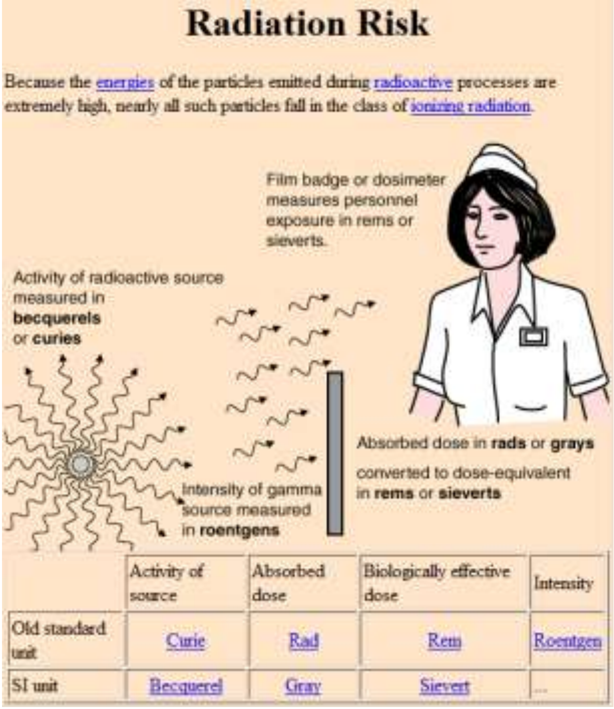
http://hyperphysics.phy-a http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/radrisk.html#c1



Radiation Risk

Because the energies of the particles emitted during radioactive processes are extremely high, nearly all such particles fall in the class of ionizing radiation.

Film badge or dosimeter measures personnel exposure in rems or sieverts.

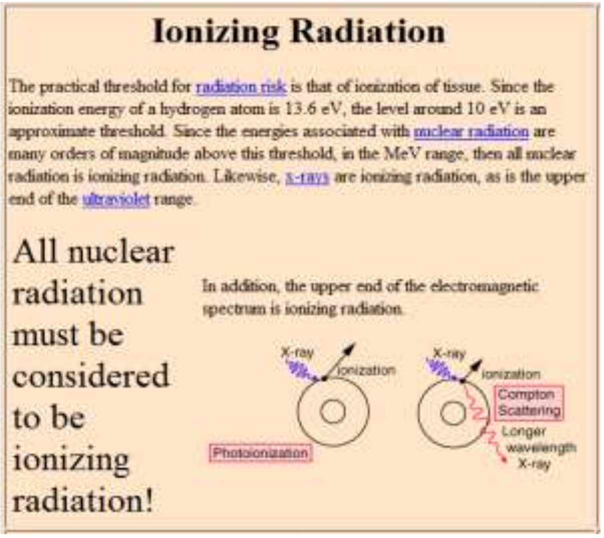
Activity of radioactive source measured in **becquerels** or **curies**

Intensity of gamma source measured in **roentgens**

Absorbed dose in **rads** or **grays**

converted to dose-equivalent in **rems** or **sieverts**

	Activity of source	Absorbed dose	Biologically effective dose	Intensity
Old standard unit	Curie	Rad	Rem	Roentgen
SI unit	Becquerel	Gray	Sievert	...

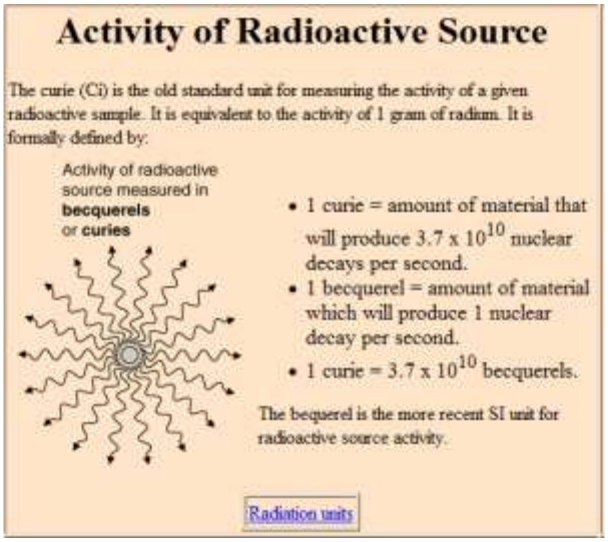


Ionizing Radiation

The practical threshold for radiation risk is that of ionization of tissue. Since the ionization energy of a hydrogen atom is 13.6 eV, the level around 10 eV is an approximate threshold. Since the energies associated with nuclear radiation are many orders of magnitude above this threshold, in the MeV range, then all nuclear radiation is ionizing radiation. Likewise, x-rays are ionizing radiation, as is the upper end of the ultraviolet range.

All nuclear radiation must be considered to be ionizing radiation!

In addition, the upper end of the electromagnetic spectrum is ionizing radiation.

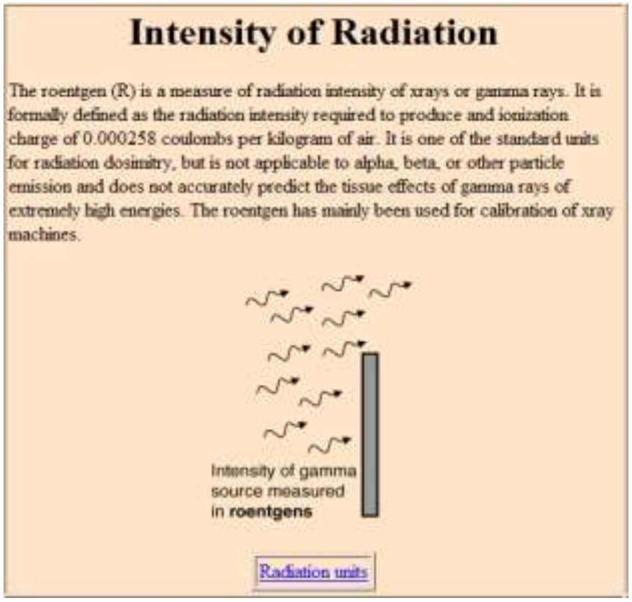


Activity of Radioactive Source

The curie (Ci) is the old standard unit for measuring the activity of a given radioactive sample. It is equivalent to the activity of 1 gram of radium. It is formally defined by:

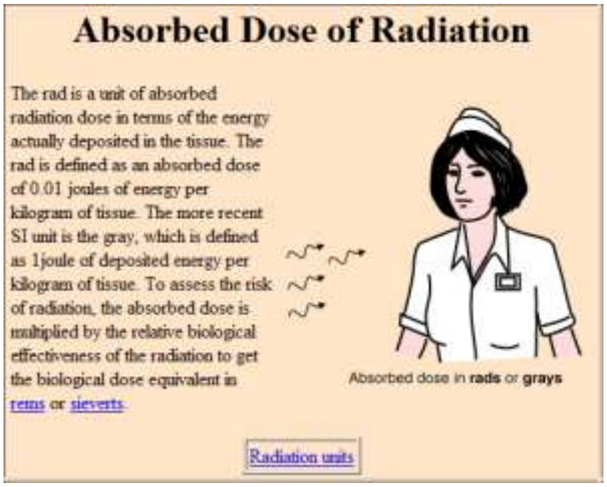
- 1 curie = amount of material that will produce 3.7 x 10^{10} nuclear decays per second.
- 1 becquerel = amount of material which will produce 1 nuclear decay per second.
- 1 curie = 3.7 x 10^{10} becquerels.

The bequerel is the more recent SI unit for radioactive source activity.



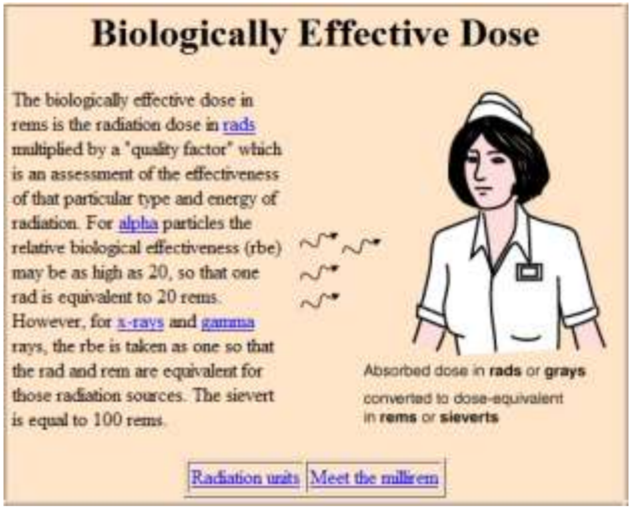
Intensity of Radiation

The roentgen (R) is a measure of radiation intensity of xrays or gamma rays. It is formally defined as the radiation intensity required to produce and ionization charge of 0.000258 coulombs per kilogram of air. It is one of the standard units for radiation dosimitry, but is not applicable to alpha, beta, or other particle emission and does not accurately predict the tissue effects of gamma rays of extremely high energies. The roentgen has mainly been used for calibration of xray machines.



Absorbed Dose of Radiation

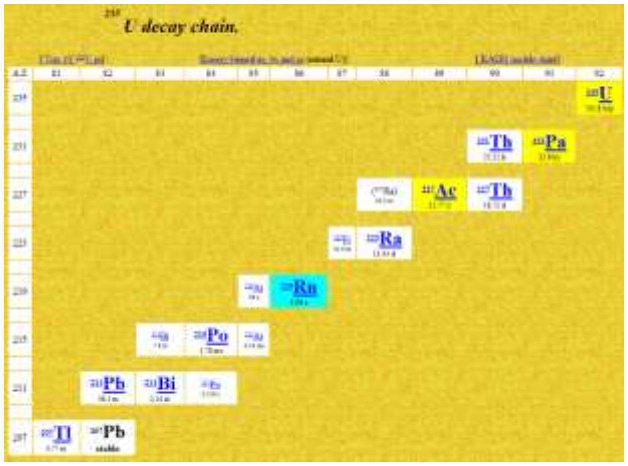
The rad is a unit of absorbed radiation dose in terms of the energy actually deposited in the tissue. The rad is defined as an absorbed dose of 0.01 joules of energy per kilogram of tissue. The more recent SI unit is the gray, which is defined as 1joule of deposited energy per kilogram of tissue. To assess the risk of radiation, the absorbed dose is multiplied by the relative biological effectiveness of the radiation to get the biological dose equivalent in rems or sieverts.



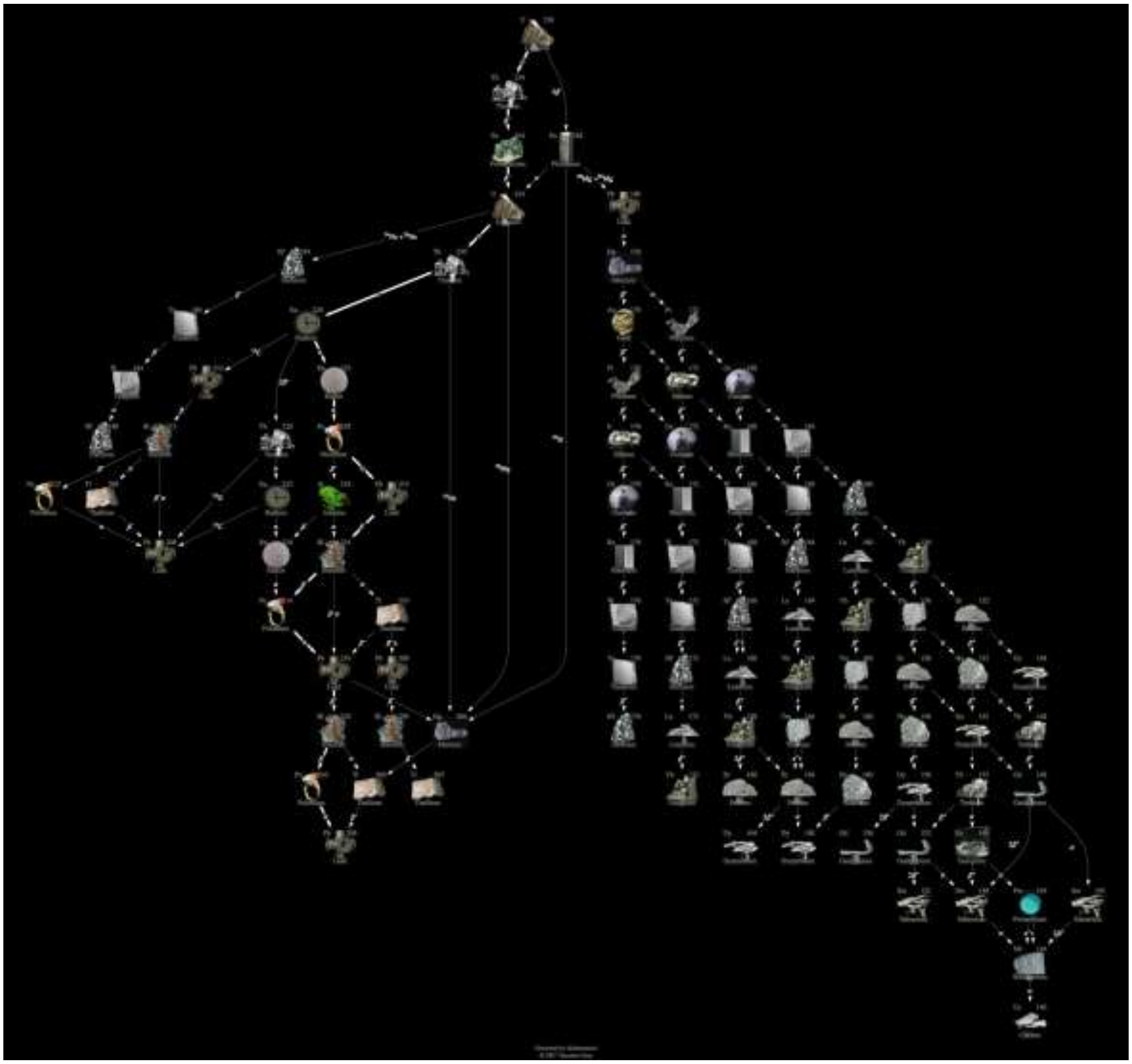
Biologically Effective Dose

The biologically effective dose in rems is the radiation dose in rads multiplied by a "quality factor" which is an assessment of the effectiveness of that particular type and energy of radiation. For alpha particles the relative biological effectiveness (rbe) may be as high as 20, so that one rad is equivalent to 20 rems. However, for x-rays and gamma rays, the rbe is taken as one so that the rad and rem are equivalent for those radiation sources. The sievert is equal to 100 rems.

^{238}U decay chain.



^{235}U decay chain.



Radioactive Decay

The chart given below lists all of the decay products of uranium-238 in their order of appearance. Each radioactive element on the list gives off either alpha radiation or beta radiation -- and sometimes gamma radiation too -- thereby transforming itself into the next element on the list. When uranium ore is extracted from the earth, most of the uranium is removed from the crushed rock during the milling process, but the radioactive decay products are left in the tailings. Thus 85 percent of the radioactivity of the original ore is discarded in the mill tailings.

Depleted uranium remains radioactive for literally billions of years, and over these long periods of time it will continue to produce all of its radioactive decay products; thus depleted uranium actually becomes more radioactive as the centuries and millennia go by because these decay products accumulate.

The horizontal bar beside the name of each decay product indicates the “half-life” of that particular substance, measured on a logarithmic scale (each half-inch to the right represents multiplication by a factor of one thousand). The half-life of a radioactive element is the time it takes for half of its atoms to decay into something else. For example, the half-life of radium-226 is 1600 years (as indicated on the chart below). Therefore, in 1600 years, one gram of radium-226 will turn into half a gram of radium-226 and half a gram of something else (the radioactive decay products of radium). After another 1600 years have elapsed, only a quarter of a gram of the original radium-226 will remain.

Questions with Answers:

1. The scale along the top is logarithmic (each half-inch to the right means multiplication by a factor of one thousand). What does each quarter-inch represent?

   Ans: Multiplication by a factor of 31.6 (the square root of 1000).

2. What is the half-life of lead-206?

   Ans: It isn’t radioactive so there is no half-life.

3. In one half-life, only one-half of the radioactive element remains. In two half-lives, only one-fourth of the original radioactive element remains. How much of the original radioactive element will remain after 10 half-lives?

   Ans: 1/1024 of the original will remain. In round figures, 1/1000.

4. If the half-life of radium-226 is 1600 years, how much of the radium-226 will have decayed at the end of the first year?

   Ans: 0.000433 = ln(2)/1600; not 1/3200 = 0.0003125.

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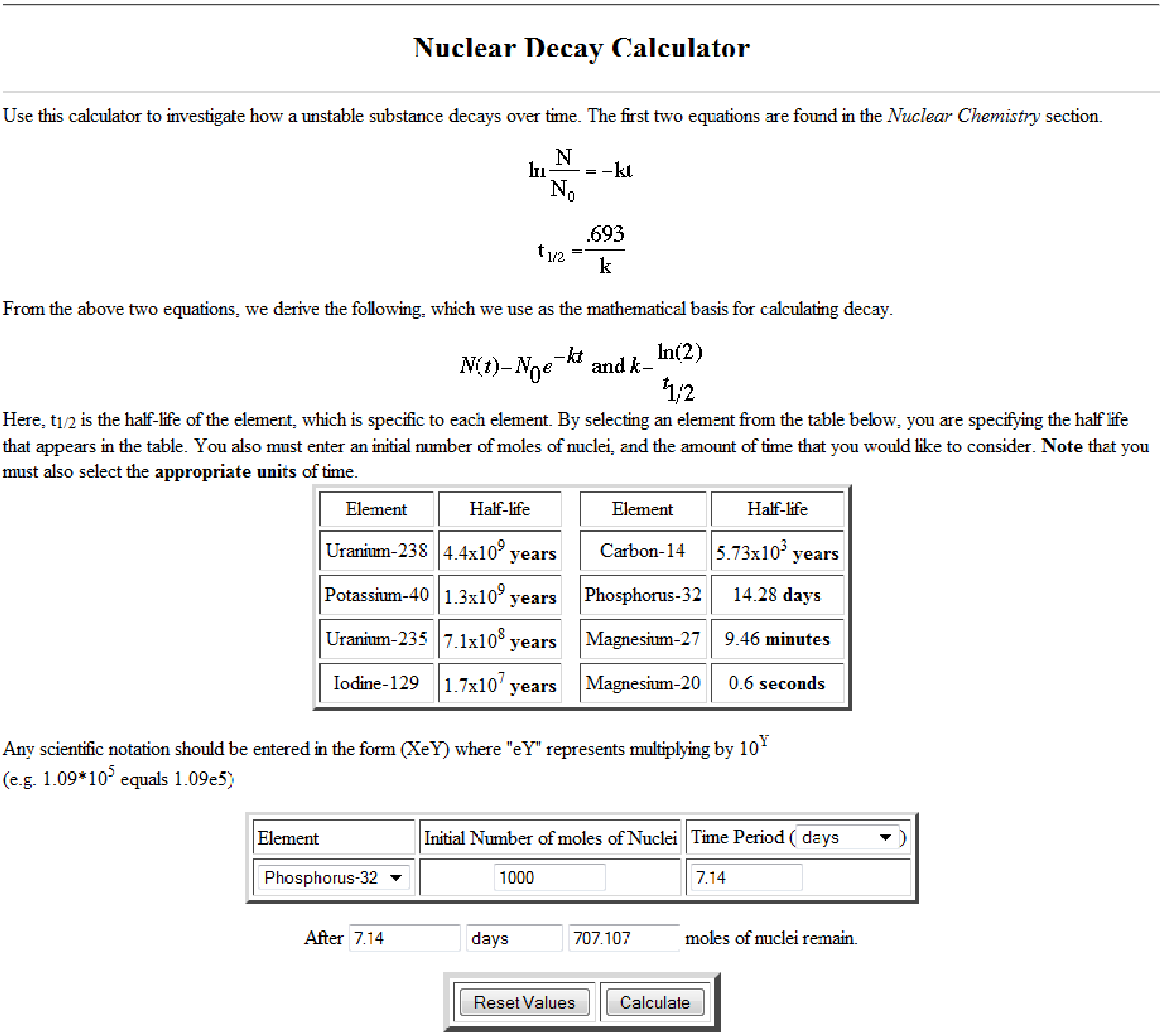

Nuclear Decay Calculator

Use this calculator to investigate how a unstable substance decays over time. The first two equations are found in the *Nuclear Chemistry* section.

$$\ln\frac{N}{N_0} = -kt$$

$$t_{1/2} = \frac{.693}{k}$$

From the above two equations, we derive the following, which we use as the mathematical basis for calculating decay.

$$N(t)=N_0e^{-kt} \text{ and } k=\frac{\ln(2)}{t_{1/2}}$$

Here, $t_{1/2}$ is the half-life of the element, which is specific to each element. By selecting an element from the table below, you are specifying the half life that appears in the table. You also must enter an initial number of moles of nuclei, and the amount of time that you would like to consider. **Note** that you must also select the **appropriate units** of time.

Element	Half-life	Element	Half-life
Uranium-238	$4.4\text{x}10^9$ **years**	Carbon-14	$5.73\text{x}10^3$ **years**
Potassium-40	$1.3\text{x}10^9$ **years**	Phosphorus-32	14.28 **days**
Uranium-235	$7.1\text{x}10^8$ **years**	Magnesium-27	9.46 **minutes**
Iodine-129	$1.7\text{x}10^7$ **years**	Magnesium-20	0.6 **seconds**

Any scientific notation should be entered in the form (XeY) where "eY" represents multiplying by 10^Y
(e.g. $1.09*10^5$ equals 1.09e5)

Element	Initial Number of moles of Nuclei	Time Period (days ▾)
Phosphorus-32 ▾	1000	7.14

After 7.14 days 707.107 moles of nuclei remain.

http://www.shodor.org/unchem/advanced/nuc/nuccalc.html

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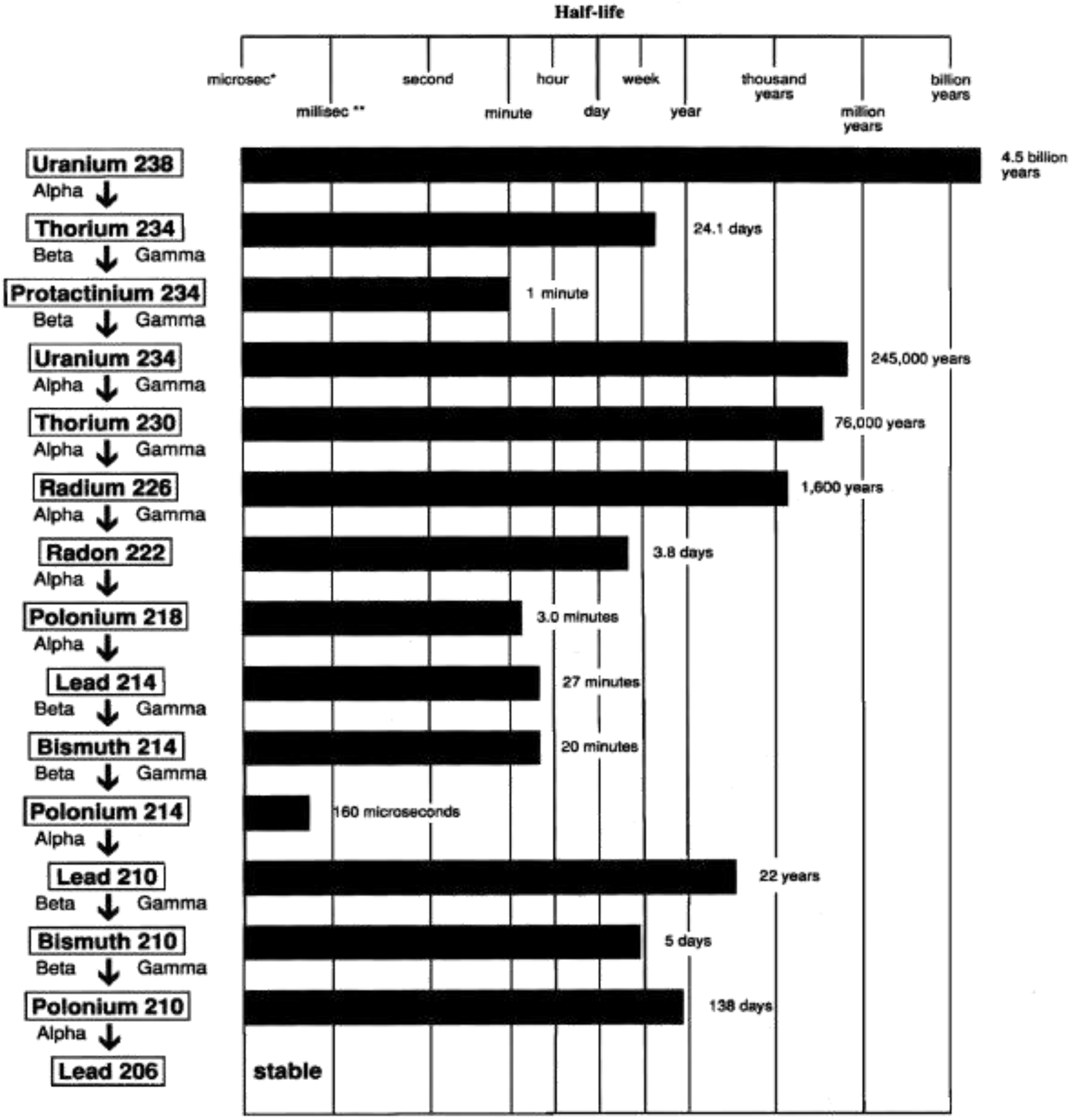
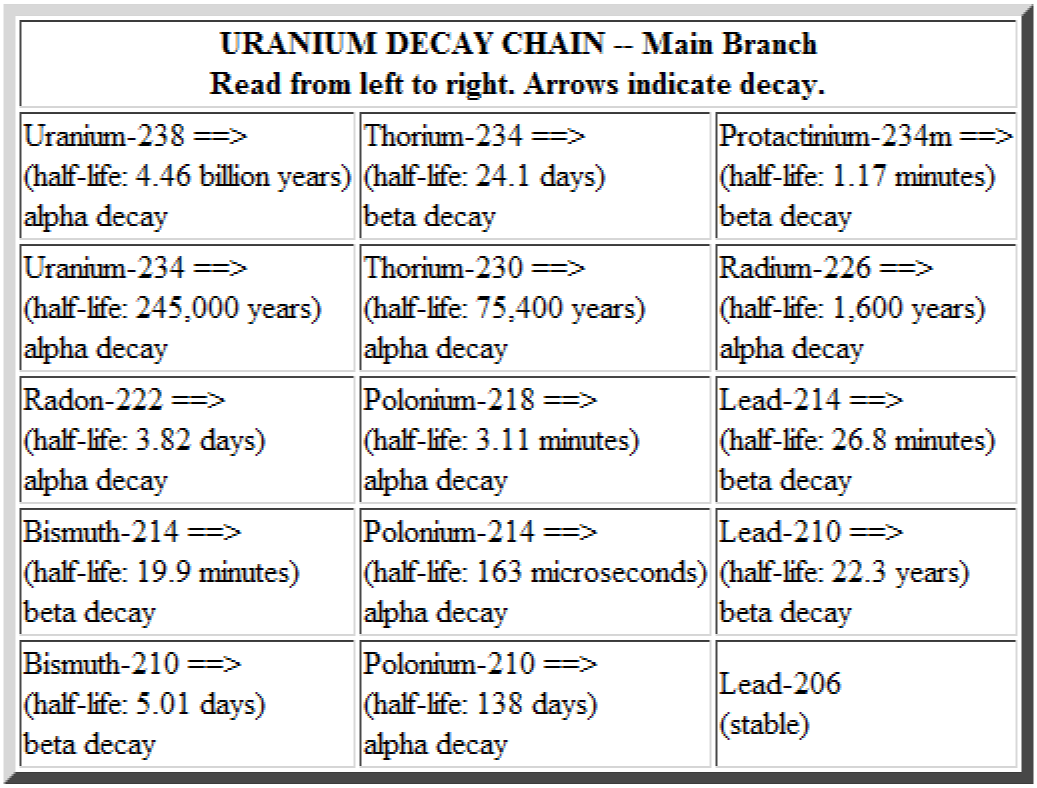
Radioactive Decay Chain

Source 1: http://www.ccnr.org/decay_U238.html



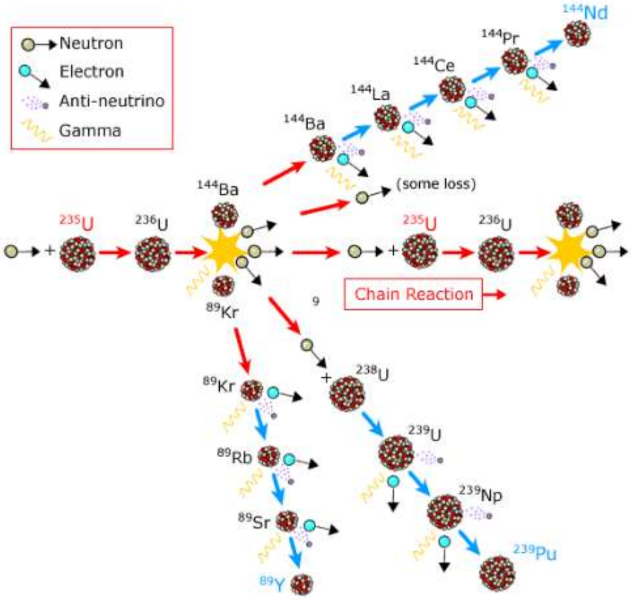
*Microsec: 1/1,000,000 of a second

**Millisec: 1/1,000 of a second



URANIUM DECAY CHAIN -- Main Branch Read from left to right. Arrows indicate decay.		
Uranium-238 ==> (half-life: 4.46 billion years) alpha decay	Thorium-234 ==> (half-life: 24.1 days) beta decay	Protactinium-234m ==> (half-life: 1.17 minutes) beta decay
Uranium-234 ==> (half-life: 245,000 years) alpha decay	Thorium-230 ==> (half-life: 75,400 years) alpha decay	Radium-226 ==> (half-life: 1,600 years) alpha decay
Radon-222 ==> (half-life: 3.82 days) alpha decay	Polonium-218 ==> (half-life: 3.11 minutes) alpha decay	Lead-214 ==> (half-life: 26.8 minutes) beta decay
Bismuth-214 ==> (half-life: 19.9 minutes) beta decay	Polonium-214 ==> (half-life: 163 microseconds) alpha decay	Lead-210 ==> (half-life: 22.3 years) beta decay
Bismuth-210 ==> (half-life: 5.01 days) beta decay	Polonium-210 ==> (half-life: 138 days) alpha decay	Lead-206 (stable)

The Fission Process in the Nuclear Reactor



A neutron colliding with a ^{235}U nucleus causes it to split into two nuclei (fission fragments, typically one heavier and one lighter nucleus) and several free neutrons (fission neutrons). The fission fragments, like ^{144}Ba and ^{89}Kr, have a very high velocity and disperse their kinetic energy into the closest environment, heating it up. 80% of the energy released in a fission process is carried by the fission fragments that are radioactive and decay fast.

Fission neutrons striking the next nuclei of uranium may start next fissions, and the next, and the next .... building up a chain reaction.

Some neutrons are absorbed in the uranium isotope ^{238}U which does not split. It captures a neutron becoming ^{239}U, which after two beta decays becomes ^{239}Pu. ^{239}Pu is a long lived alpha-radioactive isotope.

http://nobelprize.org/educational/physics/energy/fission_2.html

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http://www.enviroreporter.com/2011/03/radiation-station-faqs/

Why isn't the monitor outside?
We keep the Inspector inside so we can light it easier for you to be able to see 24/7. There is no need to have it outside or face it into the wind. The kind of radiation we're looking for at first with fallout that may travel across the Pacific Ocean to Southern California is gamma radiation. Gamma travels great distances and goes through just about anything, including you and me. Lead will stop it. In fallout, one the primary radionuclides of concern is iodine-131 which emits a lot of gamma radiation but is a beta emitter as well. If we left the Inspector outside and fallout begins to come down, the beta emitting I-131 could contaminate the instrument. Even without contamination issues, measuring it inside or outside, if at the same elevation, location and not over concrete (which has some uranium in it which skews the readings higher), is the same.

Can't you do it outdoors too?
Yes, but we have only one Inspector and they are not cheap. There also is the issue of contamination as previously noted. But if and when the fallout comes, we will certainly measure it outside.

Why do the numbers jump around?
Ions from the earth (radium and uranium) and cosmic radiation (including the Sun) do not emit in a steady manner. It's random. That said, when the numbers go up and stay up, that's the time to pay close attention.

When should I be worried?
A range of normal background radiation at this location at this time over several days has been determined to be between 40 to 46 CPM. These measurements are similar to background measurements taken in this location over long periods of time prior to the partial meltdowns in Japan.

Should radiation measured by the Inspector begin to rise to double background, we will be concerned. If the measurements go to triple background and above for a sustained period of time in the next few days, we might deduce that this may be coming from the Japan nuclear disaster.

What just happened? It just spiked from 50 to 389?
We used to leave the Inspector on view during our 10 minute averaging which counts the total ionizing events which are then divided by ten for a more accurate Counts Per Minute measurement. This practice confused and alarmed some folks because they thought that was the actual CPM going up and up. We now remove the Inspector for 10-15 minute periods to do this averaging which is then immediately posted on EnviroReporter.com's Radiation Station. **Click here to see a running list of averages**.

Can you convert CPM to millisieverts?

0-200 cpm / 0-0.05 mR/hr
200-400 cpm / 0.05-0.1 mR/hr
>400 cpm / >0.1 mR/hr [rem (Rontgen equivalent man) = R*RBE*Q, > 10 mrem/yr =0.1 mSv/yr max EPA,

http://www.enviroreporter.com/2011/03/radiation-station-faqs/

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For external radiation, gamma is the main concern. Alpha and beta particles can not go deep enough to hurt us when they outside our body. They only time they can hurt us is when we ingest them.

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Proper Geiger counter usage, and radiation monitoring

Topic started on **18-3-2011** @ 02:43 AM by **Mr Tranny**
http://www.abovetopsecret.com/forum/thread676279/pg1

Just as a general pointer here about radiation detection/monitoring and mistakes to look out for.

I keep seeing people talk about the idea that a specified CPM will correlate into a specified exposure level. That is exacerbated by the fact that some amateur radiation monitoring sites just give readouts in CPM for each site.

I will post some product specs to help people understand the “calibration factor” I am talking about.

Here is a list of thin wall Geiger tubes LND makes.
www.lndinc.com...

The model 713 has a gamma sensitivity of 7.5 CPM/mR/Hr.
That is to say that if you get a 15 CPM reading, you would be detecting 2mR/Hr
www.lndinc.com...

The model 719 has a gamma sensitivity of 90 CPM/mR/Hr
That is to say that if you get a 180 CPM reading, you would be detecting 2mR/Hr
www.lndinc.com...

Here is a tube by a different manufacture.
www.imagesco.com...
It has a calibration of 18 CPM/mR/Hr

If you have a meter that has a removable probe, and a calibrated readout, then that readout is only valid with a specified probe. The specified probe(s) in which that calibration is valid will be listed in the owners manual. The owners manual may also specify other probes and correction factors for that calibration. (2x, 7x, exec…..)

If you use it with any other probe, then that calibrated scale on the meter is meaningless. You will have to look at the CPM, and cross that with the calibration factor for your probe.

If you do not know the calibration factor for your probe, then the probe is useless for anything more than general toying around and experimenting. The cost of determining the calibration factor for an unidentified probe/tube is more than the probe/tube is worth.

Like those radiation monitoring sites that just give a readout in CPM. Unless they tell us the calibration factor for those sensors they are using, then all that data is totally useless, and their whole “radiation monitoring network” is a total waste of time.

………………………..

In regards to the units.

RAD (unit)

REM……… “Roentgen equivalent man”

The modern equivalents

Gy “Gray” (equivalent to RAD) (1Gy = 100Rad)
Sv “Sievert” (equivalent to REM) (1Sv = 100rem)
Gy/Rad is based on energy delivered by the particles.

Calibration in Gy/Rad of a non proportional GM tube is only good for one type of particle (usually gamma). A tube detecting a specified number of CPM from a gamma source will be detecting a known radiation level. That calibration doesn’t hold true when you use that tube to detect beta particles (or X rays). You may have a different calibration for beta, but usually they don’t have such a calibration for GM tubes. The reason for that is….. A GM tube gives the same single pulse for a gamma, beta, or alpha particle irrelevant of its actual energy level. And the energy level is what determines the number needed to obtain the specified RAD level.

It takes more alpha particles to get a rad than it does beta particles. It takes more beta particles to a rad than it does gamma…….. so on and so forth.

To get a tube that has a single working calibration all the way from alpha, to beta and gamma, you need what is called a proportional detector.

It gives a different response intensity depending on how energetic the particle is. The counter doesn’t count the number of pulses, it counts the total cumulative intensity of the pulses. Most hand held GM detectors are not proportional though. For proportional detection, Usually you would want to go with a Scintillation counter which will give you a fully calibrated reading for a variation of radiation types.

They use a scintillation crystal, and a photomultiplier.

REM/Sievert is the amount of radiation the human(or other) body will absorb based on weighing factors. Those weighing factors are based on radiation type and other factors.

When taking a calibrated measurement of the radioactivity of an object, the reading should be taken at a specified distance from an object with a specified detector. Remember. Radiation drops off as you get farther from the source. Measured radiation levels will change depending on how far your detector is away from the object and the sensitivity of your detector to certain particles. You may see people quoting a big reading for a “hot” object. But if they are holding the probe right against the object, then the reading is useless. The reading will be spectacularly high, but it will be useless.

You only move the probe in close when you are trying to pinpoint a small source, or you are trying to find any contamination at all on a surface.

For external radiation, gamma is the main concern. Alpha and beta particles can not go deep enough to hurt us when they outside our body. They only time they can hurt us is when we ingest them. That is the whole reason they have mica window GM tubes. To detect alpha and beta emitter contamination of food, water and other stocks that may be ingested. Or other products that may be used. But their use does not mean that the measurements they take are calibrated. It means that you detect contamination on the product, or you don’t!!!!!!!!!

If radioactive dust settles on a surface. You can use a pancake GM probe to wave across the surface and verify that there is radioactive dust on the surface, but the reading on the meter should not be construed as a calibrated reading that you can quote to someone. If you have a proportional/scintillation detector, and hold that probe over several spots at a fixed distance and take averaged readings, then you can quote the surface contamination level with some idea that the information may actually be usable.

If you use a mica window GM tube on a normal Geiger counter, and hold it by an alpha or beta source, then you will get wild reading that peg the meter. But the actual RAD dose that the probe is detecting is a small fraction of the displayed reading. Real dose may be as little as 1% or less of what the meter is displaying.

When you are taking environmental (background) radiation reading, if you have the beta/alpha window open, then your reading is worthless. The beta/alpha window must be closed, so that the detector only detects gamma particles (what it is calibrated for).

That is the most common mistake that I see on some of these monitoring websites. They have little Geiger counters that have an open mica window on the front with no secure way to cover it. That leaves the sensor open to radioactive dust (that comes from earth or outer space) that may settle on the mica window of the GM tube and greatly skew the reading.

If you are taking a valid background radiation measurement, then your reading shouldn't vary when you move your probe up or down, front to back, or left to right. If your reading changes drastically, then you are too close to a radioactive object, and your should change your objective over to making a calibrated measurement of the radioactive object in question, and finding a better place to locate your background radiation monitoring station (away from that object).

So, when you see someone holding a mica window probe against an object and saying that "It is really radioactive, and generating over 40mR of radiation!!!!!!!" Or when they have a mica window probe on a dusty table, and complain about how the radioactive it is in their house because of that stupid nuke plant close by, you will understand why I just want to cry.

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European Committee on Radiation Risk advice on Fukushima risks

ECRR Risk Model and radiation from Fukushima

Chris Busby

Scientific Secretary

European Committee on Radiation Risk

March 19th 2011

Radioactivity from the Fukushima Catastrophe is now reaching centres of population like Tokyo and will appear in the USA. Authorities are downplaying the risk on the basis of absorbed dose levels using the dose coefficients of the International Commission on Radiological Protection the ICRP. These dose coefficients and the ICRP radiation risk model are unsafe for this purpose. This is clear from hundreds of research studies of the Chernobyl accident outcomes. It has also been conceded by the editor of the ICRP risk model, Dr Jack Valentin, in a discussion with Chris Busby in Stockholm, Sweden in April 2009. Valentin specifically stated in a videoed interview (available on vimeo.com) that the ICRP model could not be used to advise politicians of the health consequences of a nuclear release like the one from Fukushima. Valentin agreed that for certain internal exposures the risk model was insecure by 2 orders of magnitude. The CERRIE committee stated that the range of insecurity was between 10 and members of the committee put the error at nearer to 1000, a factor which would be necessary to explain the nuclear site child leukemia clusters. The ECRR risk model was developed for situations like Fukushima.

Since the ECRR 2003 Radiation Risk Model, updated in 2010, was developed for just this situation it can be employed to assess the risk in terms of cancer and other ill health. See www.euradcom.org. It has been checked against many situations where the public has been exposed to internal radioactivity and shown to be accurate.

Using the ECRR 2010 radiation risk model the following guide to the health effects of exposure can be employed.

Take the dose which is published by the Japanese authorities. Multiply it by 600. This is the approximate ECRR dose for the mixture of internal radionuclides released from Fukushima. Then multiply this number by 0.1. This is the ECRR 2010 cancer risk.

Example 1: According to Japanese chief cabinet secretary Yukio Edano, the dose from exposure to radioactive milk from Fukushima is so low that you would have to drink milk for a year to get the equivalent of a CT scan dose. A CT scan dose is about 10 milliSieverts (mSv) Assuming you drink 500ml a day, the annual intake is 180litres so the dose per litre is 0.055mSv. The ECRR dose per litre is at maximum 0.055 x 600 = 33mSv. Thus the lifetime risk of cancer following drinking a litre of such contaminated milk is 0.0033 or 0.33%. Thus 1000 people each drinking 1 litre of milk will result in 3.3 cancers in the 50 years following the intake.

From the results in Sweden and elsewhere following Chernobyl, these cancers will probably appear in the 10 years following the exposure.

Example 2: External doses measured by a Geiger counter increased from 100nSv/h to 500nSv/h. What is the risk from a week's exposure? Because the external dose is only a flag for the internal dose we assume that this is the internal ICRP dose from the range of radionuclides released which include radiodines, radiocaesium, plutonium and uranium particles, tritium etc. A week's exposure is thus 400 x 10^{-9} x 24 x 7days or 6.72 x 10^{-5} Sv . We multiply by 600 to get the ECRR dose which is 0.04Sv and then by 0.1 to get the lifetime cancer risk which is 0.4%. Thus in this case, in 1000 individuals exposed for a week at this level, 4 will develop cancer because of this exposure. In 30 million, the population of Tokyo, this would result in 120,000 cancers in the next 50 years. The ICRP risk model would predict 100 cancers from the same exposure. Again we should expect to see a rise in cancer in the 10 years following the exposure. This is due to early clinical expression of pre-cancerous genomes.

Other health effects are predicted, including birth effects, heart disease and a range of other conditions and diseases. For details see ECRR2010.

These calculations have been shown to be accurate in the case of the population of Northern Sweden exposed to fallout for the Chernobyl accident, and also are accurate for the increased in cancer in northern hemisphere countries following the 1960s weapons testing fallout (the cancer epidemic). The public and the Japanese and other authorities would do well to calculate exposure risks on the basis of these approximations and to abandon the ICRP model which does not protect the public. This was the conclusion of a group of international experts who signed the 2009 Lesvos Declaration (this can be found on http://www.euradcom.org/2009/lesvosdeclaration.htm)

Reference:

ECRR 2010. The 2010 Recommendations of the European Committee on Radiation Risk. The health effects of exposure to low doses of ionizing radiation. Regulators' Edition. Eds: Chris Busby, Alexey V Yablokov, Rosalie Bertell, Molly Scott Cato, Inge Schmitz Feuerhake, Brussels: ECRR.

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LLRC Bulletin: March 13

Fukushima risks

Potential health consequences of the explosion at the Fukushima reactor in Japan

Below we offer basic advice for people living downwind of the releases of radioactivity.

On BBC Radio 4's The World This Weekend, 13th March, Dr. Chris Busby spoke about the potential health effects of the Fukushima explosion. Read transcript or listen here (the site may prompt you to download software to enable you to listen. Dr. Busby's interview is 9 minutes into the broadcast).

Dr. Busby said the reassurances being issued now by official sources and by apologists for the nuclear industry are exactly the same as those issued 25 years ago, at the time of Chernobyl. Risks were understated, as show by subsequent epidemiological studies.

Statements about allegedly low health risks are based on rates of gamma radiation measured at the site perimeter. These take no account of radiation from alpha-emitting radionuclides such as Uranium and Plutonium. It is of particular concern that the number 3 reactor at Fukushima which is now in a problematic condition is fuelled with Mixed-Oxide fuel containing Plutonium.

The health consequences of exposure to radioactive releases from nuclear plant cannot be accurately assessed by making radiation measurements based on absorbed dose. The authorities already downplay risks on the basis of the false radiation risk model advised by the International Commission on Radiological Protection (ICRP). This is an exact replication of the responses to the similar Chernobyl explosion. The effects of the Chernobyl accident have been devastating and continue to affect the health of the exposed populations as far away from Chernobyl as Europe and the USA. 1A major volume published in 2010 by the New York Academy of Sciences reveals a death toll of approaching 1 million persons by 2005.

Absorbed dose readings (milliSieverts) cannot be employed as measures of risk because some radioactive substances act from within the body, with especially high risk imparted by those that bind to DNA (e.g

Strontium-90 and Uranium). Dose to the local tissue or DNA can be enormous while the average dose recorded by a Geiger counter may be barely detectable. (More information)

If significant amounts of radioactivity from the Fukushima plume approach populated centres in any country (e.g. the western USA) the European Committee on Radiation Risk advises:

- Do not believe assurances from radiation protection advisors working for any government. They are based on an obsolete model. This is a potential Chernobyl level event and must be seen as extremely serious.
- If possible obtain a Geiger Counter or a similar radiation detector or readings from someone who owns one. If the readings increase to more than twice the normal background in your area or to a level of more than 300nSv/h (300nGy/h) then:
- Get away as soon as possible to a clean area. If it is not possible to evacuate, stay indoors and keep all the doors and windows closed for as long as the radiation levels are higher than normal. Try to keep the house sealed as far as possible.
- Drink bottled water, use only tinned milk. Avoid fresh garden produce. (We acknowledge that this is difficult advice for the people of Japan, where local produce is economically important.) Await further bulletins on this site and ECRR

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Monitoring Fukushima risks

LLRC Bulletin: March 14

If possible obtain a Geiger Counter or a similar radiation detector or readings from someone who owns one. Get readings hourly, if possible. If the readings increase to more than twice the normal background in your area or to a level of more than 300 nanoSieverts per hour (300nSv/h equivalent to 300nGy/h) then take the precautions we advised in our 13th March bulletin:- stay indoors, especially if it is raining, seal the house as far as possible, drink bottled water, use tinned milk, don't eat locally-grown produce unless it was harvested before the fallout arrived.

Since we are not aware of any coordinated attempt at monitoring, please let us know if you are able to take readings and we will post the results. We have monitoring stations in Riga (Latvia) and Aberystwyth (Wales, UK).

- Riga shows 120 nSv/h. This is the normal rate. (Unchanged 15 Mar.)
- Aberystwyth shows 150 nSv/h, also normal. (Unchanged 15 Mar.)

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Related Video: CTBTO Preparatory Commission – Radionuclid Monitoring

The Preparatory Commission is tasked with making preparations for effective implementation of the Treaty, in particular by establishing its verification regime. The main task is establishing and provisionally operating the 337 facility International Monitoring System (IMS), including its International Data Centre (IDC) and Global Communications Infrastructure (GCI). The Commission is tasked also with the development of operational manuals, including a manual to guide conduct of on-site inspections.

Any radiation found will be first detected from CTBTO's monitoring stations around the globe…

rn+77 Wake Island, USA
rn78 Midway, USA
rn+79 Oahu, USA
rn71 Alaska, USA
rn39 Kiritimati, Kiribati
rn70 Sacramento, USA
rn14 Sidney, Canada

Today, one of the monitoring stations in Sacramento, California that feeds into the IMS detected miniscule quantities of iodine isotopes and other radioactive particles that pose no health concern at the detected levels

Collectively, these levels amount to a level of approximately 0.0002 disintegrations per second per cubic meter of air (0.2 mBq/m3). Specifically, the level of Iodine-131 was 0.165 mBq/m3, the level of Iodine-132 was measured at 0.03 mBq/m3, the level of Tellurium-132 was measured at 0.04 mBq/m3, and the level of Cesium-137 was measured at 0.002 mBq/m3.

Similarly, between March 16 and 17, a detector at the Department of Energy's Pacific Northwest National Laboratory in Washington State detected trace amounts of Xenon-133, which is a radioactive noble gas produced during nuclear fission that poses no concern at the detected level. The levels detected were approximately 0.1 disintegrations per second per cubic meter of air (100 mBq/m3).

The doses received by people per day from natural sources of radiation – such as rocks, bricks, the sun and other background sources – are 100,000 times the dose rates from the particles and gas detected in California or Washington State

These types of readings remain consistent with our expectations since the onset of this tragedy, and are to be expected in the coming days.

Following the explosion of the Chernobyl plant in Ukraine in 1986 – the worst nuclear accident in world history – air monitoring in the United States also picked up trace amounts of radioactive particles, less than one thousandth of the estimated annual dose from natural sources for a typical person.

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Government Under Fire as Radiation Is Found in Milk, Rain

Federal officials have still not published any official data on nuclear fallout from Japan disaster

By John Upton on April 2, 2011 - 2:38 p.m. PDT

Source: The Bay Citizen (http://s.tt/12cPE)

Radiation from Japan rained on Berkeley during recent storms at levels that exceeded drinking water standards by 181 times and has been detected in multiple milk samples, but the U.S. government has still not published any official data on nuclear fallout here from the Fukushima disaster.

Dangers from radiation that is wafting over the United States from the Fukushima power plant disaster and falling with rain have been downplayed by government officials and others, who say its impacts are so fleeting and minor as to be negligible.

But critics say an absence of federal data on the issue is hampering efforts to develop strategies for preventing radioactive isotopes from accumulating in the nation's food and water supplies.

Three weeks after the Fukushima nuclear power plant began spewing radiation into the world's air, the U.S. government still has not revealed the amount of iodine-131 or other radioactive elements that have fallen as precipitation or made their way into milk supplies or drinking water.

“The official mantra from a lot of folks in government is, ‘Oh, it's OK in low levels,’” said Patty Lovera, a Washington-based assistant director at the nonprofit Food and Water Watch.

Related

- Radioactive Rain Falling on United States

  Fresno Nuclear Plan Moves Forward, Despite Crisis

“But low levels add up. We would like to see a more coherent strategy for monitoring air and water in agricultural areas and then using that data to come up with a plan, if you need one, to go look at the food system.”

Radiation falling with rain can cover grass that is eaten by cows and other animals. It can also fall on food crops or accumulate in reservoirs that are used for irrigation or drinking water. Seafood can also be affected.

Food and Water Watch sent a letter to President Barack Obama and members of his cabinet and Congress on Thursday urging the federal government to improve its monitoring of radiation in agricultural land and food in the wake of the Japanese tragedy.

“The three agencies that monitor almost all of the food Americans eat … have insisted that the U.S. food supply is safe,” the letter states. “The agencies, however, have done very little to detail specific ways in which they are responding to the threat of radiation in food.”

Cancer-causing radiation from Japan is circling the world, traveling quickly on jet streams high in the atmosphere and falling with rain. It is being detected in air, water and milk throughout the United States by local and state agencies.

The U.S. Food and Drug Administration, which regulates food safety, referred questions about potential milk contamination to the federal Environmental Protection Agency, which is taking the lead on testing dairy products for radiation.

The EPA on Tuesday said it expected to release results of tests for radioactivity in rain and snow within a day or so. On Friday, three days after making that pledge, EPA officials repeated the same statement and said the data would likely be released over the weekend or on Monday.


Creative Commons/David Baron
A dairy cow in the Sunol Regional Wilderness. Radiation can accumulate in milk after cows eat tainted grass.

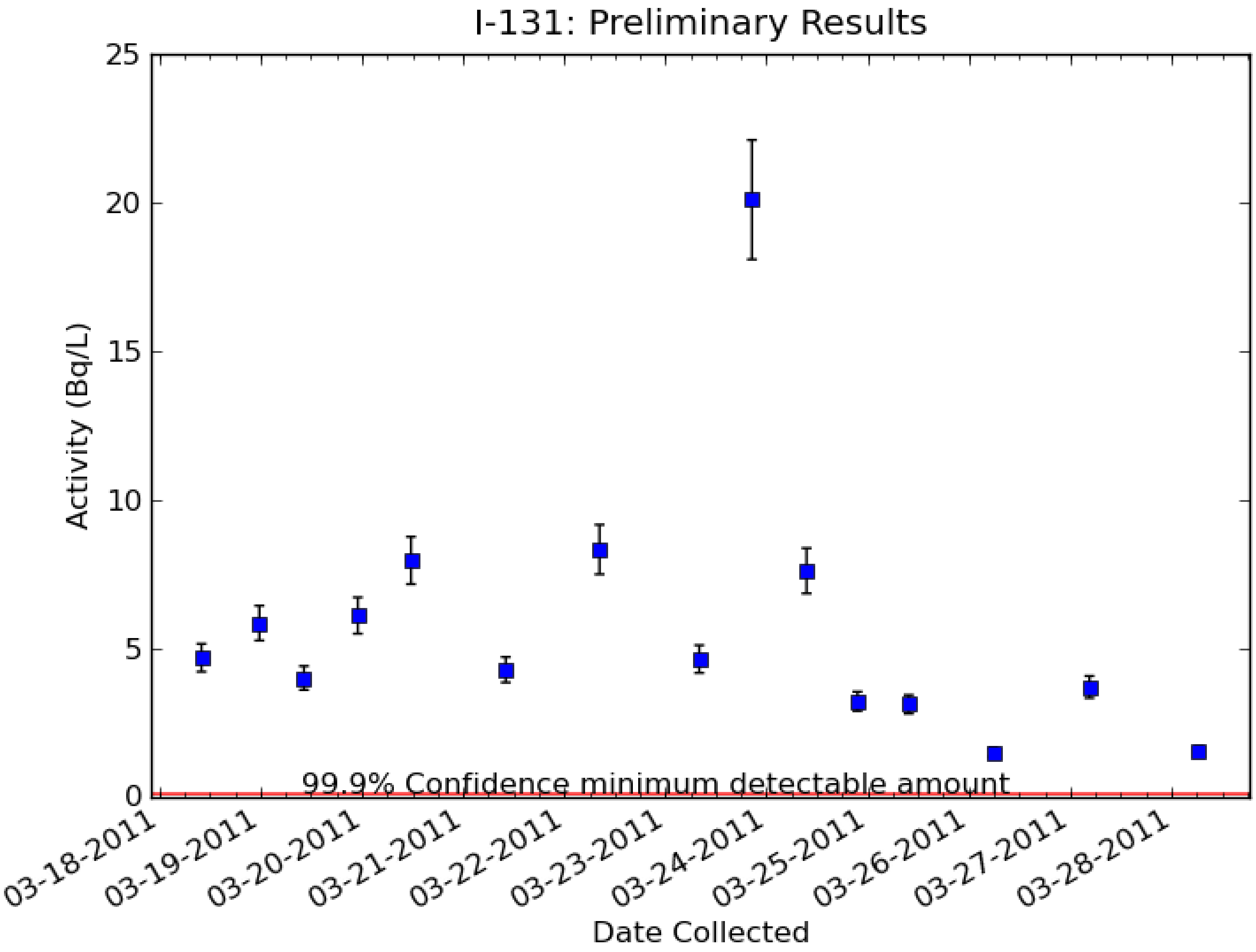
"We have accelerated our precipitation and drinking water sampling and expect to have results in the coming days," EPA spokesman Brendan Gilfillan said in a statement.

The EPA's tardy response to widespread alarm about radiation in rain and the air has been sharply criticized by Daniel Hirsch, a nuclear policy lecturer at the University of California, Santa Cruz.

"It's troubling that the EPA has to date not provided any precipitation data of its own, while measurements that have been made by states and others across the country are indicating somewhat surprising elevations of iodine-131," Hirsch said Friday.

A rooftop water monitoring program managed by UC Berkeley's Department of Nuclear Engineering detected substantial spikes in rain-borne iodine-131 during torrential downpours a week ago.

As shown in the graph below, published by UC Berkeley, Iodine-131 peaked at 20.1 becquerels per liter, a measure of radioactivity, on the roof of Etcheverry Hall during heavy rains a week ago. The federal maximum level of iodine-131 allowed in drinking water is 0.111 becquerels per liter.



The levels exceeded federal drinking water thresholds, known as maximum contaminant levels, or MCL, by as much as 181 times. However, the material has a half-life of eight days, meaning it breaks down quickly, and it quickly dissipates in the environment. Drinking water safety standards are based on prolonged exposures.

"Now, it isn't drinking water, and the MCL can be averaged for a period of up to a year," Hirsch said. "But it is striking that rainwater could be measured in Berkeley with radioiodine that is that far above the level you would generally be permitted to drink."

The material, which is one of the most toxic radioactive elements spewed when nuclear power plants melt down, is being ingested by cows, which are passing it through into their milk.

The UC Berkeley researchers also discovered trace levels of iodine-131 and other radioactive materials believed to have originated in Japan in commercially available milk and in a local stream.

Low levels of ioidine-131 were detected by state officials this week in milk harvested from San Luis Obispo. Milk from that region is tested frequently for radioactive material because its located near the Diablo Canyon nuclear power plant.

“It’s absolutely no public health risk,” California Department of Public Health spokesman Mike Sicilia said.

Similar readings have been reported in milk from Spokane, Washington.

Additionally, EPA air monitoring stations have detected airborne radioactive material believed to have blown across the Pacific Ocean from Japan at levels that federal officials insist are harmless.

Source: The Bay Citizen (http://s.tt/12cPx)

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an Dr. Chivers and team please translate your findings to match the German measurements? Thank you.

Dear Dr. Chivers:

is it possible to translate your iodine and telurium and cesium findings to make it the same unit (becquerels per cubic meter) so we can compare it to below data from Germany after Chernobyl?

After Chernobyl, for example, in the Munich area were significantly increased levels of radioactivity detected in the air, for example, 50 becquerels per cubic meter of iodine-131, 55 becquerels per cubic meter of tellurium-132 and 10 becquerels per cubic meters of radioactive cesium.

thank you so much.

‹ Bottled Mountain Spring Water Predictions for emission duration ›
»

Comparisons to Chernobyl

Submitted by cf (not verified) on Thu, 2011-03-31 04:15.

I was not able to reach any conclusions from the math here. I'm wondering if your team could possibly sum up the total fallout estimates for the Bay Area and compare that to Germany where we have a sense of the elevated cancer rates connected to Chernobyl? Whatever you can provide would be very much appreciated.

»

- reply

Since 1000 L = 1 cubic

Submitted by bandstra on Thu, 2011-03-31 03:27.

Since 1000 L = 1 cubic meter, you can multiply our air sample numbers by 1000 to convert from Bq/L to Bq/m^3.

If you do that, those post-Chernobyl numbers are ~10,000 times larger than our observations. What is the source of those numbers you're quoting?

»

- reply

please give example

Submitted by Anonymous (not verified) on Thu, 2011-03-31 03:37.

sorry, my math is not good.
For the peak for iodine 8 bequerel last week, would that mean 8000 bequerel per cubic meter? That would be quite high.

»

- reply

Your math is right, but the

Submitted by bandstra on Thu, 2011-03-31 03:44.

Your math is right, but the 8 Bq/L number is from the measurements of rainwater. The original poster was referring to air measurements, for which our highest measurement of I-131 has been 4.4E-6 Bq/L.

»

- reply

please clarify

Submitted by Anonymous (not verified) on Thu, 2011-03-31 04:01.

what exactly is 4.4 E-6 Bq? Is it 4.4/100000? or one millionbiz of 4.4?

thanks.

»

- reply

Sources

Submitted by Anonymous (not verified) on Thu, 2011-03-31 03:36.

http://www.bfs.de/de/kerntechnik/papiere/japan/strahlenschutz_japan.html/printversion

this is a German site I found, which you can translate in English, it is somewhere in that article. thanks

I am not sure how reliable that website is.