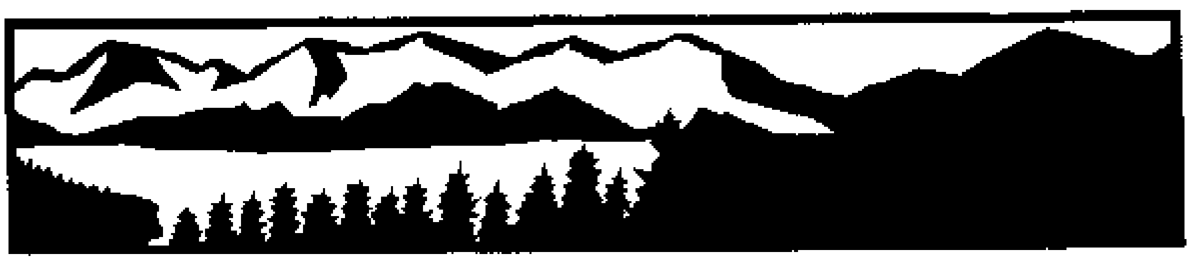
EPA
United States
Environmental Protection
Agency

Common Radionuclides



Found at Superfund Sites

Office of Radiation
and Indoor Air
Office of Solid Waste and
Emergency Response
Washington, DC 20460

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INTRODUCTION

This booklet contains two page fact sheets on some of the common radionuclides found at hazardous waste sites across the nation. It is meant to help you understand more about the various radionuclides and to assist the public in understanding how the federal government may apply legal requirements in the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The CERCLA requirements and regulations described in this document contain legally binding requirements. The information in this booklet is not a substitute for those requirements and regulations, nor is it a regulation itself. Thus, it does not impose legally-binding requirements on any party, including EPA, States, or the regulated community, and may not apply to a particular situation based on the circumstances. EPA and State decisionmakers retain the discretion to adopt approaches on a case-by-case basis that differ from this booklet where appropriate. Any decisions regarding a particular facility will be made based on the applicable statutes and regulations. Therefore, interested parties are free to raise questions and objections about the appropriateness of the application of this booklet to particular situation, and EPA will consider whether or not the recommendations or interpretations in the booklet are appropriate in that situation. EPA may change this booklet in the future.

This booklet answers such questions as: How can a person be exposed to the radionuclide?, How can it affect human health?, How it enters and leaves the body?, What levels of exposure result in harmful effects?, What recommendations has the federal government made to protect human health from the radionuclide?

What recommendations has the Environmental Protection Agency made to protect human health?

Information on recommendations EPA has made to protect human health from exposure to a particular radionuclide are contained in each of the fact sheets. General recommendations EPA has made to protect human health, which cover all radionuclides, are summarized below.

All actions to clean up contamination at CERCLA sites must be protective of human health and the environment and comply with Applicable or Relevant and Appropriate Requirements (ARARs) unless a waiver is justified. ARARs are often the determining factor in establishing cleanup levels at CERCLA sites. However, where ARARs are not available or are not sufficiently protective, EPA generally sets site-specific cleanup levels for carcinogens at a level that represents an excess upper bound lifetime cancer risk of between 10^{-4} to 10^{-6} to an individual under a reasonable maximum exposure (RME) scenario. This can be interpreted to mean that an individual may have a one in 10,000 to one in 1,000,000 increased chance of developing cancer because of exposure to a site-related carcinogen. The site-specific level of cleanup is determined using the nine criteria specified in 40 CFR 300.430(e)(9)(iii) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). EPA has developed a standard approach for calculating radionuclide soil concentrations that correspond to a cancer risk level of 1×10^{-6} and that protect against radionuclides moving from the soil into the groundwater. This electronic calculating tool may be found on the internet at http://epa-prgs.ornl.gov/radionuclides .

The Environmental Protection Agency OSWER Directive 9200.4-18, "Establishment of Cleanup Levels for

CERCLA Sites with Radioactive Contamination”, Attachment A provides a listing of Federal radiation regulations that may be ARARs for Superfund cleanup actions. This list is not a comprehensive list of Federal radiation standards and it does not include State standards which may be ARARs. It must also be cautioned that the selection of ARARs is site-specific and those determinations may differ from those listed in OSWER Directive 9200.4-18, Attachment A. To assess the potential for cumulative noncarcinogenic effects posed by multiple contaminants, EPA has developed a hazard index (HI). The HI is derived by adding the noncancer risks for site chemicals with the same target organ/mechanism of toxicity. When the HI exceeds 1.0, there may be concern for adverse health effects due to exposure to multiple chemicals.

What radionuclides are listed in this booklet?

The radionuclides listed in this booklet are:

Americium-241
Cesium-137
Cobalt-60
Iodine
Plutonium
Radium
Radon
Strontium-90
Technetium-99
Thorium
Tritium
Uranium

If you have more questions about the radionuclides mentioned in this booklet or would like more information on the U.S. Environmental Protection Agency’s Superfund hazardous waste cleanup program, please contact either *EPA’s Superfund Hotline at 1-800-424-9346 or 1-800-535-0202* or *EPA’s Superfund Radiation Webpage http://www.epa.gov/oerrpage/superfund/resources/radiation/index.htm*.

GLOSSARY

Activity: See radioactivity.

Aerobic: Able to live or grow only where oxygen is present.

Alpha particle: A positively charged particle released spontaneously form the nuclei of some radioactive elements.

Applicable or Relevant and Appropriate Requirements (ARARs): Any state or federal statute that pertains to protection of human health and the environment in addressing specific conditions or use of a particular cleanup technology at a Superfund site.

Background Concentration: The concentration of a substance in an environmental media (air, water, or soil) that occurs naturally or is not the result of activities from operations at the site.

Becquerel: The international system (SI) units of activity equal to one nuclear transformation (disintegration) per second.

Beta Particle: An electron emitted from the nucleus during radioactive decay.

Curie: The customary unit of radioactivity. A curie is equal to 37 billion disintegrations per second which is approximately the rate of decay of 1 gram of radium.

Decay products: Nuclides produced during radioactive decay of some other nuclide.

Detection limit: The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Epidemiology: Study of the distribution of disease, or other health-related states and events in human populations, as related to age, sex, occupation, ethnicity, and economic status in order to identify and alleviate health problems and promote better health.

Fission: Transformation characterized by the splitting of a nucleus into two or more parts and the release of a relatively large amount of energy.

Fission product: Nuclides produced during nuclear fission.

Gamma radiation : Penetrating high-energy, short-wavelength electromagnetic radiation (similar to X-rays) emitted during radioactive decay. Gamma rays are very penetrating and require dense materials, such as lead or steal, for shielding.

Groundwater: The supply of fresh water found beneath the Earth's surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants or leaking underground storage tanks.

Half-life: The time in which half the atoms of a particular radioactive substance disintegrate into another nuclear form.

Ingestion: The act or process of putting food, water, or other material into the body for digestion.

Inhalation: To draw air, vapor, etc. into the lungs; to breathe.

Isotope: One of two or more atoms that has the same number of protons but different number of neutrons.

Maximum Contaminant Level (MCL): EPA evaluates the health risks associated with various contaminant levels to ensure that public health is adequately protected. The MCL, as it is commonly known, is the maximum allowable concentration of a specific contaminant in public drinking water. Superfund sites are cleaned up so that the level of contamination in the groundwater does not exceed the MCL for that radionuclide. The MCLs for radionuclides are currently being revised. For further information concerning the MCLs for radionucludides, please refer to the following Internet address: http://www.epa.gov/safewater/radionuc.html

Neutron particle : A particle that is similar in mass to a proton, but carries no charge and is found in the nucleus of every atom heavier than hydrogen.

Nucleus: The small, central, positively charged region of an atom that carries essentially all the mass.

Nuclide: A general term referring to all known isotopes, both stable and unstable, of the chemical elements.

Picocurie (pCi): one-trillionth of a curie. A curie is equal to 37 billion disintegrations per second which is approximately the rate of decay of 1 gram of radium.

Radioactivity: The mean number of nuclear transformations occurring in a given quantity of radioactive material per unit time. The customary unit is the *Curie (Ci)*. The International System unit of radioactivity is the *Becquerel (Bq)*.

Radioactive decay: The spontaneous transformation of an unstable atom into one or more different nuclides accompanied by either the emission of energy and/or particles from the nucleus, nuclear capture or ejection of orbital electrons, or fission.

Radionuclide: An unstable nuclide that undergoes radioactive decay.

"Reasonable maximum exposure" (RME) : The maximum exposure reasonably expected to occur in a population.

Superfund Program: The program operated under the legislative authority of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) that provided broad Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.

Toxic: A poisonous or hazardous substance; having poisonous or harmful qualities.

Working Level(WL): Any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of alpha particles with a total energy of 130 billion electron volts.

EPA Facts About Americium-241

July 2002

What is americium-241?

Americium is a man-made radioactive metal that exists as a solid under normal conditions. Americium is produced when plutonium absorbs neutrons in nuclear reactors and nuclear weapons tests.

Americium occurs in several forms called isotopes. The most common isotope is americium-241.

What are the uses of americium-241?

Americium when blended with beryllium is used as a neutron source in the testing of machinery and in thickness gauges in the glass industry. Americium also is used as a radiation source in medical diagnostic devices and in research. It is commonly used in minute amounts in smoke detectors as an ionization source.

How does americium-241 change in the environment?

Americium-241 is formed in the environment by the decay of plutonium contamination from nuclear weapons production and testing. Americium-241 is an unstable isotope. As americium decays, it releases radiation and forms "daughter" elements. The first decay product of americium-241 is neptunium-237, which also decays and forms other daughter elements. The decay process continues until stable bismuth is formed.

The radiation from the decay of americium-241 and its daughters is in the form of alpha particles, beta particles, and gamma rays. Alpha particles can travel only short distances and generally will not penetrate the outer layer of human skin. Gamma rays can penetrate the body. Beta particles are generally absorbed in the skin and do not pass through the entire body. The time in which half the atoms of a radioactive substance disintegrate to another nuclear form is known as the half-life. The half-life of americium-241 is about 432 years.

How are people exposed to americium-241?

Americium has been released to the environment primarily by atmospheric testing of nuclear weapons. Concentrations of americium introduced into the environment through nuclear weapons production operations have been negligible compared with those released during atmospheric testing of nuclear explosives.

Weapon sites and industries that manufacture smoke detectors are potential sources of exposure from americium-241. Potential pathways of exposure include ingestion, inhalation, and the external pathway from gamma radiation.

How does americium-241 get into the body?

Americium can enter the body when it is inhaled or swallowed. When inhaled, the amount of americium that remains in the lungs depends upon the particle size and the chemical form of the americium compound. The chemical forms that dissolve easily may be absorbed through the lung and pass into the blood stream. The forms that dissolve less easily are typically swallowed where some may pass into the blood stream and the remainder will pass through the feces. However, some undissolved material may also remain in the lung.

Is there a medical test to determine exposure to americium-241?

Tests are available that can reliably measure the amount of americium in a urine sample, even at very low levels. These measurements can be used to estimate the total amount of americium present in the body. There are also tests to measure americium in soft tissues (such as body organs), feces, bones, and breast milk. Whole body testing and nasal smears may also be used to measure americium in the body. These tests are not routinely available in a doctor's office because special laboratory equipment is required.

How can americium-241 affect people's health?

Because americium emits alpha particles, americium poses a significant risk if enough is swallowed or inhaled. Once in the body, americium tends to concentrate primarily in the skeleton, liver, and muscle. It generally stays in the body for decades and continues to expose the surrounding tissues to radiation. This may eventually increase a person's chance of developing cancer, but such cancer effects may not become apparent for several years. Americium, however, also can pose a risk from direct external exposure.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to americium-241. General recommendations EPA has made to protect human health, which cover all radionuclides including americium-241, are summarized in the Introduction section of this booklet.

EPA has established a Maximum Contaminant Level (MCL) of 15 picocuries per liter (pCi/l) for total alpha particle activity, excluding radon and uranium, in drinking water. Americium-241 would be covered under this MCL.

For more information about how EPA addresses americium-241 at Superfund sites, please contact either:

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation/

EPA Facts About Cesium-137

July 2002

What is cesium-137?

Radioactive cesium-137 is produced spontaneously when other radioactive materials such as uranium and plutonium absorb neutrons and undergo fission. Cesium-137 is therefore a common radionuclide produced when nuclear fission, or splitting, of uranium and plutonium occurs in a reactor or atomic bomb.

What are the uses of cesium-137?

Cesium-137 and its decay product, barium-137m, are used for sterilization activities for food products, including wheat, spices, flour, and potatoes. Cesium-137 is also used in a wide variety of industrial instruments such as level and thickness gauges and moisture density gauges. Cesium-137 is also commonly used in hospitals for diagnosis and treatment, as a calibration source, and large sources can be used to sterilize medical equipment.

How does cesium change in the environment?

Cesium-137 decays in the environment by emitting beta particles. As noted above, cesium-137 decays to a short lived decay product, barium-137m. The latter isotope emits gamma radiation of moderate energy, which further decays to a stable form of barium.

Cesium-137 is significant because of its prevalence, relatively long half life (30 years), and its potential effects on human health. Cesium-137 emits beta particles as it decays to the barium isotope, Ba-137m (half life = 2.6 minutes).

How are people exposed to cesium-137?

People may be exposed externally to gamma radiation emitted by cesium-137 decay products. If very high doses are received, skin burns can result. Gamma photons emitted from the barium decay product, Ba-137m, are a form of ionizing radiation that can pass through the human body, delivering doses to internal tissue and organs. People may also be exposed internally if they swallow or inhale cesium-137.

Large amounts of cesium-137 were produced during atmospheric nuclear weapons tests conducted in the 1950s and 1960s. As a result of atmospheric testing and radioactive fallout, this cesium was dispersed and deposited world wide.

Sources of exposure from cesium-137 include fallout from previous nuclear weapons testing, soils and waste materials at radioactively contaminated sites, radioactive waste associated with the operation of nuclear reactors, spent fuel reprocessing plants, and nuclear accidents. Cesium-137 is also a component of low level radioactive waste at hospitals and research facilities.

How does cesium-137 get into the body?

Cesium-137 can enter the body when it is inhaled or ingested. After radioactive cesium is ingested, it is distributed fairly uniformly throughout the body's soft tissues. Slightly higher concentrations are found in muscle; slightly lower concentrations are found in bone and fat. Cesium-137 remains in the body for a relatively short time. It is eliminated more rapidly by infants and children than by adults.

Is there a medical test to determine exposure to cesium-137?

Generally, levels of cesium in the body are inferred from measurements of urine samples using direct gamma spectrometry (ICRP Publication 54, 1988). Because of the presence of the gamma-emitting barium daughter product, a technique called whole-body counting may also be used; this test relies on detection of gamma photon energy. Skin contamination can be measured directly using a variety of portable instruments. Other techniques that may be used include the taking of blood or fecal samples, then measuring the level of cesium.

How can cesium-137 affect people's health?

Based on experimentation with ionizing radiation and human epidemiology, exposure to radiation from cesium-137 can result in malignant tumors and shortening of life. Great Britain's National Radiological Protection Board (NRPB) predicts that there will be up to 1,000 additional cancers over the next 70 years among the population of Western Europe exposed to fallout from the accident at Chernobyl.

For scenarios involving nuclear accidents or waste materials the magnitude of the health risk would depend on exposure conditions, such as types of radioactivity encountered, nature of exposure, and time period.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to cesium-137. General recommendations EPA has made to protect human health, which cover all radionuclides including cesium-137, are summarized in the Introduction section of this booklet.

EPA, has established a Maximum Contaminant Level (MCL) of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. Cesium-137 would be covered under this MCL. The average concentration of cesium-137 which is assumed to yield 4 millirem per year is 200 picocuries per liter (pCi/l). If other radionuclides which emit beta particles and photon radioactivity are present in addition to cesuim-137, the sum of the annual dose from all the radionuclides shall not exceed 4 millirem/year.

For more information about how EPA addresses cesium-137 at Superfund sites, please contact either:

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation

EPA Facts About Cobalt-60

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What is cobalt-60?

The most common radioactive form of cobalt is cobalt-60 which is produced commercially and used as a tracer and radiotherapeutic agent. It is produced in a process called activation, when materials in reactors, such as steel, are exposed to neutron radiation.

What are the uses of cobalt-60?

Cobalt-60 is widely used as a medical and industrial radiation source. Medical use consists primarily of cancer radiotherapy. Industrial uses include testing of welds and castings, and a large variety of measurement and test instruments including leveling devices and thickness gauges. It is also used to sterilize instruments, and to irradiate food to kill microbes and prevent spoilage.

How does cobalt-60 change in the environment?

Cobalt-60 decays by beta and gamma emission to non-radioactive nickel.

Most of the radiation from the decay of cobalt-60 is in the form of gamma emissions; some is in the form of beta particles. Beta particles are generally absorbed in the skin and do not pass through the entire body. Gamma radiation, however, can penetrate the body.

The time in which half the atoms of a radioactive substance disintegrate to another nuclear form is known as the half-life. The half-life of cobalt-60 is about 5.2 years.

How are people exposed to cobalt-60?

Most exposure to cobalt-60 takes place intentionally during medical tests and treatments. Such exposures are carefully controlled to avoid adverse health impacts. Cobalt-60 is produced as a result of weapons testing or in other nuclear reactions. Since cobalt-60 has a short half-life there is no significant presence of the isotope in the general environment at this time. Exposures have occurred as the result of improper disposal of medical radiation sources, and the accidental melting of cobalt-60 sources by metal recycling facilities.

How does cobalt-60 get into the body?

The major concern posed by cobalt-60 is from external exposure to gamma radiation. Cobalt-60 can be swallowed with food or inhaled in dust. Once in the body, some of it is quickly eliminated in the feces. The rest is absorbed into the blood and tissues, mainly the liver, kidney, and bones. This cobalt leaves the body slowly, mainly in the urine.

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

Cobalt in the body can be detected in the urine. In addition, a procedure known as whole-body counting can measure the amount of gamma ray-emitting radioactive material in the body such as the amount of cobalt-60 that has been inhaled and is still in the lungs. Other techniques that may be used include the taking of blood or fecal samples, then measuring the level of cobalt-60. These tests are more sensitive and more accurate if done shortly after exposure.

How can cobalt-60 affect people's health?

Because cobalt-60 releases gamma rays, it can affect the health of people nearby even if they do not ingest or inhale it. Exposure to low levels of gamma radiation over an extended period of time can cause cancer. The magnitude of the risk of adverse health effects is depends on the quantity of cobalt-60 involved and on exposure conditions, such as time of exposure, distance from an the source (for external exposure), and whether the cobalt-60 was ingested or inhaled.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to cobalt-60. General recommendations EPA has made to protect human health, which cover all radionuclides including cobalt-60, are summarized in the Introduction section of this booklet.

EPA has established a Maximum Contaminant Level (MCL) of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. Cobalt-60 would be covered under this MCL. The average concentration of cobalt-60 which is assumed to yield 4 millirem per year is 100 picocuries per liter (pCi/l). If other radionuclides which emit beta particles and photon radioactivity are present in addition to cobalt-60, the sum of the annual dose from all the radionuclides shall not exceed 4 millirem/year.

For more information about how EPA addresses cobalt-60 at Superfund sites, please contact either:

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation

EPA Facts About Iodine

July 2002

What is Iodine?

Iodine is a metal found throughout the environment in a stable form, iodine-127, and as unstable radioactive isotopes of iodine. These radioactive forms include iodine-129 and iodine-131. Iodine-129 is produced naturally in the upper atmosphere. Iodine-129 and iodine-131 are also produced in nuclear explosions. In addition, iodine-129 is released at very low levels into the environment from facilities that separate and reprocess nuclear reactor fuels, and from waste storage facilities.

What are the uses of iodine?

Stable iodine-127 is used as a dietary supplement for thyroid deficiencies. In addition, iodine-131, iodine-125, and iodine-123 are used for imaging and iodine-131 for therapy for treatment of various thyroid conditions.

How does iodine change in the environment?

Iodine-129 and 131 are two of the more common radioactive forms of iodine. Both iodine-129 and iodine-131 release radiation during the decay process by emitting a beta particle and gamma radiation. The half life of iodine-131 is relatively short at eight days while the half life of iodine-129 is much longer at over fifteen million years

How are people exposed to iodine ?

People can be exposed to all forms of iodine through the food chain. However, current environmental levels of radioactive iodine are low. In addition fish, bread, milk, and iodized salt contain stable iodine.

Large quantities of radioactive iodine-131 have been released into the environment by nuclear weapons and the Chernobyl accident; however, the current inventory of iodine 131 in the environment is very low. The reason for this is iodine-131 has a very short half life. Iodine- 129 is naturally occurring in the environment, and it has also been produced by nuclear weapons testing. The amount of iodine-129 produced by nuclear weapons testing is less than the inventory of naturally occurring iodine-129. Iodine-129, however, is found in radioactive wastes from defense-related government facilities and nuclear fuel cycle facilities.

How does iodine get into the body?

Iodine is soluble in water which allows it to move easily from the atmosphere into living organisms. For this reason iodine can be concentrated in marine organisms. Iodine can also be concentrated in grass where it then can be ingested by cows and incorporated into their milk. Iodine can be found on leafy vegetables and then consumed directly by humans. Once iodine is ingested into the human body, a portion of it is concentrated in the thyroid gland and the rest excreted. The most probable means of exposure to radioactive iodine is from a patient who has been recently administered radioactive iodine for imaging or therapeutic purposes.

The uptake of radioactive iodine by the thyroid is inversely related to the intake of stable iodine. For this reason protection from radioactive iodine following an emergency release is accomplished by ingesting large doses of stable iodine. It should be noted that large doses of stable iodine can be a health hazard and should not be taken except in an emergency and when directed by the appropriate emergency response officials.

Is there a medical test to determine exposure to iodine?

Since iodine is concentrated in the thyroid gland, radioassay of the thyroid is used to determine the exposure level from iodine. Whole body counts which measure iodine gamma radiation can also be used to measure iodine in the body.

How can iodine affect people’s health?

The predominant health concern for radioactive iodine is in the thyroid gland where it may induce nodules or thyroid cancer. High doses of iodine are used to treat thyroid cancer. Lower doses of radioactive iodine will result in reducing activity of the thyroid gland which will result in lower hormone production in the gland. There is a fine balance when treating thyroid problems with radioactive iodine. Such treatments are only performed when the benefits outweigh the risks. As with any radioactive material, there is an incremental chance that a cancer or other adverse health effect can result from that incremental exposure to radioactive materials.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to iodine-131. General recommendations EPA has made to protect human health, which cover all radionuclides including iodine-131, are summarized in the Introduction section of this booklet.

EPA has established a Maximum Contaminant Level (MCL) of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. The average concentration of iodine-131, which is assumed to yield 4 millirem per year, is 3 picocuries per liter (pCi/l). If other radionuclides which emit beta particles and photon radioactivity are present in addition to iodine- 131, the sum of the annual dose from all the radionuclides shall not exceed 4 millirem/year.

For more information about how EPA addresses iodine 131 at Superfund sites, please contact either:

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation/index.htm

EPA Facts About Plutonium

July 2002

What is plutonium?

Plutonium is a radioactive metal that exists as a solid under normal conditions. It is produced when uranium absorbs an atomic particle such as a neutron. Small amounts of plutonium occur naturally, but large amounts have been produced in nuclear reactors as a result of neutron irradiation.

Plutonium occurs in several forms called isotopes. The most common plutonium isotopes are plutonium-238, plutonium-239 and plutonium-240.

What are the uses of plutonium?

Plutonium-238 is used as a heat source to generate thermoelectric power for electronic systems in satellites and for heart pacemakers. Plutonium-239 is used primarily in nuclear weapons. Plutonium-239 and plutonium-240 are two of the most prevalent plutonium byproducts of weapons testing.

How does plutonium change in the environment?

Plutonium is not a stable element. As plutonium decays, it releases radiation and forms decay products . For example, the decay products of plutonium-238 and plutonium-239 are uranium-234 and uranium-235, respectively. The decay process continues until a stable, non-radioactive decay product is formed.

Radiation is released during the decay process in the form of alpha and beta particles, and gamma radiation. Alpha particles can travel only short distances and generally will not penetrate human skin. Beta particles are generally absorbed in the skin and do not pass through the entire body. Gamma radiation, however, can penetrate the body.

Plutonium-238, plutonium-239, and plutonium-240 are isotopes of plutonium, and have half-lives of 87 years, 24,065 years, and 6,537 years respectively.

How are people exposed to plutonium?

Plutonium has been released to the environment primarily by atmospheric testing of nuclear weapons and by accidents at facilities where plutonium is used. The amount of plutonium introduced into the environment through nuclear weapons production operations have been negligible compared with those released during testing of nuclear explosives.

Plutonium-238, plutonium-239, and plutonium-240 are alpha emitters. As a result, the potential for direct exposure is minimal from these isotopes. When mixed in soil on the ground these plutonium isotopes have a potential risk that is predominantly from the inhalation and ingestion pathways.

How does plutonium get into the body?

Plutonium can enter the body when it is inhaled or swallowed. Once inhaled, the amount of plutonium that remains in the lungs depends upon the particle size and the chemical form of the plutonium. The chemical forms that dissolve less easily may be absorbed or may remain in the lung. The forms that dissolve less easily are often swallowed. Plutonium swallowed with food or water is poorly absorbed from the stomach, so most of it leaves the body in the feces.

Is there a medical test to determine exposure to plutonium?

Tests are available that can reliably measure the amount of plutonium in a urine sample, even at very low levels. There are also tests to measure plutonium in soft tissues (such as body organs), feces, and bones. These measurements can be used to estimate the total amount of plutonium present in the body. These tests are not routinely available in a doctor's office because special laboratory equipment is required. Other medical tests for plutonium include whole body counting for americium-241and nasal smears.

How can plutonium affect people's health?

Plutonium may remain in the lungs or move into the bones, liver, or other body organs. The plutonium that is not readily extracted stays in the body for decades and continues to expose the surrounding tissue to radiation. Plutonium inhaled or ingested will increase a person's chance of developing cancer, but such cancer effects may not become apparent for several years.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to plutonium. General recommendations EPA has made to protect human health, which cover all radionuclides including plutonium, are summarized in the Introduction section of this booklet.

EPA has established a Maximum Contaminant Level (MCL) of 15 picocuries per liter (pCi/l) for alpha particle activity, excluding radon and uranium, in drinking water. Plutonium would be covered under this MCL.

For more information about how EPA addresses plutonium at Superfund sites, please contact either:

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation

EPA Facts About Radium

July 2002

What is radium?

Radium is a naturally occurring radioactive metal that exists as one of several isotopes. It is formed when uranium and thorium decay in the environment. In the natural environment, radium is found at low levels in soil, water, rocks, coal, plants, and food.

What are the uses of Radium?

In the early 1900's, radium was erroneously used to treat rheumatism and mental disorders, and as a general tonic. Radium was also used to make luminous paints for watch dials, clocks, glow in the dark buttons, and military instruments. Because of the health hazards from these types of exposures the use of radium for these purposes was discontinued. Radium has also been widely used in medical therapy to irradiate cancerous cells in the body, but this use has largely been replaced by other radioactive materials or methods. Radium-226 has also been used in medical equipment, gauges, and calibrators, and in lightening rods. Alpha emitters such as radium and plutonium can be used as components of a neutron generator.

How does radium change in the environment?

Radium is not a stable element. As radium decays, it releases radiation and forms decay products. Like radium, many of these decay products also release radiation and form other elements. The decay process continues until a stable, nonradioactive decay product is formed.

Radiation is released during the decay process in the form of alpha and beta particles, and gamma radiation. Alpha particles can travel only short distances and cannot penetrate human skin. Beta particles are generally absorbed in the skin and do not pass through the entire body. Gamma radiation, however, can penetrate the body.

Isotopes of radium decay to form radioactive isotopes of radon gas. Radium-224, radium-226, and radium-228, the most common isotopes of radium, have half-lives of 3.5 days, 1,600 years, and 6.7 years respectively, after which each forms an isotope of radon. Radon is known to accumulate in homes and buildings.

How are people exposed to radium?

Since radium is present at relatively low levels in the natural environment, everyone has some level of exposure from it. However, individuals may be exposed to higher levels of radium and its associated external gamma radiation if they live in an area where there is an elevated level of radium in soil. In addition, radium is particularly hazardous because it continually produces radon which can diffuse into nearby homes.

An individual can be exposed to radium if one comes into contact with waste from 20th century ore at radium processing facilities, former radium dial facilities, or radium dials. In addition, exposure from radium can occur if radium is released into the air from the burning of coal or other fuels, or if drinking water taken from a source that is high in natural radium is used. Individuals may also be exposed to higher levels of radium if they work in a mine or in a plant that processes ores. Phosphate rocks which can contain relatively high levels of uranium and radium are also a potential source of exposure. 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 may occur due to geologic sources.

Radium exposure therefore can be from gamma radiation from radium decay products, lung exposure from radon gas and its decay products, and inhalation and ingestion exposure.

How does radium get into the body?

Radium can enter the body when it is inhaled or swallowed. Radium breathed into the lungs may remain there for months; but it will gradually enter the blood stream and be carried to all parts of the body, with a portion accumulating in the bones.

If radium is swallowed in water or with food, most of it (about 80%) will promptly leave the body in the feces. The other 20% will enter the blood stream and be carried to all parts of the body. Some of this radium will then be excreted in the feces and urine on a daily basis; however, a portion will remain in the bones throughout the person's lifetime.

Is there a medical test to determine exposure to radium?

Urine and bone biopsy tests are sometimes used to determine if individuals have ingested or swallowed a source of radioactivity such as radium. Radon, a decay product of radium, can also be measured in air that is exhaled from the body. Another technique, gamma spectroscopy, can measure the amount of radioactivity in portions of the body. These tests require special equipment and cannot be done in a doctor's office. There is no test that can detect external exposure to radium's gamma radiation alone.

How can radium affect people's health?

Exposure to radium over a long period may result in many different harmful effects. If inhaled as dust, or ingested as a contaminant, risk is increased for several diseases including, lymphoma, bone cancer, and hematopoietic (blood-formation) diseases, such as leukemia, and aplastic anemia. These effects take years to develop. If exposed externally to radium's gamma radiation, risk of cancer is increased in essentially all tissues and organs, though to varying degrees. However, in the environment, the greatest risk associated with radium is actually posed by it's direct decay product radon. Radon has been shown to cause lung cancer.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to radium. General recommendations EPA has made to protect human health, which cover all radionuclides including radium, are summarized in the Introduction section of this booklet.

For uranium mill tailing sites with radium contamination, EPA has established a radium level of 5 picocuries per gram (pCi/g) above background as a protective health based level for the cleanup of soil in the top 15 centimeters. These regulations under 40 CFR Part 192.12 are often ARARs at Superfund sites. The EPA OSWER Directive 9200.4-25, "Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA sites" provides guidance regarding when of 5 pCi/g is an ARAR or otherwise recommended cleanup level for any 15 centimeters of subsurface radium contaminated soil other than the first 15 centimeters.

If regulations under 40 CFR Part 192.12 are an ARAR for radium in soil at a Superfund site, then Nuclear Regulatory Commission regulations for uranium mill tailing sites under 10 CFR Part 40 Appendix A, I, Criterion 6(6) may possibly be an ARAR at the same site. Criterion 6(6) requires that an estimate be made of the level of radiation, called a "benchmark dose," that an individual would receive after that site was cleaned up to the radium soil regulations under 40 CFR Part 192.12. This benchmark dose then becomes the maximum level of radiation that an individual may be exposed to from all radionuclides, except radon, in both the soil and buildings at the site. The EPA OSWER Directive 9200.4-35P "Remediation Goals for Radioactively Contaminated CERCLA Sites Using the Benchmark Dose Cleanup Criterion 10 CFR Part 40 Appendix A, I, Criterion 6(6)" provides guidance regarding how Criterion 6(6) should be implemented as an ARAR at Superfund sites, including using a radium soil cleanup level of 5 pCi/g in both the surface and subsurface when estimating a benchmark dose.

EPA has established a Maximum Contaminant Level (MCL) of 5 picocuries per liter (pCi/l) for any combination of radium-226 and radium-228 in drinking water. EPA has also established a MCL of 15 pCi/l for alpha particle activity, excluding radon and uranium, in drinking water. Radium-226 would also be covered under this MCL.

For more information about how EPA addresses radium at Superfund sites, please contact either:

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation

EPA Facts About Radon

July 2002

What is radon?

Radon is a naturally occurring radioactive gas without color, odor, or taste, that undergoes radioactive decay and emits ionizing radiation. Radon comes from the natural (radioactive) breakdown of uranium and thorium in soil, rock and ground water and is found all over the U.S. The largest fraction of the public's exposure to natural radiation comes from radon, mostly from soil under homes. [There are three forms of radon, but this document refers primarily to radon-222 and its progeny.]

How does radon change in the environment?

The primary source of radon is from uranium in soils and rocks, and in ground water. Over time uranium decays into radium, which then decays directly into radon. (See EPA Facts About Radium and Uranium.) Uranium is present naturally in all soil, although quantities differ from place to place. Because radon is a gas and chemically unreactive with most materials, it moves easily through very small spaces such as those between particles of soil and rock, to the soil surface. Radon is also moderately soluble in water, and it can be absorbed by ground water flowing through rock or sand. Radon also undergoes radioactive decay, during which it releases ionizing radiation and forms "daughter" elements, known as decay products. It is the release of radiation from this decay process that leads to exposure and health risks from radon.

During the decay process, radiation is released in the form of alpha particles, beta particles, and gamma rays. Alpha particles can travel only short distances and cannot penetrate human skin. However, when inhaled they can penetrate the cells lining the lungs. Beta particles penetrate skin, but cannot pass through the entire body. Gamma radiation can travel all the way through the body. The health risk associated with each type of radiation is a function of how and what parts of the body are exposed. The half-life of uranium-238 is about 4.5 billion years. The half-life of radon is 3.8 days.

How are people exposed to radon?

Outside air typically contains very low levels of radon (about 0.4 pCi/L of air). But it can build up to higher concentrations in indoor air from soil under foundations of homes, schools, and office buildings where it can seep into buildings. EPA estimates that the national average annual indoor radon level in homes is about 1.3 pCi/L of air. However, over 6 percent of all homes nationwide have elevated levels at or above EPA's voluntary action level of 4 pCi/L. Levels greater than 2,000 pCi/L of air have been measured in some homes.

Although radon in indoor air from soil gas typically accounts for the bulk of the total radon risk to individuals, people may also be exposed to radon and its daughters through use of drinking water from ground water that contains radon. When water that contains radon is used in the home for showering, washing dishes, and cooking, radon gas escapes from the water and goes into the air. Radon in domestic water generally contributes only a small proportion (about 1 to 2%) of the total radon in indoor air. Radon levels in air and ground water will generally be higher in areas of the country with rock types that contain high amounts of uranium and radium, such as phosphate or granite.

How does radon get into the body?

Radon and its radioactive daughters can enter the body through inhalation and ingestion. Inhaling radon is the main route of entry into the body, with most of the radon being exhaled again. However, some radon and its daughter products will remain in the lungs where radiation released during the decay process passes into the lung tissues causing damage. Radon is also produced in the body from parent radium deposited in the body.

Is there a medical test to determine exposure to radon?

Radon in human tissue is not detectable by routine medical testing. However, several of its decay products can be detected in urine, in lung and bone tissue, and by breath tests. These tests however are not generally available to the public. They are also of limited value since they cannot be used to determine accurately how much radon a person was exposed to, nor can these tests be used to predict whether a person will develop harmful health effects.

How can radon affect people's health?

Exposure to radon and its daughters increases the chance that a person will develop lung cancer. The increased risk of lung cancer from radon primarily results from alpha particles irradiating lung tissues. Most of the damage is not from radon gas itself, which is removed from the lungs by exhalation, but from radon's short-lived decay products (half-life measured in minutes or less). When inhaled, these decay products may be deposited in the airways of the lungs especially if attached to dust particles and subsequently emit alpha particles as they decay further, resulting in damage to cells lining the airways.

Radon is considered a known human carcinogen based on extensive studies of exposure to human beings. In two 1999 reports, the National Academy of Sciences (NAS) concluded that radon in indoor air is the second leading cause of lung cancer in the U.S. after cigarette smoking. The NAS estimated that the annual number of radon-related lung cancer deaths in the U.S., is about 15,000 to 22,000. NAS also estimated that radon in drinking water causes about 180 cancer deaths each year in the United States. Approximately 89% of these cancer deaths are due to lung cancer from inhalation of radon released to indoor air from the water, and about 11 % are due to cancers of internal organs, mostly stomach cancers, from ingestion of radon in water.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to radon. General recommendations EPA has made to protect human health, which cover all radionuclides including radon, are summarized in the Introduction section of this booklet.

For uranium mill tailings sites, at which radon poses the major health threat, EPA has established a limitation to exposure to radon decay products of less than 0.02 Working Levels (WL). These regulations under 40 CFR Part 192.12(b) are often ARARs at Superfund sites with either radium or thorium contaminated soil.

In 1988, EPA and the U.S. Surgeon General issued a Health Advisory recommending that all homes below the third floor be tested for radon and fixed if the radon level is 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. (Exposure to 4 pCi/l of radon corresponds to an approximate annual average exposure of 0.02 WL for radon decay products in the home.) For more details, see EPA's "A Citizen's Guide to Radon, September 1994, USEPA #402-K92-001 and "Consumer's Guide to Radon Reduction", August 1992, USEPA 402-K92-003. For copies, contact the National Radon Hotline (800) 767-7236 or EPA's web site http://www.epa.gov/iaq/radon.

There is currently a proposed Maximum Contaminant Level (MCL) for radon in drinking water from community water systems using ground water. The Safe Drinking Water Act directs EPA to set both a maximum contaminant level (MCL) for radon in drinking water, as well as an alternative, higher alternative maximum contaminant level (AMCL) accompanied by a multimedia mitigation program to address radon risks in indoor air. This approach reflects radon's unique characteristics: that radon released to indoor air from soil under homes and buildings in most cases is the main source of exposure, with radon released from tap water being a much smaller source of radon exposure. For more information, contact the Safe Drinking Water Hotline at (800) 426-4791 or EPA's web site at http://www.epa.gov/safewater.

For more information about how EPA addresses radon at Superfund sites, please contact either :

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation

EPA Facts About Strontium-90

July 2002

What is strontium-90?

Radioactive strontium-90 is produced as a fission byproduct of uranium and plutonium. Large amounts of radioactive strontium-90 were produced during atmospheric nuclear weapons tests conducted in the 1950s and 1960s. As a result of atmospheric testing and radioactive fallout, this strontium was dispersed and deposited on the earth.

What are the uses of strontium-90?

Strontium-90 is used as a radioactive tracer in medical and agricultural studies. It is also used in thermoelectric devices that are built into small power supplies for use in remote locations, such as navigational beacons, remote weather stations, and space vehicles. Strontium-90 is also used in electron tubes, as a radiation source in industrial thickness gauges, and for treatment of eye diseases.

How does strontium-90 change in the environment?

Strontium-90 is not a stable isotope. Strontium-90 decays to yttrium-90, which in turn decays to stable zirconium. The isotopes of strontium and yttrium emit beta particles as they decay. The release of radiation during this decay process causes concern about the safety of strontium and all other radioactive substances. Beta particles can pass through skin, but they cannot pass through the entire body.

The most common isotope of strontium is strontium-90. Strontium-90 has a half-life of 29 years and emits beta particles of relatively low energy as it decays. Yttrium-90, its decay product, has a shorter half-life (64 hours) than strontium-90, but it emits beta particles of higher energy.

How are people exposed to strontium-90?

Although external exposure to strontium-90 from nuclear testing is of minor concern because environmental concentrations are low, strontium in the environment can become part of the food chain. This pathway of exposure became a concern in the 1950s with the advent of atmospheric testing of nuclear explosives. With the suspension of atmospheric testing of nuclear weapons, dietary intake has steadily fallen in the last 30 years. These concerns have shifted somewhat to exposure related to possible accidents at nuclear reactors or fuel reprocessing plants, and exposure to high level waste at weapons facilities. Strontium-90 is a component of contaminated soils at radioactively contaminated sites where nuclear fission has been used (e.g., research reactors and nuclear power plants).

Accidents involving nuclear reactors such as Chernobyl have released strontium into the atmosphere, which ultimately settles to the earth's surface as fallout. Chernobyl contributed the largest worldwide burden of strontium-90 contamination, and a substantial portion of the strontium-90 released was deposited in the former Soviet Republics; with the rest being dispersed as fallout worldwide.

How does strontium-90 get into the body?

Ingestion, usually through the swallowing of food or water, is the primary health concern for entry of strontium into the human body. Small dust particles contaminated with strontium also may be inhaled, but this exposure pathway is of less concern than the ingestion pathway. After radioactive strontium is ingested, 20 to 30 percent of it is absorbed from the gastrointestinal tract, while the rest is excreted. Of the portion absorbed, virtually all (99 percent) of the strontium is deposited in the bone volume or skeleton. The balance is distributed among the blood stream, extracellular fluid, soft tissue, and bone surface, where it may stay and decay or be metabolized and excreted in urine and fecal matter.

Is there a medical test to determine exposure to strontium-90?

Generally, levels of strontium in the body are measured by urinalysis. As with most cases of internal contamination, the sooner after an intake the measurement is made, the more accurate it is.

How can strontium affect people's health?

Strontium-90 behaves like calcium in the human body and tends to deposit in bone and blood-forming tissue (bone marrow). Thus, strontium-90 is referred to as a "bone seeker" and exposure to it will increase the risk for several diseases including bone cancer, cancer of the soft tissue near the bone, and leukemia. Risks from exposure depend on the concentration on strontium-90 in air, water, and soil. At higher exposures, such as those associated with the Chernobyl accident, or other conceivable scenarios involving nuclear accidents or exposure to radioactive waste materials, the cancer risks may be elevated. The magnitude of this health risk would depend on exposure conditions, such as amount ingested.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to strontium-90. General recommendations EPA has made to protect human health, which cover all radionuclides including strontium-90, are summarized in the Introduction section of this booklet.

EPA has established a Maximum Contaminant Level (MCL) of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. The average concentration of strontium-90 which is assumed to yield 4 millirem per year is 8 picocuries per liter (pCi/l). If other radionuclides which emit beta particles and photon radioactivity are present in addition to strontium-90, the sum of the annual dose from all the radionuclides shall not exceed 4 millirem/year.

For more information about how EPA addresses strontium-90 at Superfund sites, please contact either:

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation/index.htm

EPA Facts About Technetium-99

July 2002

What is technetium-99?

Technetium-99 (Tc-99) is predominantly an artificially produced radioactive metal. Tc-99 also occurs naturally in very small amounts in the earth's crust. Tc-99 was first obtained from molybdenum but is also produced as a nuclear reactor fission product of uranium and plutonium. All isotopes of technetium are radioactive, and the most commonly available forms are Tc-99 and Tc-99m.

In addition to being produced during nuclear reactor operation, Tc-99 is produced in atmospheric nuclear weapons tests. Metastable Tc-99 (Tc-99m), the shorter-lived form of Tc-99, is also a component of nuclear reactor gaseous and liquid effluent. Tc-99m is used primarily as a medical diagnostic tool, and it can be found as a component of industrial and institutional wastes from hospitals and research laboratories..

What are the uses of technetium-99?

Tc-99 is an excellent superconductor at very low temperatures. In addition, Tc-99 has anti-corrosive properties. Five parts of technetium per million will protect carbon steels from corrosion at room temperature. Tc-99m is used in medical therapy in brain, bone, liver, spleen, kidney, and thyroid scanning and for blood flow studies. Tc-99m is the radioisotope most widely used as a tracer for medical diagnosis.

How does technetium-99 change in the environment?

Technetium-99 is not a stable isotope. As Tc-99 decays, it releases beta particles and eventually forms a stable nucleus. Beta particles can pass through skin, but they cannot pass through the entire body. The time required for a radioactive substance to lose 50 percent of its radioactivity by decay is known as the half-life. The half life of Tc-99 and Tc-99m is 210,000 years and 6 hours respectively.

How are people exposed to technetium-99?

Man-made Tc-99 has been found in isolated locations at federal sites in the ground water beneath uranium processing facilities. Tc-99 contamination at these selected sites is a concern if individuals are exposed to Tc–99 through drinking contaminated water and ingesting contaminated plants. The potential exposure from external radiation by Tc-99 is minimal because the isotope is a weak beta emitter. Tc-99m is not a concern at these sites because of its short half-life. Tc-99 is also found in the radioactive waste of nuclear reactors, fuel cycle facilities, and hospitals.

In the natural environment, Tc-99 is found at very low concentrations in air, sea water, soils, plants, and animals. The behavior of Tc-99 in soils depends on many factors. Organic matter in soils and sediments plays a significant role in controlling the mobility of Tc-99. In soils rich in organic matter, Tc-99 is retained and does not have high mobility. Under aerobic conditions, technetium compounds in soils are readily transferred to plants. Some plants such as brown algae living in seawater are able to concentrate Tc-99. Tc-99 can also transfer from seawater to animals.

How does technetium-99 get into the body?

At radioactively contaminated sites with Tc-99 contamination, the primary routes of exposure to an individual are from the potential use of contaminated drinking water and ingestion of contaminated plants.

Technetium exposure may occur to persons working in research laboratories that perform experiments using Tc-99 and Tc-99m. Patients undergoing diagnostic procedures may receive controlled amounts of Tc-99m, but also avoid a more invasive diagnostic technique.

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, hair, and exhaled air can determine if a person has been exposed to technetium. These tests are useful only if performed soon after exposure. The tests require special equipment and cannot be done in a doctor's office.

How can technetium-99 affect people's health?

Once in the human body, Tc-99 concentrates in the thyroid gland and the gastrointestinal tract. The body, however, constantly excretes Tc-99 once it is ingested. As with any other radioactive material, there is an increased chance that cancer or other adverse health affects can result from exposure to radiation.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to technetium-99. General recommendations EPA has made to protect human health, which cover all radionuclides including technetium-99, are summarized in the Introduction section of this booklet.

EPA has established a Maximum Contaminant Level (MCL) of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. Technetium-99 would be covered under this MCL. The average concentration of technetium-99 which is assumed to yield 4 millirem per year is 900 picocuries per liter (pCi/l). If other radionuclides which emit beta particles and photon radioactivity are present in addition to technetium-99, the sum of the annual dose from all the radionuclides shall not exceed 4 millirem/year.

For more information about how EPA addresses technetium-99 at Superfund sites, please contact either:

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation

EPA Facts About Thorium

July 2002

What is thorium?

Thorium is a naturally occurring radioactive metal that is found at low levels in soil, rocks, water, plants and animals. Almost all naturally occurring thorium exists in the form of either radioactive isotope thorium-232, thorium-230 and thorium-228. There are more than 10 other thorium isotopes that can be artificially produced. Smaller amounts of these isotopes are usually produced as decay products of other radionuclides and as unwanted products of nuclear reactions.

What are the uses of thorium?

Thorium is used to make ceramics, lantern mantles, welding rods, camera and telescope lenses, and metals used in the aerospace industry.

How does thorium change in the environment?

Thorium-232 is not a stable isotope. As thorium-232 decays, it releases radiation and forms decay products which include radium-228 and thorium-228. The decay process continues until a stable, nonradioactive decay product is formed. In addition to thorium-232, thorium-228 is present in background. Thorium-228 is a decay product of radium-228 and thorium-228 decays into radium-224.

The radiation from the decay of thorium and its decay products is in the form of alpha and beta particles, and gamma radiation. Alpha particles can travel only short distances and cannot penetrate human skin. Beta particles are generally absorbed in the skin and do not pass through the entire body. Gamma radiation, however, can penetrate the body.

The half-life of thorium-232 is very long at about 14 billion years. Due to the extremely slow rate of decay, the total amount of natural thorium in the earth remains fairly constant, but it can be moved from place to place by natural processes and human activities.

How are people exposed to thorium?

Since thorium is present at very low levels almost everywhere in the natural environment, everyone is exposed to it in air, food, and water. Normally, very little of the thorium in lakes, rivers, and oceans is absorbed by the fish or seafood that a person eats. The amounts in the air are usually small and do not constitute a health hazard.

Exposure to higher levels of thorium may occur if a person lives near an industrial facility that mines, mills or manufactures products with thorium.

Thorium-232 on the ground is of a health risk because of the rapid build up of radium-228 and its associated gamma radiation. Thorium-230 is part of the uranium-238 decay series. Thorium- 230 is typically present with its decay product radium-226 and it is therefore a health risk from gamma radiation from radium decay products, lung exposure from radon gas and its decay products, and inhalation and ingestion exposure.

How does thorium get into the body?

Thorium can enter the body when it is inhaled or swallowed. In addition, radium can come from thorium deposited in the body. Thorium enters the body mainly through inhalation of contaminated dust. If a person inhales thorium into the lungs, some may remain there for long periods of time. In most cases, the small amount of thorium left in the lungs will leave the body in the feces and urine within days.

If thorium is swallowed in water or with food, most of it will promptly leave the body in the feces. 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.

Is there a medical test to determine exposure to thorium?

Special tests that measure the level of radioactivity from thorium or thorium isotopes in the urine, feces, and exhaled air can determine if a person has been exposed to thorium. These tests are useful only if taken within a short period of time after exposure. They require special equipment and cannot be done in a doctor’s office.

How can thorium affect people's health?

Studies of workers have shown that inhaling thorium dust will cause an increased risk of developing lung disease, including lung cancer, or pancreatic cancer. Liver disease and some types of cancer have been found in people injected in the past with thorium in order to take special X-rays. Bone cancer is also a potential health effect due to the storage of thorium in the bone.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to thorium. General recommendations EPA has made to protect human health, which cover all radionuclides including thorium, are summarized in the Introduction section of this booklet.

For uranium mill tailing sites, EPA has established 5 picocuries per gram (pCi/g) of radium as a protective health based level for the cleanup of the top 15 centimeters of soil. Since thorium decays into radium, these regulations for radium under 40 CFR Part 192.12 have often been used as ARARs at Superfund sites for thorium contaminated soil. The EPA OSWER Directive 9200.4-25, "Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA sites" provides guidance regarding when 5 pCi/g of thorium is an ARAR or otherwise recommended cleanup level for any 15 centimeters of subsurface thorium contaminated soil other than the first 15 centimeters.

If regulations under 40 CFR Part 192.12 are an ARAR for radium in soil at a Superfund site, then NRC regulations for uranium mill tailing sites under 10 CFR Part 40 Appendix A, I, Criterion 6(6) may possibly be an ARAR at the same site. Criterion 6(6) requires that an estimate be made of the level of radiation, called a "benchmark dose," that an individual would receive after that site was cleaned up to the radium soil regulations under 40 CFR Part 192.12. This benchmark dose then becomes the maximum level of radiation that an individual may be exposed to from all radionuclides, except radon, in both the soil and buildings at the site. The EPA OSWER Directive 9200.4-35P, "Remediating Goals for Radioactively Contaminated CERCLA Sites Using the Benchmark Dose Cleanup Criterion 10 CFR Part 40 Appendix A, I, Criterion 6(6)" provides guidance regarding how Criterion 6(6) should be implemented as an ARAR at Superfund sites, including using a radium soil cleanup level of 5 pCi/g in both the surface and subsurface when estimating a benchmark dose.

EPA has established a Maximum Contaminant Level (MCL) of 15 picocuries per liter (pCi/l) for alpha particle activity, excluding radon and uranium, in drinking water. Thorium would be covered under this MCL.

For more information about how EPA addresses thorium at Superfund sites, please contact either:

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation

EPA Facts About Tritium

July 2002

What is Tritium?

Tritium is a form of hydrogen that is radioactive, and like hydrogen it reacts with oxygen to form water. Tritium is produced naturally in the upper atmosphere when cosmic rays strike atmospheric gases. Tritium can also be produced by man during nuclear weapon explosions, in reactors intended to produce tritium for nuclear weapons, and by reactors producing electricity.

What are the uses of tritium?

Tritium has been produced in large quantities by the nuclear military program. It is also used to make luminous dials and as a source of light for safety signs. Tritium is used as a tracer for biochemical research, animal metabolism studies and ground water transport measurements.

How does tritium change in the environment?

Tritium is not a stable element. Tritium decays by emitting a beta particle and turning into helium. The release of radiation during this decay process causes concern about the safety of tritium and all other radioactive substances. The radiation from the decay of tritium is in the form of beta particles which are of very low energy. Because of this the particles cannot pass through the skin surface.

Tritium is the only radioactive isotope of hydrogen and like hydrogen it reacts with oxygen to form water. The transformation of tritium to tritiated water is a complex and slow process. Tritium is a colorless, odorless gas with a half-life of 12.3 years. Tritiated water moves through the environment like ordinary water.

How are people exposed to tritium?

Although large quantities of tritium have been released into the environment, the dose to humans is small. Tritium was disbursed throughout the world by atmospheric nuclear weapons tests that took place from the mid 1950s to the early 1960s. The inventory of tritium in the atmosphere peaked in 1963 and has been decreasing rapidly since then. Levels of naturally occurring tritium in the atmosphere produced by cosmic rays are constant, and it is projected that levels of manmade tritium will be comparable to natural tritium by 2030.

Tritium is currently produced by reactors producing electricity. However, releases of tritium from these facilities are at fractions of the natural background production rates. Other sources of tritium include government plants which have reprocessed reactor fuels. Individuals can also be exposed to tritium broken exit signs and luminous dial items that contain tritium.

Since tritium reacts similarly to ordinary hydrogen it is incorporated into the body easily in the form of water.

Overall, since current world wide levels of tritium in the environment from man-made and natural sources are low, the risk to the average person from tritium is typically not significant. Accidental exposure from elevated levels of tritium from broken exit signs or other concentrated sources, however can pose a health risk to individuals.

How does tritium get into the body?

Most tritium in the environment is in the form of tritiated water which is dispersed throughout the environment in the atmosphere, streams, lakes, and oceans. Tritium in the environment can enter the human body as a gas or as a liquid by ingestion and inhalation, and through the skin by absorption. Once entered into the body, tritium tends to disperse quickly so that it is uniformly distributed throughout the body. The tritium distribution in tissue is dependent on the amount of water contained in the tissues. Tritium is rapidly excreted over a month or two after ingestion.

Is there a medical test to determine exposure to tritium?

Since tritium is distributed throughout the body within a few hours after ingestion, levels within the body are measured by collecting a urine sample and analyzing it for tritium.

How can tritium affect people's health?

With respect to chemical reactions, tritium reacts similarly to ordinary hydrogen. Tritium therefore dilutes through the body as ordinary water. Tritium concentration in soft tissue and the associated dose to these tissues is generally uniform and dependent on the water content of the tissue. Because the water content in the body turns over frequently, tritium is rapidly cleared from tissues.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to tritium. General recommendations EPA has made to protect human health, which cover all radionuclides including tritium, are summarized in the Introduction section of this booklet.

EPA has established a Maximum Contaminant Level (MCL) of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. The average concentration of tritium which is assumed to yield 4 millirem per year is 20,000 picocuries (pCi/l). If other radionuclides which emit beta particles and photon radioactivity are present in addition to tritium, the sum of the annual dose from all the radionuclides shall not exceed 4 millirem/year.

For more information about how EPA addresses tritium at Superfund sites, please contact either:

EPA's Superfund Hotline
1-800-424-9346 or 1-800-535-0202
or EPA's Superfund Radiation Webpage
http://www.epa.gov/superfund/resources/radiation/index.htm

EPA Facts About Uranium

July 2002

What is uranium?

Uranium is a radioactive metal that is present in low amounts in rocks, soil, water, plants, and animals. Uranium and its decay products contribute to low levels of natural background radiation in the environment. Significant concentrations of uranium occur naturally in some substances such as phosphate deposits and uranium-enriched ores.

How does uranium change in the environment?

Natural uranium is found in the environment in three forms, called isotopes: uranium-234, uranium-235, and uranium-238. Ninety-nine percent of natural uranium occurring in rock is uranium-238. Uranium-235 accounts for just 0.72 percent of natural uranium, but it is more radioactive than uranium-238. Uranium-234 is the least abundant uranium isotope in rock.

Uranium is not a stable element. As uranium decays, it releases radiation and forms decay products. Uranium-238 decay products include uranium-234, radium-226, and radon-222. See EPA Fact About Radon and Radium for additional information on these radionuclides.

Natural uranium releases alpha particles and low levels of gamma rays. Alpha particles can travel only short distances and cannot penetrate human skin. Gamma radiation, however, can penetrate the body.

The half-life for uranium-238 is about 4.5 billion years, uranium-235 is 710 million years and uranium-234 is 250,000 years. Because of the slow rate of decay, the total amount of natural uranium in the earth stays almost the same, but radionuclides can move from place to place through natural processes or by human activities. Rain can wash soil containing uranium into rivers and lakes. Mining, milling, manufacturing, and other human activities also release uranium to the environment.

What are the uses of uranium?

Uranium-235 is used in nuclear weapons and nuclear reactors. Depleted uranium (natural uranium in which almost all of the uranium-235 has been removed) is used to make ammunition for the military, guidance devices and compasses, radiation shielding material, and X-ray targets. Uranium dioxide is used to extend the lives of incandescent lamps used for photography and motion pictures. Very small amounts of other uranium compounds are used in photography for toning, in the leather and wood industries for stains and dyes, and in the wool industries. Uranium has also been used in the past in ceramics as a coloring agent.

How are people exposed to uranium?

Uranium-238 and members of its decay chain which include uranium-234, radium-226, and radon-220 are present in nature. The members of the decay chain in undisturbed soil are present often at concentrations that approximate that of the parent uranium-238. Uranium ore contains all the daughter elements of uranium-238 and uranium-235, but during uranium processing the uranium-238, uranium-234 and uranium-235 are extracted and chemically separated. This concentrated uranium product which is generated at uranium mill tailing sites and uranium processing facilities is a potential source of exposure to individuals and the environment and is a primary concern for the cleanup of these sites. Potential individual exposure at these sites may be from different pathways, but because of the mobility of uranium the ground water pathway is of particular concern.

How does uranium get into the body?

Uranium can enter the body when it is inhaled or swallowed or through cuts in the skin. 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 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 be deposited in a person's bones, where it will remain for several years.

Alpha particles released by uranium cannot penetrate the skin, so natural uranium that is outside the body is less harmful than that which is inhaled, swallowed or enters through the skin. When uranium gets inside the body, radiation and chemical damage can lead to cancer or other health problems including kidney damage.

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. These tests are useful if a person is exposed to a larger-than-normal amount of uranium, because most uranium leaves the body in the feces within a few days. 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 exposure. Since uranium is known to cause kidney damage, urine tests are often used to determine whether kidney damage has occurred.

How can uranium affect people's health?

In addition to the risks of cancer posed by uranium and all other radionuclides, uranium is associated with non-cancer effects and the major target organ of uranium's chemical toxicity is the kidney. Radioactivity is a health risk because the energy emitted by radioactive materials can damage or kill cells. The level of risk is dependent on the level of uranium concentration.

What recommendations has the Environmental Protection Agency made to protect human health?

Please note that the information in this section is limited to recommendations EPA has made to protect human health from exposure to uranium. General recommendations EPA has made to protect human health, which cover all radionuclides including uranium, are summarized in the Introduction section of this booklet.

EPA has established a Maximum Contaminant Level (MCL) of 30 micrograms per liter (ug/liter) for uranium in drinking water. For uranium mill tailing sites, EPA has established 30 picocuries per Liter (pCi/l) for uranium 234 and 238 as standards for protecting groundwater. The EPA OSWER Directive 9283.1-14 "Use of Uranium Drinking Water Standards under 40 CFR 141 and 40 CFR 192 as Remediation Goals for Groundwater at CERCLA sites" provides guidance regarding how these two standards should be implemented as an ARAR at Superfund sites.

For uranium mill tailing sites, EPA has established 5 picocuries per gram (pCi/g) of radium as a protective health based level for the cleanup of the top 15 centimeters of soil. If regulations under 40 CFR Part 192.12 are an ARAR for radium in soil at a Superfund site, then NRC regulations for uranium mill tailing sites under 10 CFR Part 40 Appendix A, I, Criterion 6(6) may possibly be an ARAR at the same site, particularly if uranium-234 or uranium-238 is a contaminant at the site. Criterion 6(6) requires that an estimate be made of the level of radiation, called a "benchmark dose," that an individual would receive after that site was cleaned up to the radium soil regulations under 40 CFR Part 192.12. This benchmark dose then becomes the maximum level of radiation that an individual may be exposed to from all radionuclides, except radon, in both the soil and buildings at the site. The EPA OSWER Directive 9200.4-35P, "Remediating Goals for Radioactively Contaminated CERCLA Sites Using the Benchmark Dose Cleanup Criterion 10 CFR Part 40 Appendix A, I, Criterion 6(6)" provides guidance regarding how Criterion 6(6) should be implemented as an ARAR at Superfund sites, including using a radium soil cleanup level of 5 pCi/g in both the surface and subsurface when estimating a benchmark dose.

For more information about how EPA addresses uranium at Superfund sites, please contact either:

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http://www.epa.gov/superfund/resources/radiation