United States
Environmental Protection Agency

Office of Superfund
Remediation and
Technology Innovation

Directive 9230.1-48
EPA -540-R-012-015
May 2014

Superfund Radiation Risk Assessment:

A Community Toolkit

Introduction

This toolkit was developed by the U.S. Environmental Protection Agency (EPA) to help the public understand more about the risk assessment process used at Superfund sites with radioactive contamination. The toolkit is made up of a collection of 22 fact sheets that provide information that may be important to the risk assessment process for Superfund sites with radioactive contamination. Not all of these fact sheets will be useful at all sites. It is recommended EPA staff working on a site provide only the fact sheets that are useful for the public at that specific site. The fact sheets will also be available on the Internet for any interested members of the public. The fact sheets in this toolkit are:

1. Superfund Radiation Fact Sheet (10 pages)
2. Superfund Radiation Risk Assessment Fact Sheet (8 pages)

Attachment A: Compendium of Information on the Preliminary Remediation Goal (PRG) and Dose Compliance Concentration (DCC) Calculators

3. Primer on EPA PRG and DCC Calculators (1 page)
4. Preliminary Remediation Goals (PRG) Calculator (1 page)
5. Dose Compliance Concentration (DCC) Calculator (1 page)
6. Building Preliminary Remediation Goals (BPRG) Calculator (1 page)
7. Building Dose Compliance Concentration (BDCC) Calculator (1 page)
8. Surface Preliminary Remediation Goals (SPRG) Calculator (1 page)
9. Surface Dose Compliance Concentration (SDCC) Calculator (1 page)

Attachment B: Compendium of Information on Radionuclides Commonly Found at Superfund Sites

10. Primer on Radionuclides Commonly Found at Superfund Sites (2 pages)
11. Americium-241(2 pages)
12. Cesium-137 (2 pages)
13. Cobalt-60 (2 pages)
14. Iodine (2 pages)
15. Plutonium (2 pages)

Superfund Radiation Fact Sheet

What is Superfund? **The Superfund program is administered by U.S. Environmental Protection Agency (EPA) in cooperation with state and tribal governments. It allows EPA to clean up hazardous waste sites and to force responsible parties to perform cleanups or reimburse the government for cleanups led by EPA.**

For a variety of reasons, hazardous commercial and industrial wastes were mismanaged and may pose unacceptable risks to human health and the environment. This waste was dumped on the ground or in waterways, left out in the open, or otherwise improperly managed. As a result, thousands of hazardous waste sites were created throughout the United States. These hazardous waste sites commonly include manufacturing facilities, processing plants, landfills, and mining sites.

Superfund was established in 1980 by an act of Congress, giving EPA the funds and authority to clean up polluted sites

Goals of Superfund:

- **Protect human health and the environment by cleaning up polluted sites**
- **Involve communities in the Superfund process**
- **Make responsible parties pay for work performed at Superfund sites**

Superfund is the informal name for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In 1980, Congress enacted CERCLA in response to growing concerns over the health and environmental risks posed by hazardous waste sites. This law was enacted in the wake of the discovery of chemically contaminated toxic waste dumps such as Love Canal and Valley of the Drums in the 1970s.

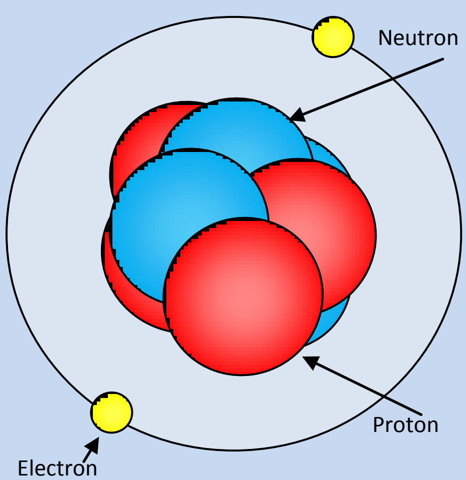
Some Superfund sites contain radioactive contamination. This document was developed by EPA to answer questions about radiation hazards and how EPA assesses health risks from potential exposure to radioactive contamination at Superfund sites.

What are atoms?

To understand radiation and radioactivity, it is important to understand atoms.

Atoms are the very small particles that make up our bodies and everything around us. Atoms consist of a central nucleus made up of protons and neutrons. Protons are positively charged, while neutrons have no charge. Electrons have a negative charge and orbit (or go around) the nucleus. Most atoms are neutral, which means they have the same number of protons and electrons. Atoms that are not neutral are called ions.

Atomic Structure



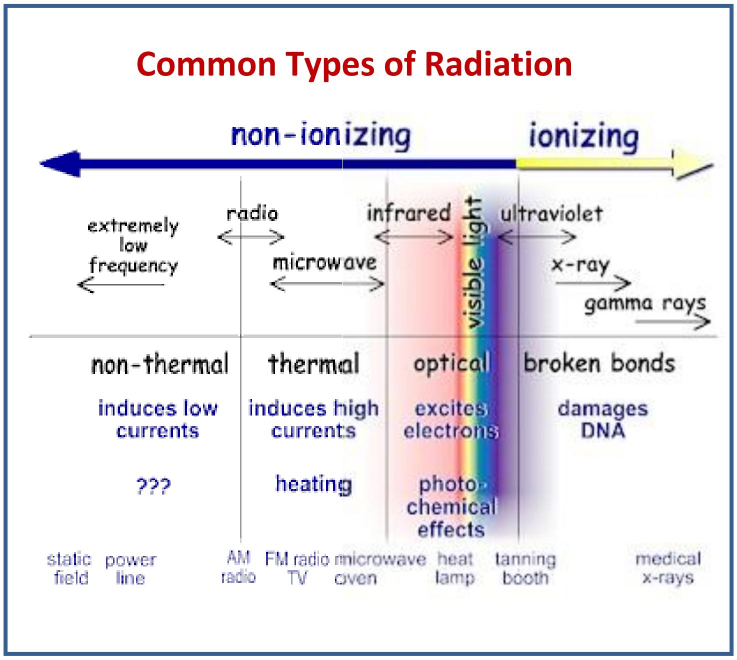
An atom consists of a central nucleus (made of protons and neutrons) orbited by electrons

An element is a specific type of atom. All atoms of an element have the same number of protons. For example, all atoms of oxygen have eight protons, while all uranium atoms have 92 protons. It is possible for atoms of the same element to have different numbers of neutrons. These various forms are called isotopes. For example, while all atoms of oxygen have eight protons, isotopes of oxygen can have from four to 16 neutrons.

What is Radiation?

Radiation is energy that travels in the form of waves or high-speed particles. There are two types of radiation:

- **Non-ionizing radiation** is low energy. It includes radio waves, microwaves, and visible light. Non-ionizing radiation can generate heat, but it does not have enough energy to remove electrons from atoms.
- **Ionizing radiation** is high energy. It can remove tightly bound electrons from an atom. Ionizing radiation can be harmful to humans by damaging living tissue and increasing cancer risk. X-rays are a familiar form of ionizing radiation.

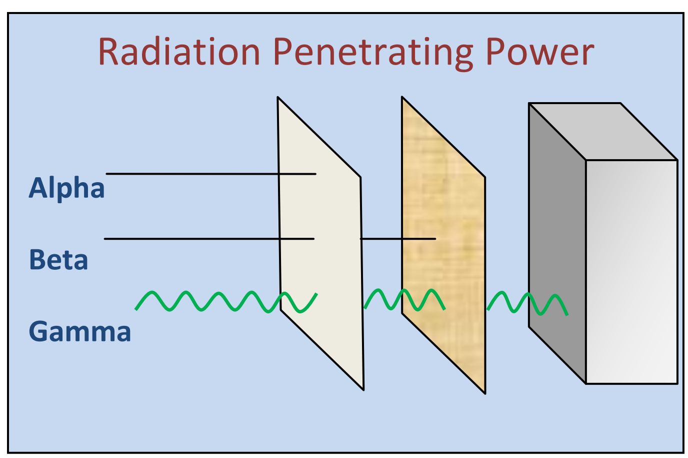


In this fact sheet, the term "radiation" will mean ionizing radiation.

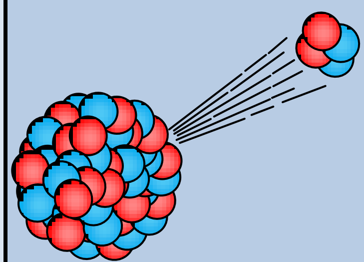
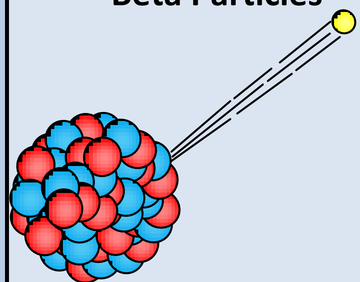
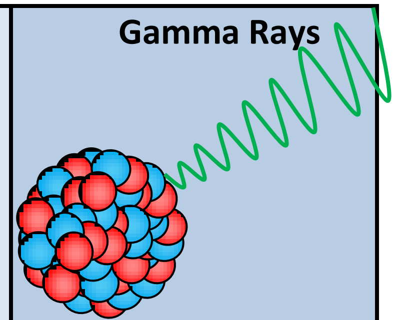
What is Radioactivity?

Some isotopes of certain atoms are unstable. When these unstable atoms release ionizing radiation in the form of waves or particles, it is called **radioactivity**. A radioactive atom is called a **radionuclide**. When a radionuclide emits (gives off) radiation, it is said to **decay**. There are three main types of radiation given off when a radionuclide decays:

- **Alpha particles** are heavy, relatively slow moving, particles. They can be blocked by a piece of paper or by skin. However, radionuclides that give off alpha particles can be very harmful if they enter your body in other ways such as through the air, food, or water because your internal organs are not protected by skin.
- **Beta particles** are light weight, relatively fast moving particles. They can be blocked by a thin piece of metal or wood. Beta particles can penetrate (pass through) the outer layer of skin and cause radiation burns. Like alpha particles, beta particles can damage your health if they enter your body.
- **Gamma rays** are waves of pure energy that often accompany beta and alpha particles. Gamma rays can pass through the body and damage internal organs. A thick wall of metal or concrete is needed to absorb gamma radiation.



Ionizing Radiation Found at Superfund Sites

	Alpha Particles 	Beta Particles 	Gamma Rays 
Description	• Two protons and two neutrons bound together into a single particle • Heaviest and slowest moving type of ionizing radiation • Positively charged	• Made up of an electron ejected from nucleus • Fast moving, low mass particle • Negatively charged	• Pure energy traveling at the speed of light • Often accompanies the emission of alpha or beta particles • Has no rest mass and no charge
Ionizing Power	• **HIGH** • Interacts strongly with surrounding material • Very energetic	• **MODERATE** • Interact less strongly than alpha particles but more strongly than gamma rays with surrounding material	• **LOW** • Since they have no mass and no charge, gamma rays interact with matter less than alpha and beta particles
Penetrating Power	• **LOW** • Travels no more than a few centimeters in air • Can be stopped by a sheet of paper • Unable to penetrate skin	• **MODERATE** • Able to travel several meters through air • Can be stopped by a thin layer of metal or plastic • Can penetrate outer layers of skin	• **HIGH** • Able to travel hundreds of meters through air • Can be stopped by a thick concrete wall • Able to pass through the human body
Human Health Effects	• No health effects from external exposure since they are unable to penetrate skin • Very harmful if alpha-emitting radionuclide is taken into the body by ingestion,r breathing, or through an open wound	• Can cause skin burns from external exposure • Harmful if taken into the body (though not usually as harmful as alpha particles)	• Can cause harm from external exposure • Can pass into the body and cause internal radiation exposure

What happens to radionuclides as they decay?

As radionuclides decay, they become new elements called **daughter products**, which are also known as decay products**.** These daughter products may or may not be radioactive themselves. If a daughter product is also radioactive, it in turn will decay to form a different daughter product. This process will continue until a stable, nonradioactive product is formed. The radioactive decay of a radionuclide and all of its daughters is known as a **decay chain.**

What is half-life?

The rate a radionuclide decays is its **half-life**. Half-life is defined as the amount of time it takes for half of the amount of a substance to emit radiation and change to a different substance. Radionuclide half-lives can be very long or very short. For example, uranium-238 has a half-life of 4.5 *billion* years, while carbon-11 has a half-life of only a few minutes.

How is radioactivity measured?

Radioactivity is measured by the **activity** of a material. The activity is the number of radionuclides that decay each second. EPA often uses a unit called a **curie** to

measure activity. One curie is 37 *billion* decays per second. This unit is too large to use at most Superfund sites to assess radiation risk, so EPA usually uses a unit called a **picocurie**. One picocurie is equal to one *trillionth* of a curie, or about 2.2 radionuclide decays per minute.

EPA measures radioactive contamination by the number of picocuries measured in a specific amount of contaminated material. Soil contamination, for example, is measured in picocuries per gram.

Why are radionuclides harmful to human health?

The human body is made up of atoms. When radionuclides decay, they release alpha, beta, and gamma radiation. This radiation can break the bonds between the atoms, damaging living tissue and

DNA. Usually, our bodies can repair this type of damage, but sometimes there may be too much damage to repair. This damage to living tissue and DNA can lead to cancer or other health effects. The risk of cancer increases as exposure to radiation increases.

How can you be exposed to harmful radiation?

Radionuclides cause the most harm when they are inside of the body. There are three ways to be exposed to radionuclides:

- **Inhalation** – Breathing contaminated vapors, dust particles, or radon gas.
- **Ingestion** – Eating contaminated food, drinking contaminated water, or accidentally ingesting small amounts of contaminated dust or soil.
- **External** – Radiation emitting out from a source such as radioactively contaminated soil or object, and then penetrating from outside of the body.

How is radiation exposure measured?

Under most situations, radiation exposure is measured in **dose**. Dose is related to the amount of radiation absorbed by a person's body. The unit for radiation dose that EPA uses is the **millirem**. Millirem relates the absorbed dose of radiation to the amount of biological damage from the radiation.

However, radiation exposure at Superfund sites is measured by **cancer risk**. All radionuclides can cause cancer, and the cancer risk increases as exposure increases. Not all radiation has the same biological effect, even when the absorbed dose is the same, however. Therefore, EPA's use of cancer risk accounts for the different types of radiation as well as its effects on different parts of the body.

How does EPA calculate risks to human health from radiation exposure at Superfund sites?

EPA assesses the health effects of radiation by calculating **excess cancer risk** posed by radioactive contamination. Excess cancer risk is the additional probability that a person exposed to the contamination will develop cancer over a lifetime.

EPA considers excess cancer risk to be any risk above the **protective range**. The protective range is a probability that a person exposed to radioactive and chemical contaminants will have between a one in ten thousand and a one in a million chance of developing cancer, known as the 10^{-4} to 10^{-6} cancer risk range.

It is important to note that, even in the protective range, most people will have less of a chance of developing cancer than these numbers indicate. EPA uses assumptions about exposure levels that are higher than most people's actual exposure.

EPA may also calculate health risk from radiation exposure in dose per year, measured in **millirem per year**. Some regulations at Superfund sites are based on what EPA has calculated to be acceptable dose limits per year.

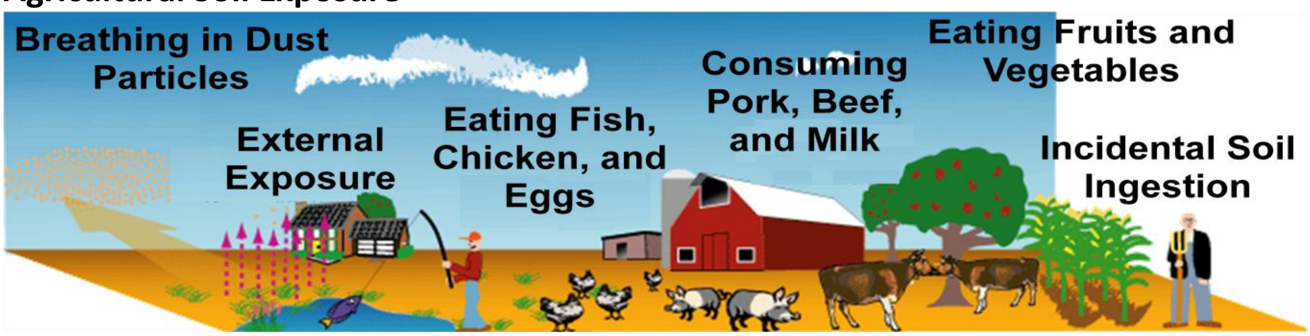
What is background radiation?

Radiation is everywhere in our environment. The average person in the United States receives a radiation exposure of approximately 620 millirems per year from both natural and man-made sources. For examples of radiation in our environment, see the chart "Relative Doses from Radiation Sources" on page 9. These examples include cosmic radiation from space, medical procedures, radiation found naturally in the soil and water, and indoor radon. However, at Superfund sites, EPA is comparing radioactive pollution at the site with background radiation of the same radionuclides where the pollution occurs, such as in the soil and water.

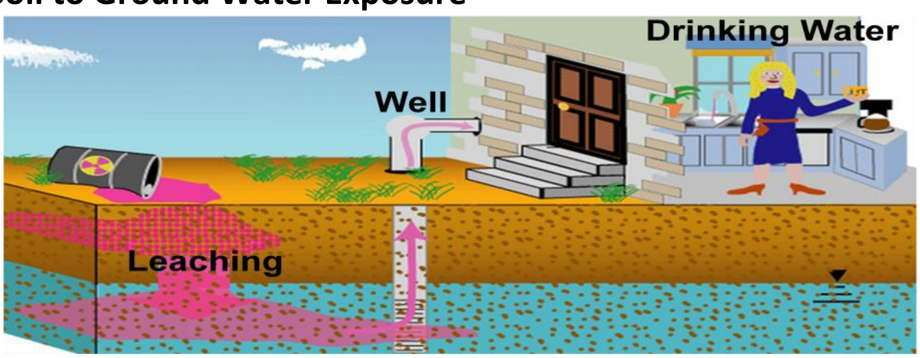
Some Common Ways to be Exposed to Radionuclides at Contaminated Sites

Residential Soil Exposure

Agricultural Soil Exposure

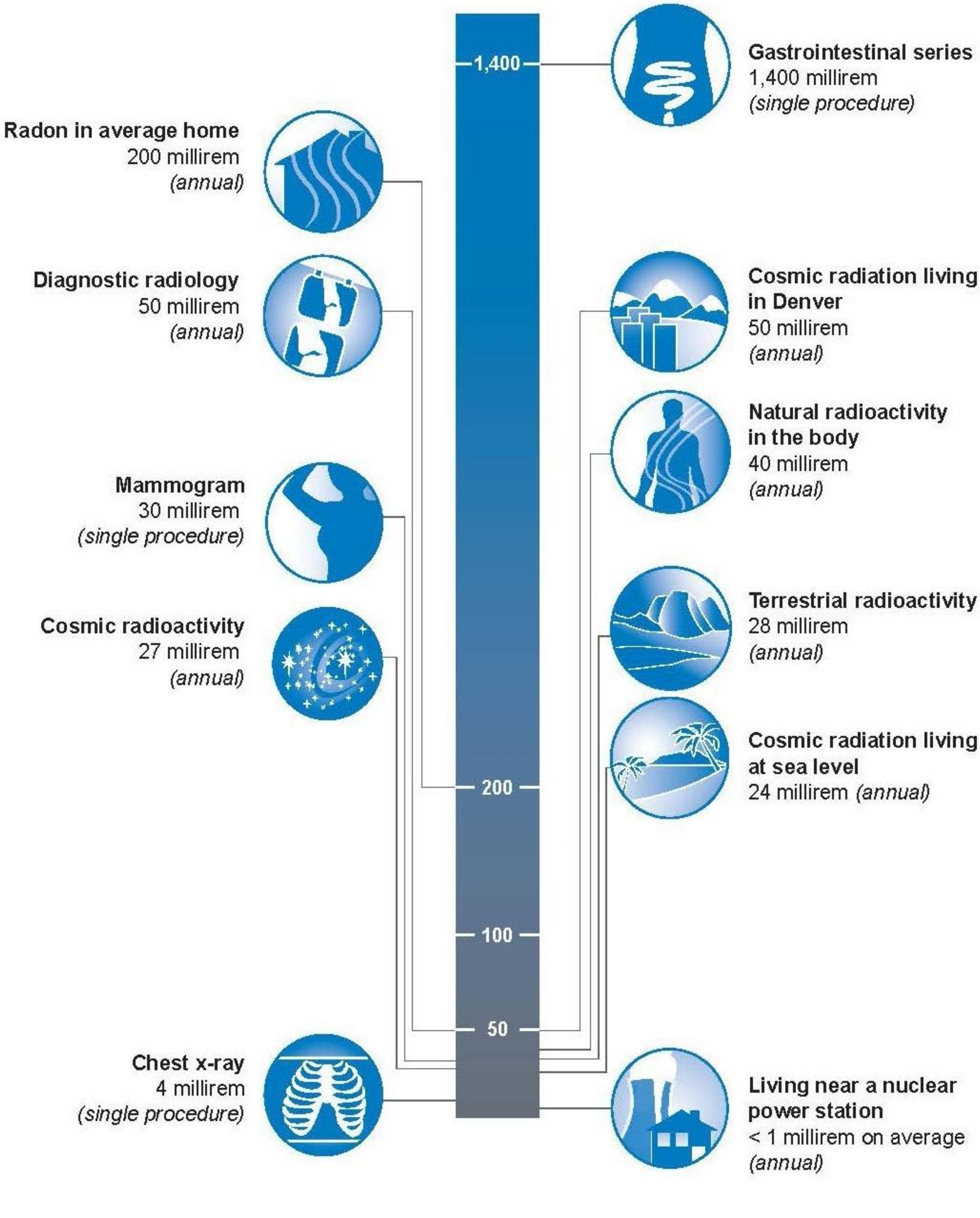


Soil to Ground Water Exposure



Tap Water Exposure

RELATIVE DOSES FROM RADIATION SOURCES
Millirem Doses



What if I want More Information?

If you would like to learn more about EPA's Superfund program, you may want to read the document "This is Superfund: A Community Guide to EPA's Superfund Program," available online at:

http://www.epa.gov/superfund/community/today/pdfs/TIS%20FINAL%209.13.11.pdf

If you have questions about this document, you can contact Stuart Walker of EPA by e-mail at walker.stuart@epa.gov or by telephone at (703) 603-8748.

Superfund Radiation Risk Assessment Fact Sheet

The Superfund program uses a process called **risk assessment** to calculate health risks posed by hazardous contamination and waste. A risk assessment conducted at Superfund sites with radioactive contamination is divided into four parts:

1. Data Collection and Evaluation
2. Exposure Assessment
3. Toxicity Assessment
4. Risk Characterization

The first three steps allow EPA to answer key questions about the contaminated site:

- **What type of radioactive contamination is present?**
- **Where is the radioactive contamination located?**
- **How could people be exposed to the contamination?**
- **What are the potential harmful health effects from the contamination?**
- **And what are the uncertainties?**

All of this information is then incorporated in the risk characterization, which is used to make a decision about how to clean up the site.

Step 1: Data Collection and Evaluation

During Data Collection and Evaluation, EPA has to find out how the site became contaminated and what radionuclides are present. This step is a four-part process.

1. Information Gathering

In the first step, EPA collects information about the site. Information can be collected in many ways, including:

- Looking at old photographs of the site
- Studying maps of the site and surrounding areas
- Reading documents related to the site
- Interviewing community members who are knowledgeable about the site.

By gathering this information, EPA can gain a better understanding of the history and geography of the site and what activities may have taken place there.

Community Involvement

Community involvement is important in the EPA risk assessment process. By engaging the community in the process, we are able to gain local information and insight into the site and its history. This information can allow us to better understand risks to the public near the site.

2. Field Survey

Next, EPA uses special equipment to find areas that may be contaminated. Hand-held instruments are used for smaller areas, but larger sites may require equipment mounted on a van, tractor, or aircraft.

3. Sample Collection

Samples are collected from contaminated areas identified in the field survey. It is important that samples are collected in the right places so that no radionuclides are missed. For example, samples may be collected from soil, air, water, fish, and vegetation in multiple locations.

4. Determining list of radionuclides

Samples collected are then sent to a laboratory to be analyzed.

The result of all the sampling and laboratory work is a list of radionuclides found at the site and the concentration (or amount) of those radionuclides.

Understanding Background Radiation

Many of the same radionuclides that contaminate a Superfund site also occur naturally. As a result, samples are also collected in uncontaminated areas surrounding the site. These samples allow EPA to determine local background concentrations. Understanding background concentration allows EPA to decide which radionuclides will require the most focus during the investigation.

At this point, it is not known if the levels of these radioactive contaminants could be harmful. The next step of the risk assessment process evaluates whether the contamination from the site may pose a risk to human health.

Step 2: Exposure Assessment

Exposure assessments are used to calculate the amount of exposure to radionuclides on a site that is likely to occur for people near the site (such as residents, workers, and visitors). This assessment is important because radiation that cannot reach you cannot hurt you.

Once it is known which radionuclides are on the site, their concentrations, and where they are, calculations are made to estimate the amount of radiation people may be exposed to. Many factors are included in making these calculations, such as:

- How much air people breathe.
- How much water they drink and use for other purposes.
- How much time people spend near the contaminated site. (Someone who lives near the site, for example, would have a different exposure level than someone working at or visiting the site.)

All of this information is then used to determine how much contact people have with the radioactive contamination.

Community Involvement

The public can be exposed to radiation at Superfund sites through many daily activities. By working with the public, EPA can learn how people in the area could come into contact with the radionuclides from a Superfund site.

Unique community interaction with the environment, such as eating wild fish and game or locally grown foods, is also considered to account for other potential routes of exposure.

Now that the types of radionuclides and the extent of exposure to them have been determined, the next step is to understand harmful health effects from this exposure.

Step 3: Toxicity Assessment

The toxicity assessment phase answers two key questions: what potential harmful health effects can the radionuclide cause, and how much exposure to the radionuclide does it take to pose a significant risk to people?

The toxicity assessment is concerned with the potential for radionuclides to cause cancer. All radionuclides can cause cancer and are assumed to be potentially harmful even at low doses. The risk of cancer from radiation increases as the exposure increases. Uranium radionuclides are the only radionuclides where the noncancer effects are also considered during Superfund site cleanup.

In estimating the toxicity of a radionuclide, EPA must take into account the type of radiation it emits and how the radiation affects different organs in the body. Alpha particles, for example, inflict about 20 times more damage to living tissue than beta particles or gamma rays. In addition, different organs in the body have different cancer rates even when exposed to the same level of radiation. As a result, EPA must consider both whole body radiation exposure as well as specific organ exposure for certain radionuclides.

Understanding Radiation Toxicity

At much higher radiation exposures than would be expected at a Superfund site, harmful effects can be produced in a relatively short time. An example of this is the sickness seen in atomic bomb survivors. Since exposure at Superfund sites is usually much lower, EPA focuses primarily on the cancer risk from exposure to radionuclides.

EPA has developed two methods to assess the harmful effects of exposure to specific radionuclides:

- **Slope factors** provide cancer risk posed by lifetime exposure to specific radionuclides. Slope factors also take into account the type of exposure (inhalation, ingestion, or external).

- **Dose conversion factors (DCFs)** convert concentration of specific radionuclides (in air, soil, water, or food) to a radiation dose based on a person's type of exposure.

EPA uses this information, combined with the exposure assessment, to calculate how toxic the radionuclides are at the Superfund site.

Step 4: Risk Characterization

Risk characterization is the final phase in a Superfund radiation risk assessment. From the data collection and evaluation phase, we developed a list of radionuclides, and the concentrations of those radionuclides, found at the site. We learned from the exposure assessment phase who is exposed, how they are exposed, and how much of the radioactive contaminants they are exposed to. And from the toxicity assessment, we found out how toxic these contaminants could be based on the exposure. During the risk characterization, we use all of this information to calculate the risk of potential health effects from exposure to radionuclides at the site.

Health risk is based on the excess risk of cancer from exposure to radioactive contamination. This risk is described in terms of the probability that an exposed individual will develop cancer over a lifetime as a result of that exposure.

EPA generally considers excess cancer risk in the range of 1 out of ten thousand people to 1 out of one million people, or 10^{-4} to 10^{-6}, as a protective range for both chemical and radioactive contaminants. If a site is contaminated with radionuclides and cancer-causing chemicals, cancer risk is combined for both. Most people will have less chance of getting cancer than these numbers indicate because EPA uses assumptions about exposure to contaminants that are designed to ensure that everyone at a site is protected, including vulnerable populations such as children.

Once the health risks from the site are understood, the list of radionuclides found at the site is reviewed and a determination is made as to which radionuclides pose a significant risk. This information, as well as information about risks to the environment, can now be used to develop a cleanup plan that will make the site safe for both current and future uses, protecting human health and the environment.

What if I want More Information?

If you would like to learn more about EPA's risk assessment process for radiation at Superfund sites, you may want to watch the video "Superfund Radiation Risk Assessment and How You Can Help: An Overview" available online at: http://www.epa.gov/superfund/health/contaminants/radiation/radvideo.htm.

You may also read documents that EPA has written to help its own staff in conducting risk assessments for radiation at Superfund sites. The "Radiation Risk Assessment at CERCLA Sites: Q & A" is a good place to start since it provides an overview for EPA staff of the material available for them to use. This document is available online at: http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/riskqa-second.pdf.

If you would like to learn more about EPA's Superfund program, you may wish to read "This is Superfund: A Community Guide to EPA's Superfund Program." This guide is available online at: http://www.epa.gov/superfund/community/today/pdfs/TIS%20FINAL%209.13.11.pdf.

If you have questions about this document, you can contact Stuart Walker of EPA by e-mail at walker.stuart@epa.gov or by telephone at (703) 603-8748.

Attachment A

Compendium of Information on the

Preliminary Remediation Goal (PRG)

and Dose Compliance Concentration (DCC) Calculators

Primer on PRG and DCC Calculators

What are the Preliminary Remediation Goal (PRG) and Dose Compliance Concentration (DCC) calculators?

The PRG and DCC calculators were developed to help EPA staff and others who are assessing radiation at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) sites. The PRG calculators are used to identify the amount of radiation that equals the 10^{-4} to 10^{-6} cancer risk range that EPA considers protective. The DCC calculators are used to determine the amount of radiation that equals a dose-based regulation that is measured in millirem per year.

How do the PRG and DCC calculators work?

The calculators use a series of equations to estimate radiation concentrations that EPA considers protective. They include assumptions about how people live at the site and the site itself, including the weather. These assumptions can be adjusted to more accurately reflect the situation at your site.

What is an Applicable or Relevant and Appropriate Requirement (ARAR)?

An ARAR is an environmental law or regulation from the federal government or a state government that addresses conditions or a particular cleanup technology at a Superfund site.

All actions to clean up contamination at Superfund sites must be protective of human health and the environment and comply with ARARs, unless a waiver is justified. ARARs are often the deciding factor in establishing cleanup levels at CERCLA sites.

The DCC calculators may be used for developing cleanup levels if an ARAR is a dose-based millirem regulation.

What if I want more information?

There are 1-page fact sheets describing each of the six PRG and DCC calculators. If you have questions about the PRG or DCC calculators, you can contact Stuart Walker of EPA by e-mail at walker.stuart@epa.gov or by telephone at (703) 603-8748.

Preliminary Remediation Goals (PRG) Calculator

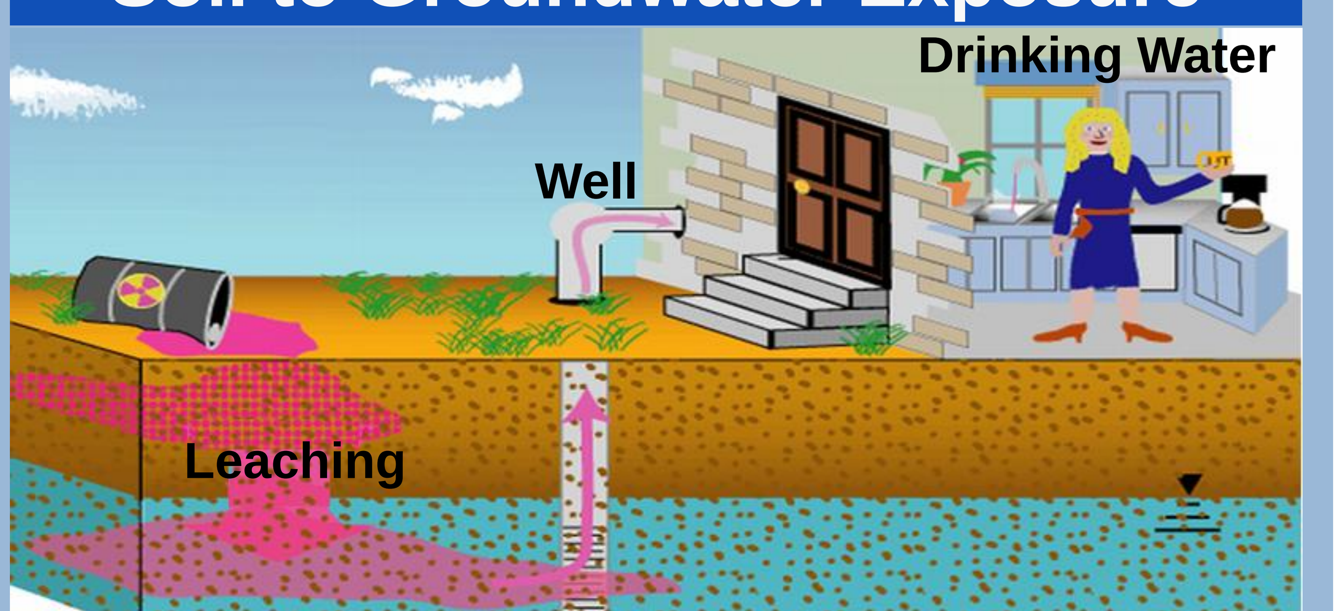
Stuart Walker – walker.stuart@epa.gov, (703) 603-8748
Office of Superfund Remediation and Technology Innovation, US Environmental Protection Agency

PRG: http://epa-prgs.ornl.gov/radionuclides

What is PRG?

- PRG stands for **Preliminary Remediation Goal**.
- PRGs are the initial cleanup goals at a Superfund site and usually are not final cleanup levels.
- Used when there is no appropriate government regulation of cleanup levels.

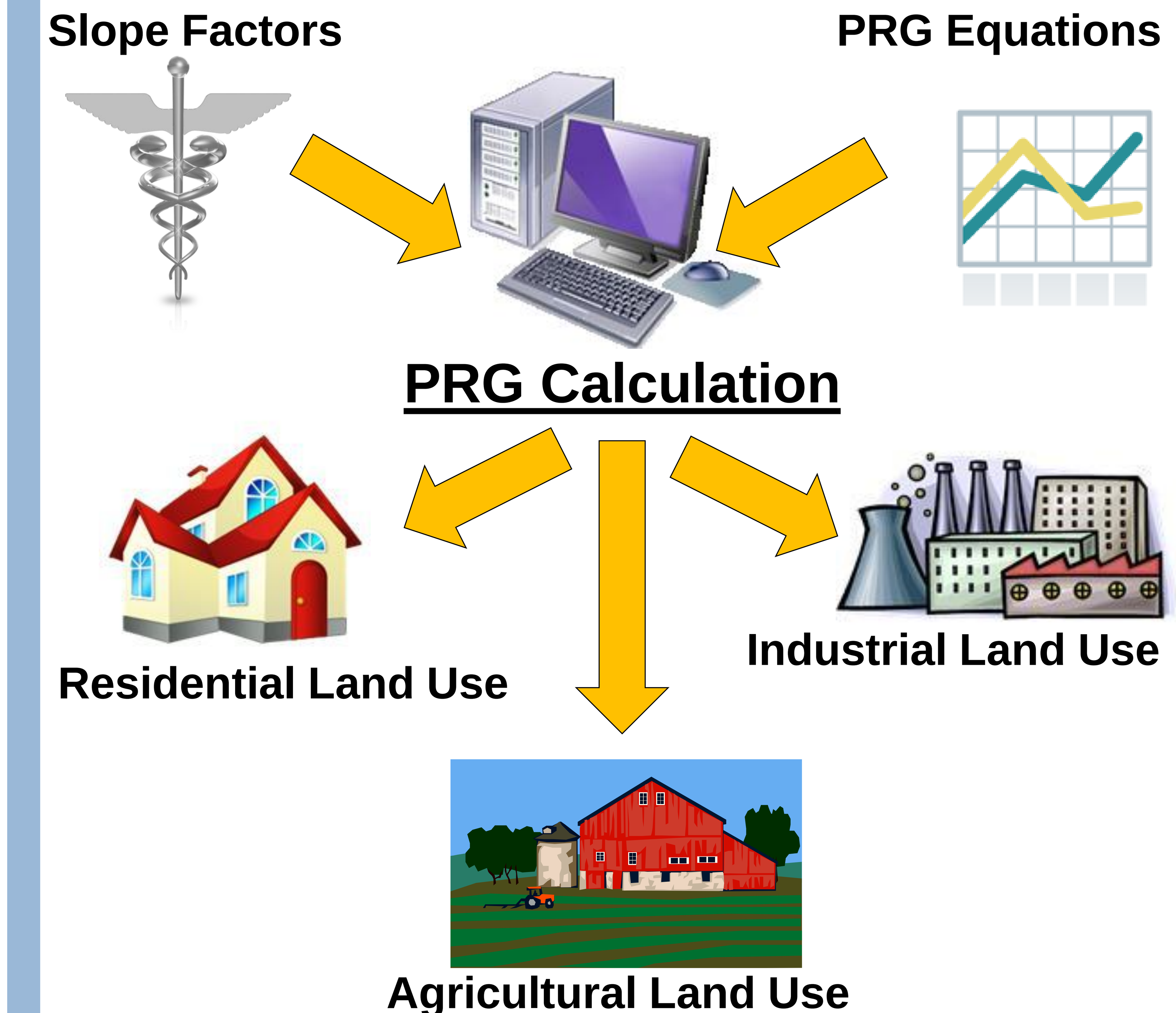
Soil to Groundwater Exposure



PRG Calculator

- The **PRG Calculator** is a tool that allows EPA to calculate initial cleanup levels for radiation in soil, water, and air at Superfund sites.
- Uses **slope factors** to calculate cleanup levels based on a **target cancer risk of 10^{-6}** .
  - **Slope factors** provide cancer risk posed by lifetime exposure to specific radionuclides. Slope factors also take into account the type of exposure (inhalation, ingestion, or external) and amount of exposure. For example, a resident on a site would expect to have a different exposure level than a worker on the same site.
  - **Target cancer risk of 10^{-6}** means that a person exposed to the contamination has a one in a million chance of developing cancer. (Target is based on highest estimated level of exposure. Most people will have less of a chance of developing cancer.)
- The exposure pathways calculated by the PRG calculator are shown in the diagrams below.

How does the PRG Calculator Work?



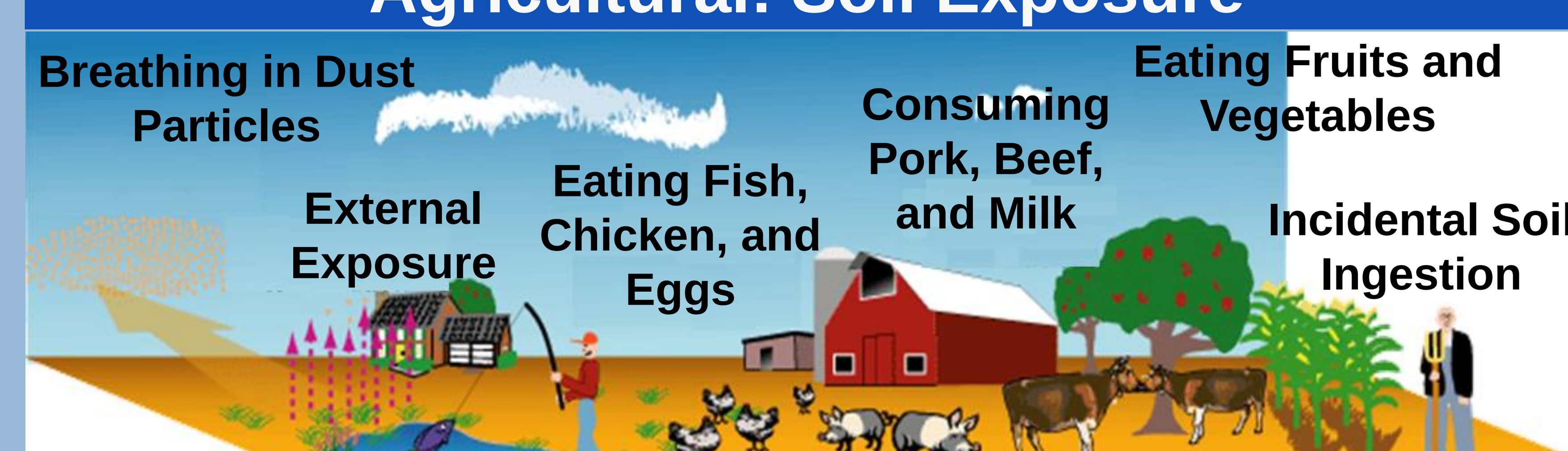
Outdoor (or Composite) Worker: Soil Exposure

Resident: Soil Exposure

Tapwater Ingestion Exposure

Indoor Worker: Soil Exposure

Agricultural: Soil Exposure



Fish Ingestion Exposure

Dose Compliance Concentration (DCC) Calculator

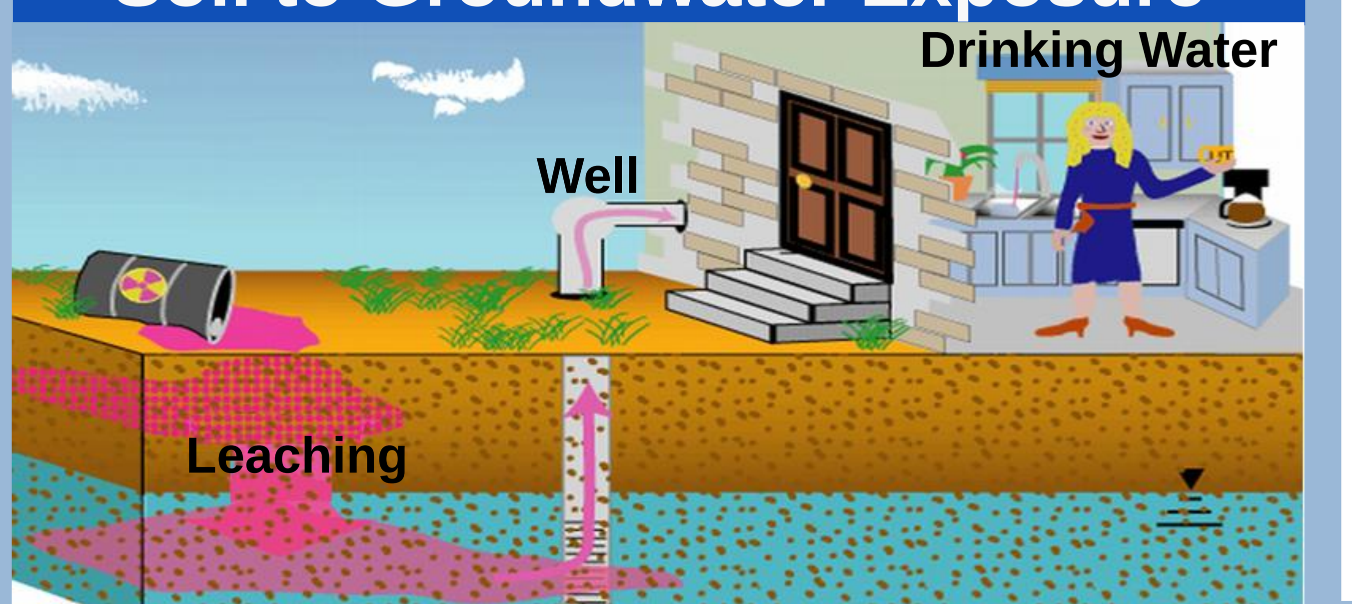
Stuart Walker – walker.stuart@epa.gov, (703) 603-8748
Office of Superfund Remediation and Technology Innovation, US Environmental Protection Agency

DCC: http://epa-dccs.ornl.gov/

What is DCC?

- DCC stands for **dose compliance concentrations**.
- DCCs are cleanup levels that correspond to a specific dose of radiation.
- Superfund is **NOT** a dose-based program.

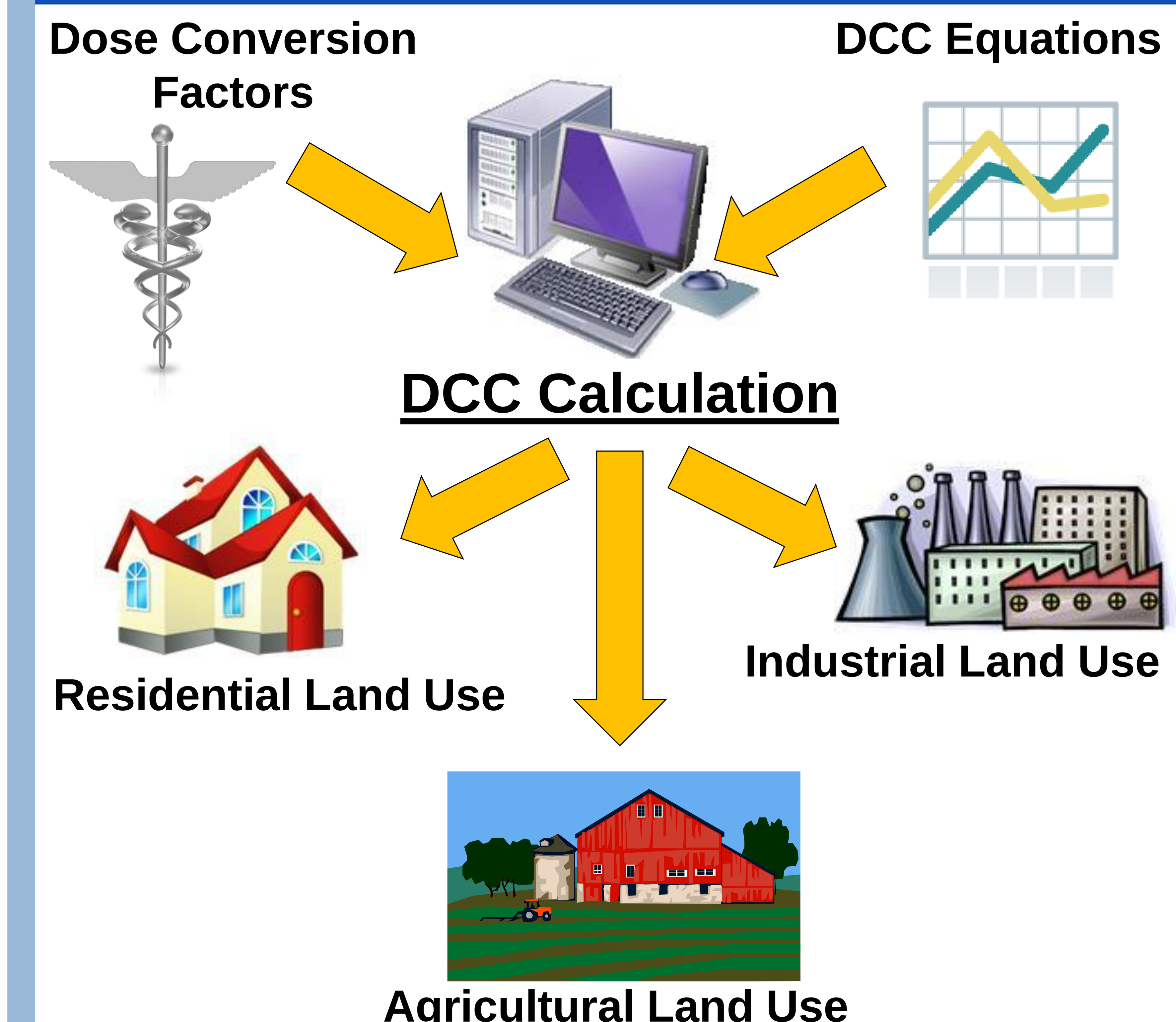
Soil to Groundwater Exposure



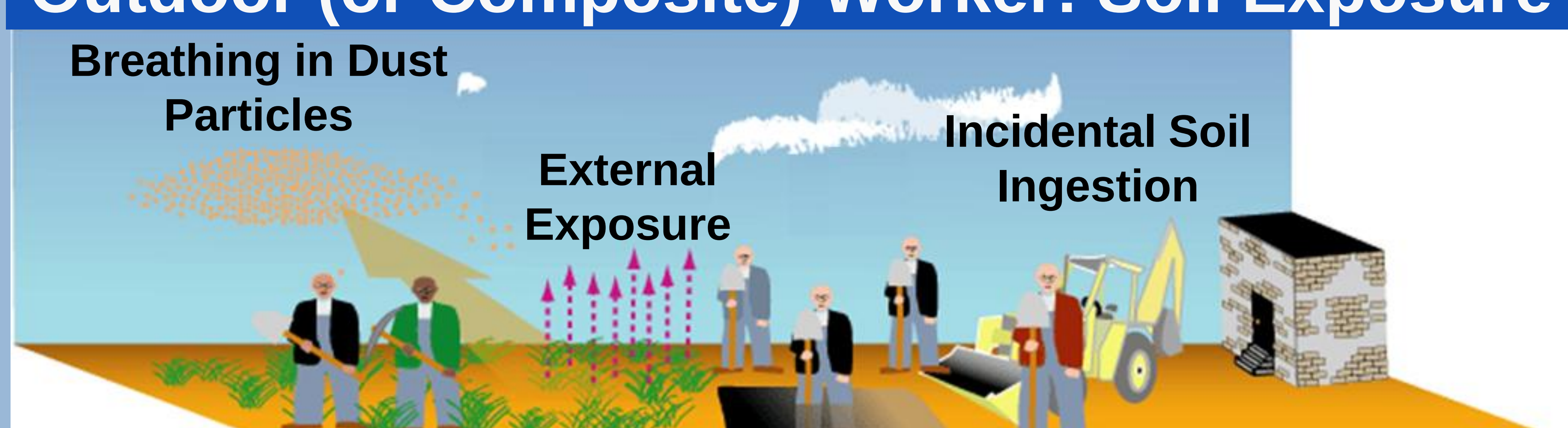
DCC Calculator

- The **DCC Calculator** is a tool that allows EPA to calculate cleanup levels in soil, water, and air that correspond to a specific dose of radiation at a Superfund site. The calculator uses **dose conversion factors (DCF)** in calculating radiation dose.
  - **Dose** is the amount of radiation absorbed by a person's body.
  - **DCFs** use concentration of a radionuclide in soil, air, water, and food to determine the dose of radiation a person at a contaminated site is exposed to. DCFs also take into account the type of exposure (inhalation, ingestion, or external) in determining dose.
- Superfund takes into account cancer risk, not radiation dose, in deciding cleanup levels. The DCC calculator is useful to show compliance with existing regulation of cleanup levels that may be in place.

How does the DCC Calculator Work?



Outdoor (or Composite) Worker: Soil Exposure

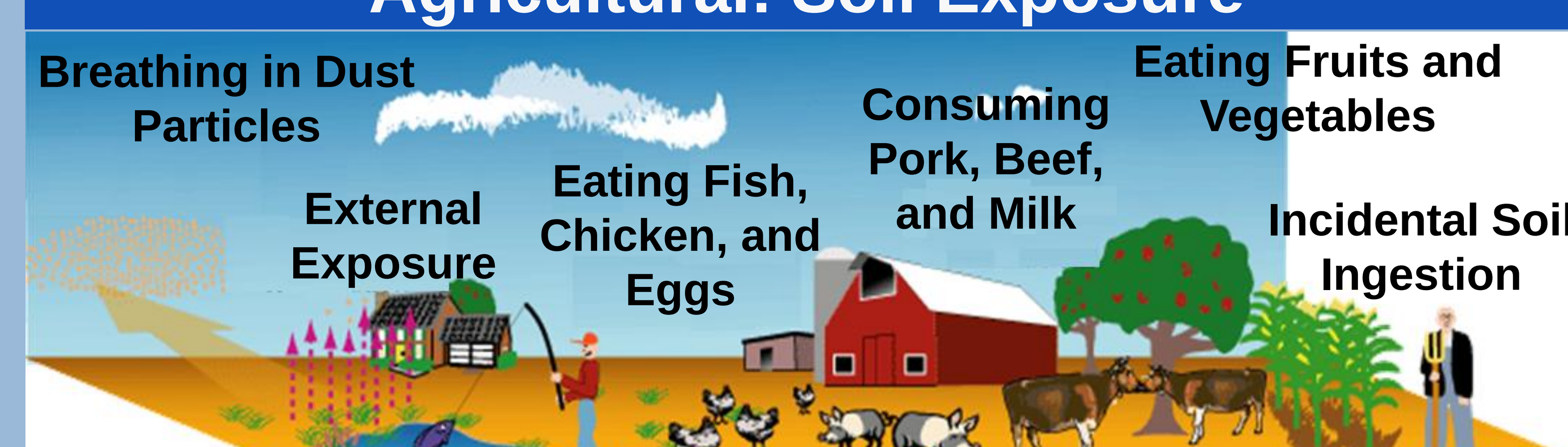


Resident: Soil Exposure

Tapwater Ingestion Exposure

Indoor Worker: Soil Exposure

Agricultural: Soil Exposure



Fish Ingestion Exposure

Building Preliminary Remediation Goals (BPRG) Calculator

Stuart Walker – walker.stuart@epa.gov, (703) 603-8748
Office of Superfund Remediation and Technology Innovation, US Environmental Protection Agency

BPRG: http://epa-bprg.ornl.gov

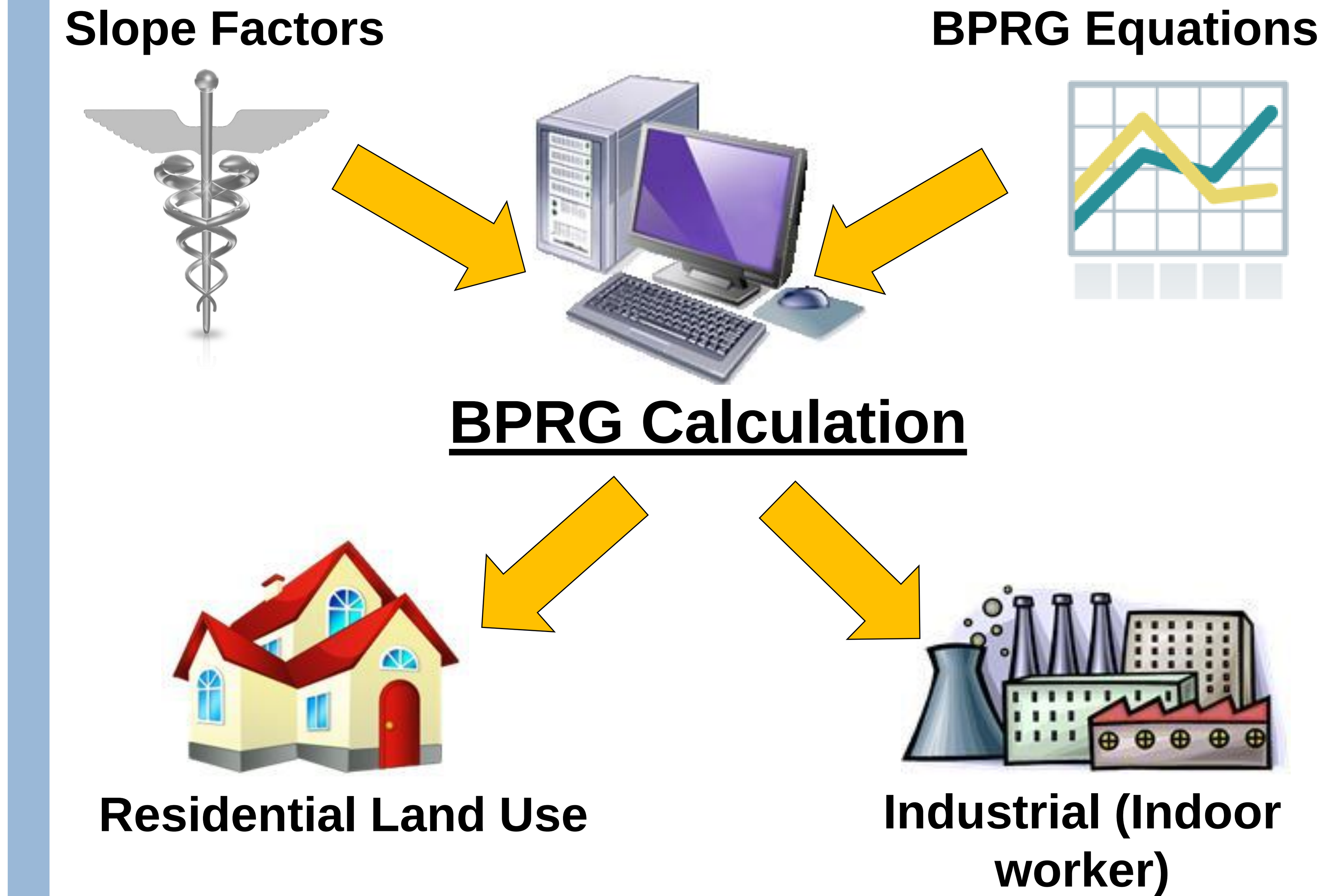
What is BPRG?

- BPRG stands for **Building Preliminary Remediation Goal**.
- BPRGs are the initial cleanup goals for contamination inside of buildings at a Superfund site and usually are not final cleanup standards.
- Used when there is no appropriate government regulation of cleanup levels.
- Used for residential and commercial/industrial indoor worker exposure.

BPRG Calculator

- The **BPRG Calculator** is a tool that allows EPA to calculate radiation cleanup levels inside of buildings at Superfund sites.
- Uses **slope factors** to calculate cleanup levels based on a **target cancer risk of 10^{-6}** .
  - **Slope factors** provide cancer risk posed by lifetime exposure to specific radionuclides. Slope factors also take into account the type of exposure (inhalation, ingestion, or external) and the amount of exposure. For example, a resident on a site would expect to have a different exposure level than a worker on the same site.
  - **Target cancer risk of 10^{-6}** means that a person exposed to the contamination has a one in a million chance of developing cancer. (Target is based on highest estimated level of exposure. Most people will have less of a chance of developing cancer.)
- The exposure pathways used by the BPRG calculator are shown in the diagrams below.

How does the BPRG Calculator work?



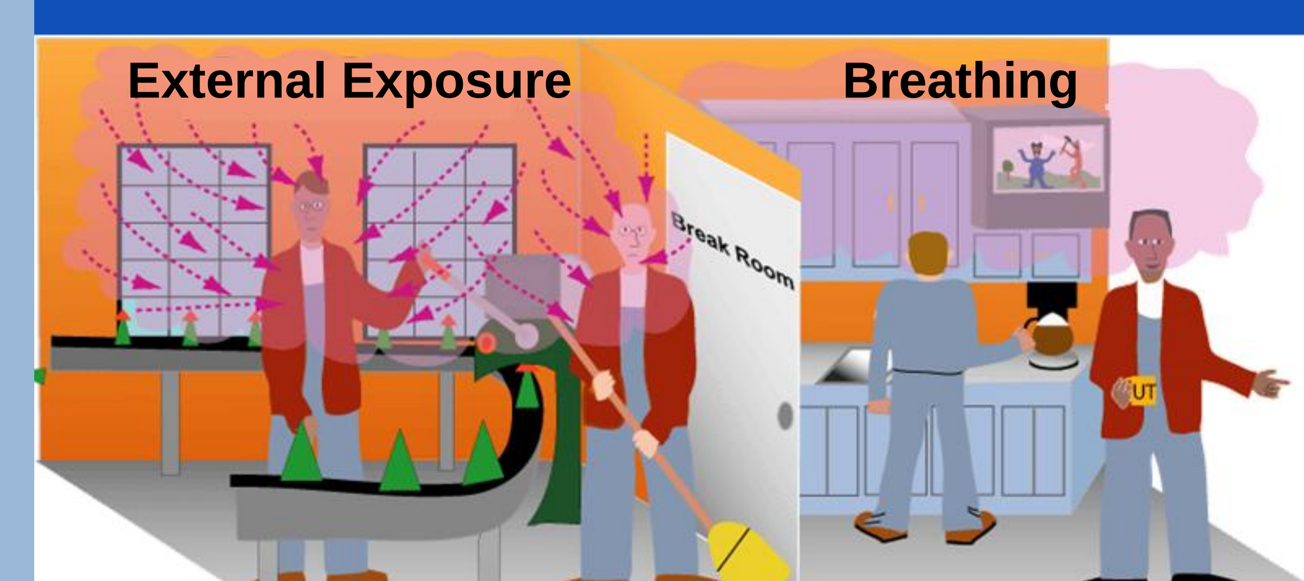
Resident: Settled Dust

Resident: Ambient Air

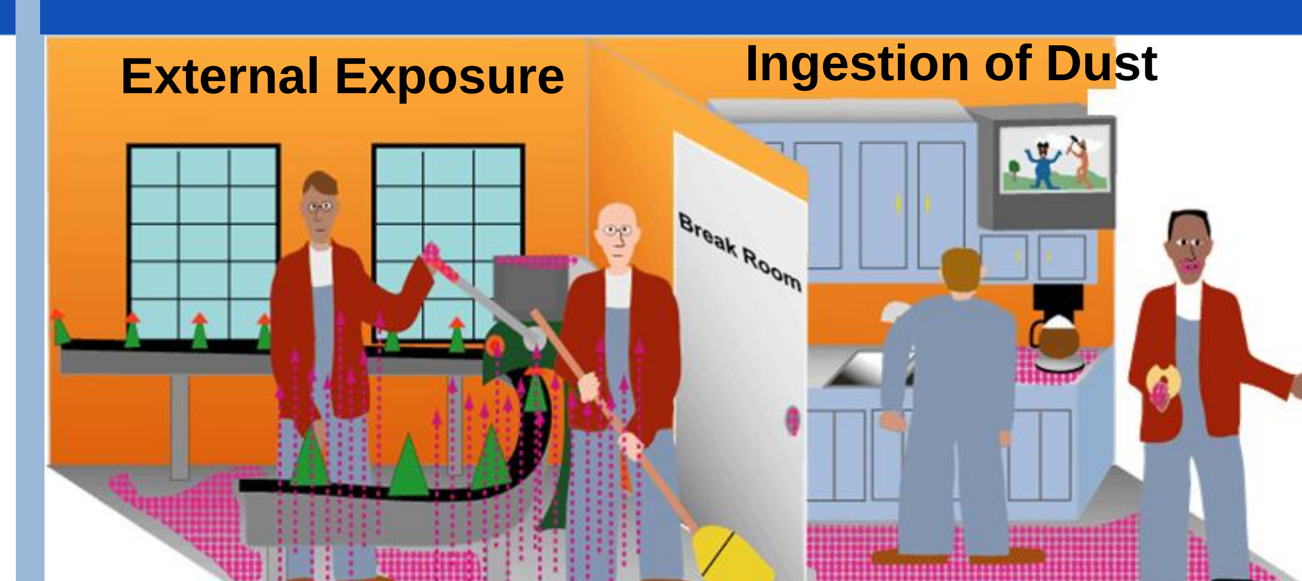
Resident: Contaminated Building Materials

Indoor Worker: Contaminated Building Materials

Indoor Worker: Ambient Air



Indoor Worker: Settled Dust



Building Dose Compliance Concentration (BDCC) Calculator

Stuart Walker – walker.stuart@epa.gov, (703) 603-8748
Office of Superfund Remediation and Technology Innovation, US Environmental Protection Agency

BDCC: http://epa-bdcc.ornl.gov

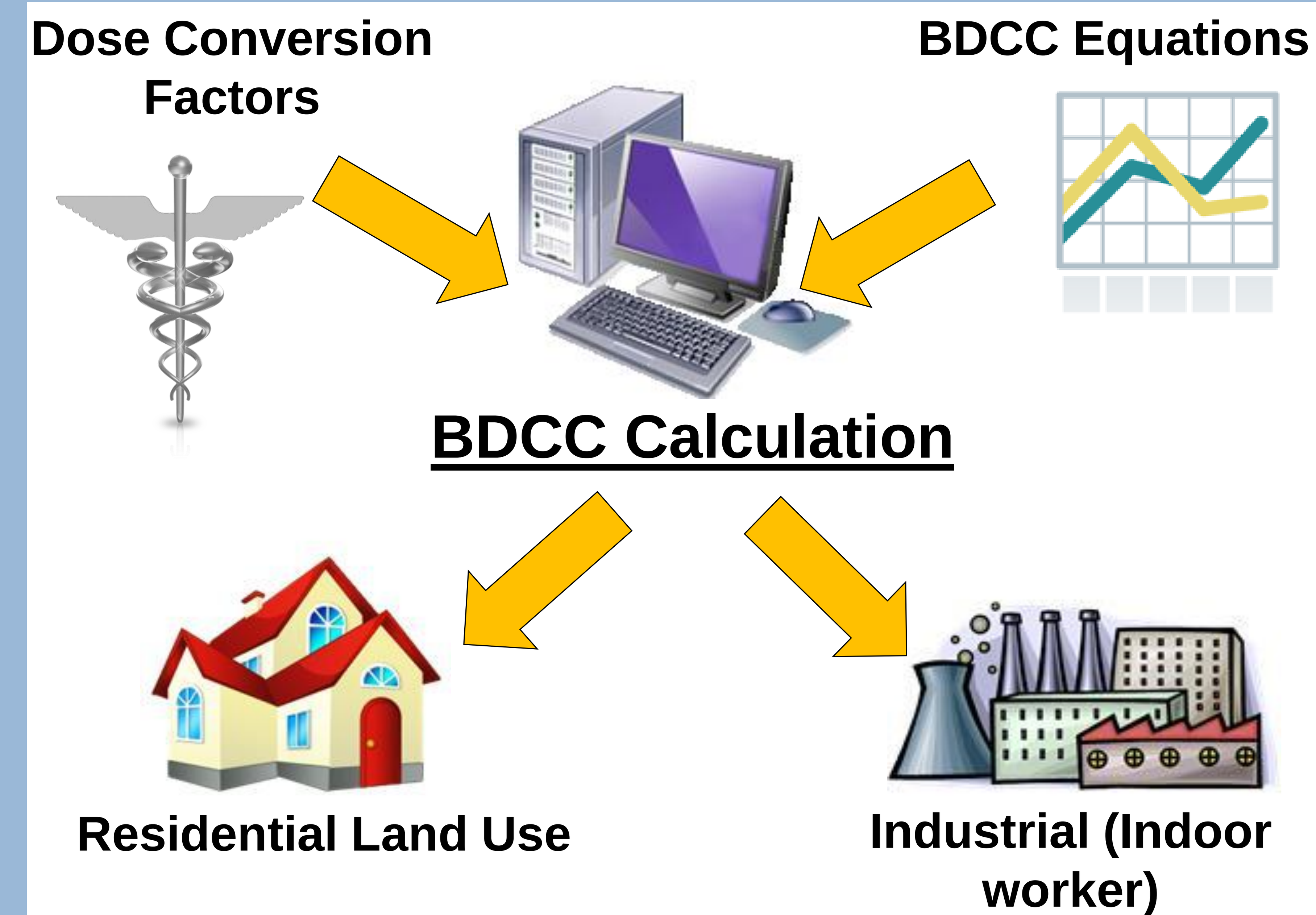
What is BDCC?

- BDCC stands for **building dose compliance concentrations**.
- BDCCs are cleanup levels that correspond to a specific dose of radiation in radioactively contaminated buildings.
- Superfund is **NOT** a dose-based program.
- Used for residential and commercial/industrial indoor worker exposure.

BDCC Calculator

- The **BDCC Calculator** is a tool that allows EPA to calculate cleanup levels that correspond to a specific dose of radiation in radioactively contaminated buildings at a Superfund site. The calculator uses **dose conversion factors (DCF)** in calculating radiation dose.
  - **Dose** is the amount of radiation absorbed by a person's body.
  - **DCFs** use concentration of a radionuclide in soil, air, water, and food to determine the dose of radiation a person at a contaminated site is exposed to. DCFs also take into account the type of exposure (inhalation, ingestion, or external) in determining dose.
- Superfund takes into account cancer risk, not radiation dose, in deciding cleanup levels. The DCC calculator is useful to show compliance with previously existing regulation of cleanup levels that may be in place.
- Below are some exposure pathways considered by the DCC.

How does the BDCC Calculator work?



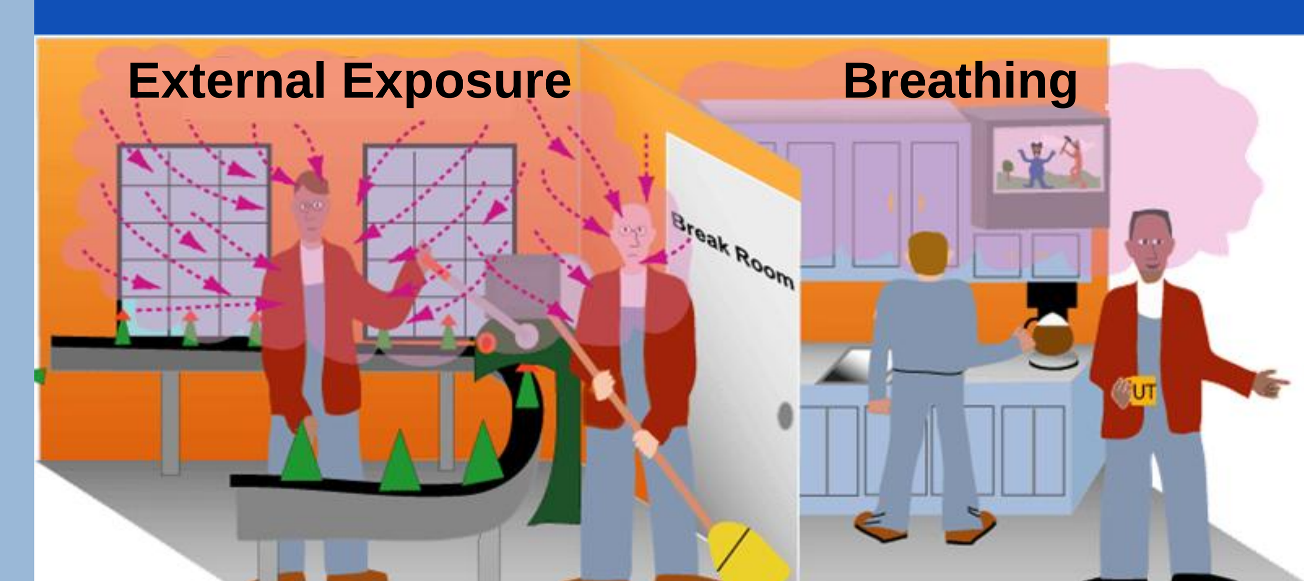
Resident: Settled Dust

Resident: Ambient Air

Resident: Contaminated Building Materials

Indoor Worker: Contaminated Building Materials

Indoor Worker: Ambient Air



Indoor Worker: Settled Dust

Surface Preliminary Remediation Goals (SPRG) Calculator

Stuart Walker – walker.stuart@epa.gov, (703) 603-8748
Office of Superfund Remediation and Technology Innovation, US Environmental Protection Agency

SPRG: http://epa-sprg.ornl.gov

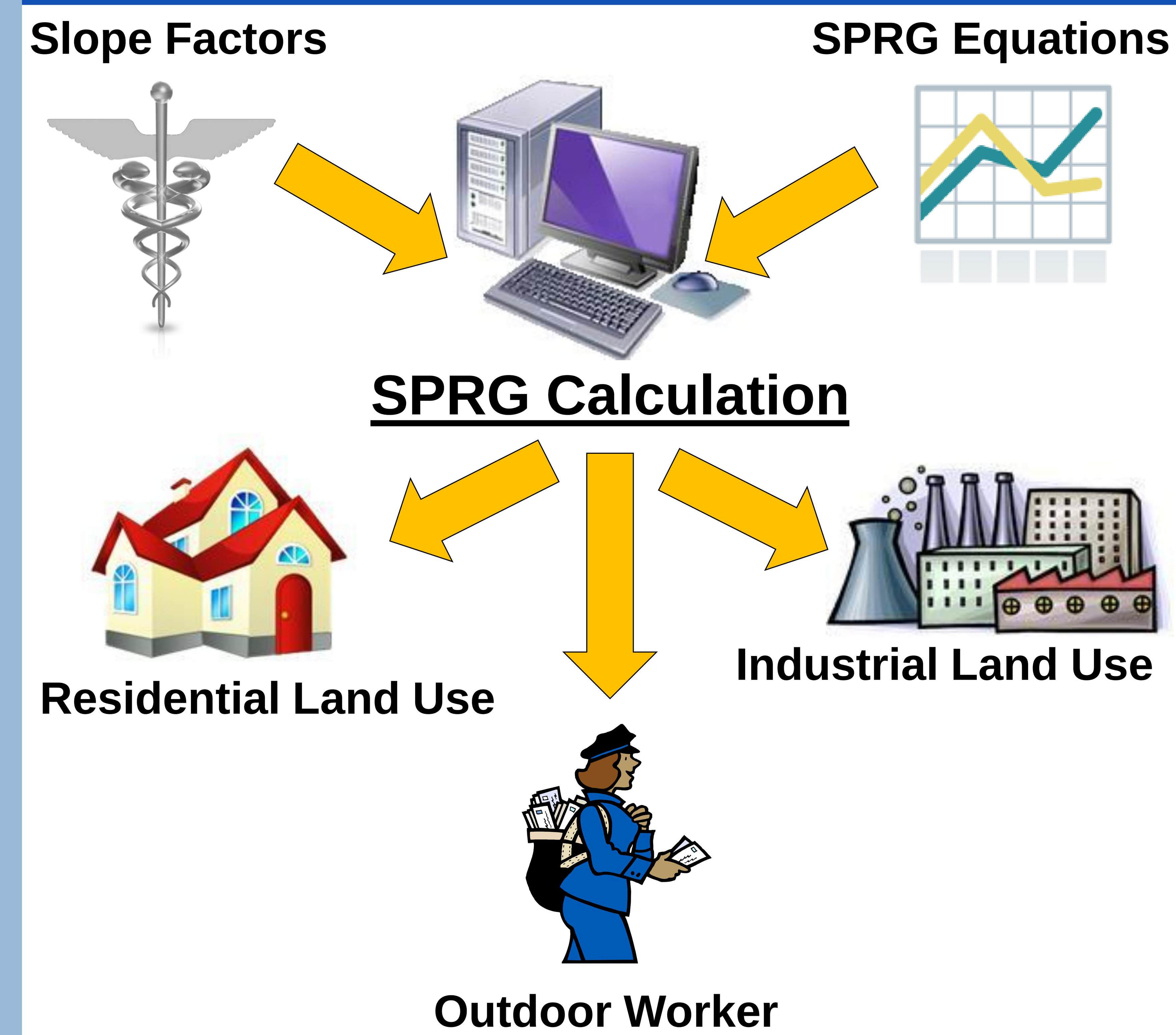
What is SPRG?

- SPRG stands for **Surface Preliminary Remediation Goal**.
- SPRGs are the initial cleanup goals for contamination on hard surfaces at a Superfund site and usually are not final cleanup levels.
- Used when there is no appropriate government regulation of cleanup levels.
- Used for residential , indoor worker, and outdoor worker exposure.

SPRG Calculator

- The **SPRG Calculator** is a tool that allows EPA to calculate radiation cleanup levels on contaminated hard outside surfaces (streets or sides of buildings.)
- Uses **slope factors** to calculate clean-up levels based on a **target cancer risk of 10^{-6}** .
  - **Slope factors** provide cancer risk posed by lifetime exposure to specific radionuclides. Slope factors also take into account the type of exposure (inhalation, ingestion, or external) and amount of exposure. For example, a resident on a site would expect to have a different exposure level than a worker on the same site.
  - **Target cancer risk of 10^{-6}** means that a person exposed to the contamination has a one in a million chance of developing cancer. (Target is based on highest estimated level of exposure. Most people will have less of a chance of developing cancer.)
  - Takes into account different exposure pathways (shown in the diagrams below)

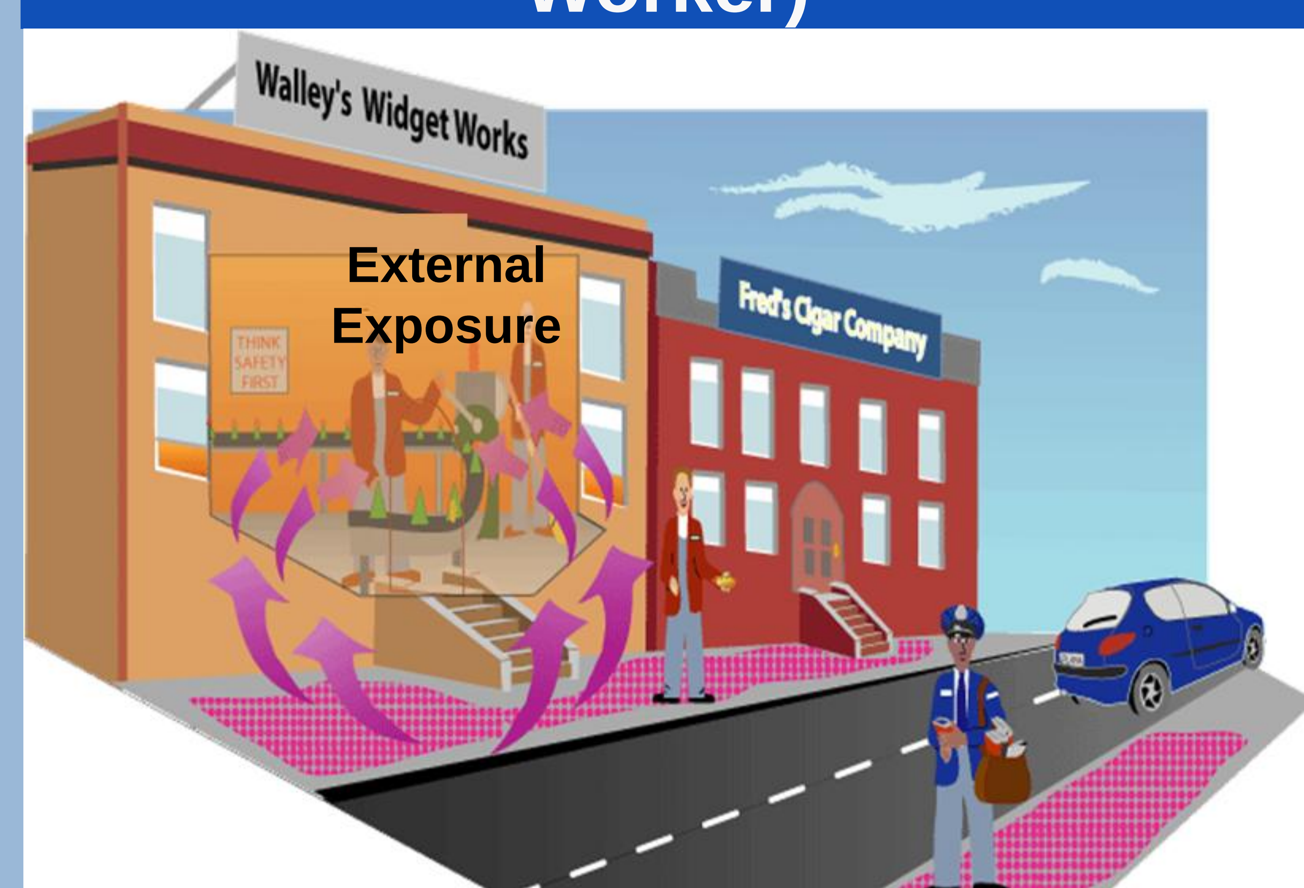
SPRG Calculator



2D Exposure to Fixed Settled Dust on Finite Slabs (Outdoor Worker)

Settled Dust (Resident)

3D Exposure to Fixed Settled Dust on Outdoor Surfaces (Indoor Worker)



3D Exposure to Fixed Contaminated Building Materials (Outdoor Worker)

2D Exposure to Fixed Contaminated Finite Slabs (Resident)

Surface Dose Compliance Concentration (SDCC) Calculator

Stuart Walker – walker.stuart@epa.gov, (703) 603-8748
Office of Superfund Remediation and Technology Innovation, US Environmental Protection Agency

SDCC: http://epa-sdcc.ornl.gov

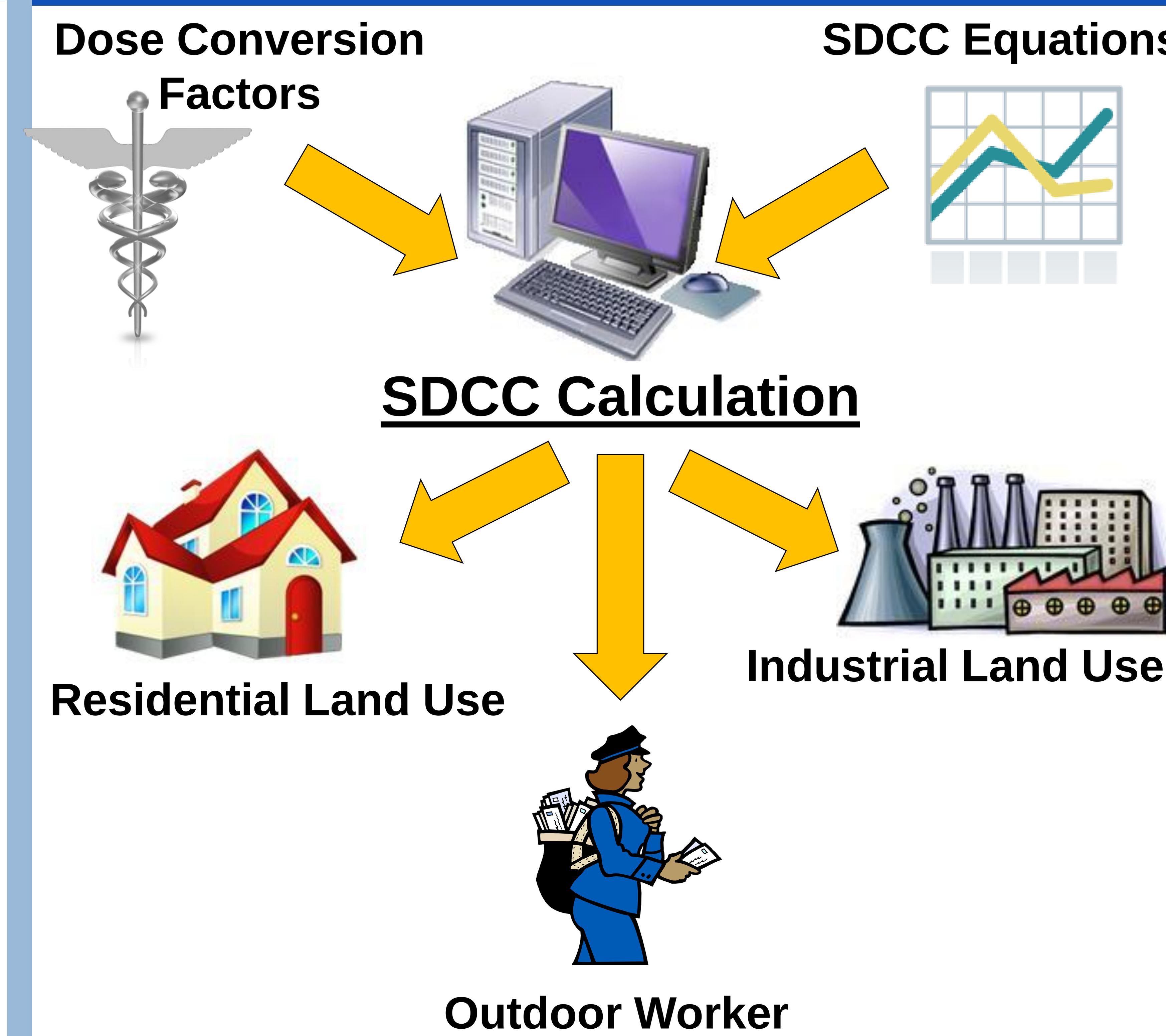
What is SDCC?

- SDCC stands for **surface dose compliance concentrations**.
- SDCCs are cleanup levels that correspond to a specific dose of radiation for radioactive contamination on hard surfaces.
- Superfund is **NOT** a dose-based program.
- Used for residential, indoor worker, and outdoor worker exposure.

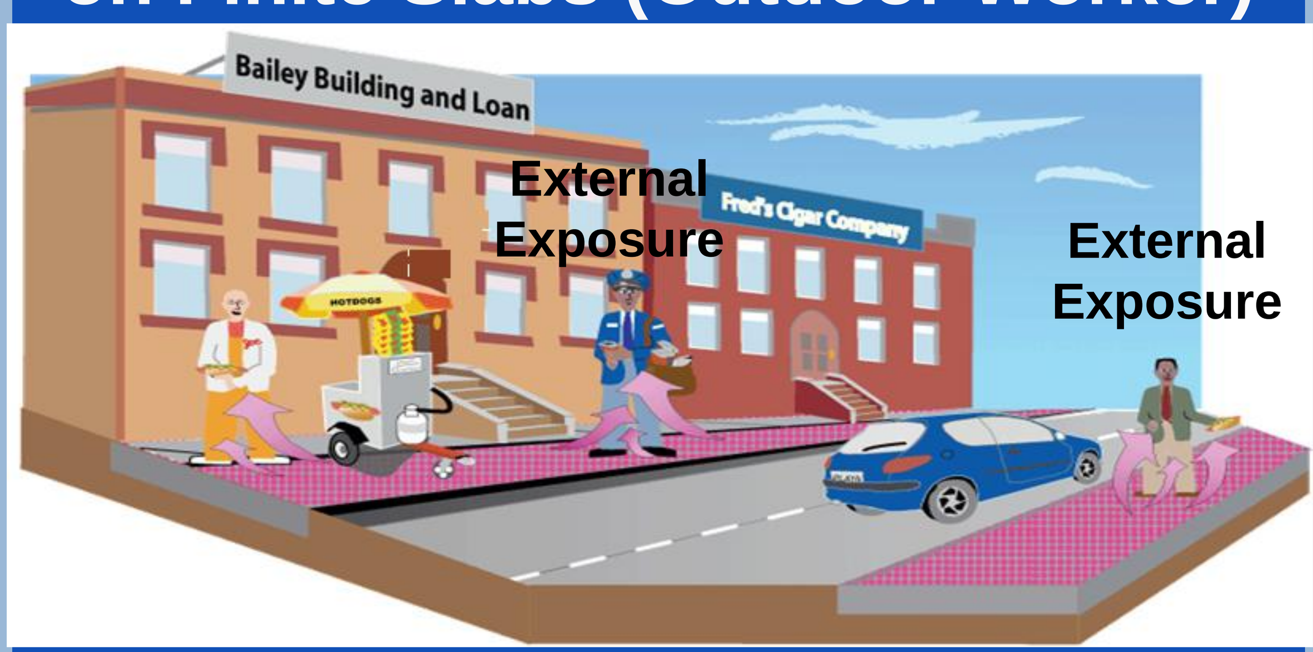
SDCC Calculator

- The **SDCC Calculator** is a tool that allows EPA to calculate radiation cleanup levels that correspond to a specific **dose** from contaminated, hard, outside surfaces (streets, sides of buildings.) The calculator uses **dose conversion factors (DCF)** in calculating radiation dose.
  - **Dose** is the amount of radiation absorbed by a person's body.
  - **DCFs** use concentration of a radionuclide in soil, air, water, and food to determine the dose of radiation a person at a contaminated site is exposed to. DCFs also take into account the type of exposure (inhalation, ingestion, or external) in determining dose.
- Superfund takes into account cancer risk, not radiation dose, in deciding cleanup levels. The DCC calculator is useful to show compliance with previously existing regulation of clean-up levels that may be in place.
- Below are some exposure pathways considered by the SDCC Calculator.

SDCC Calculator

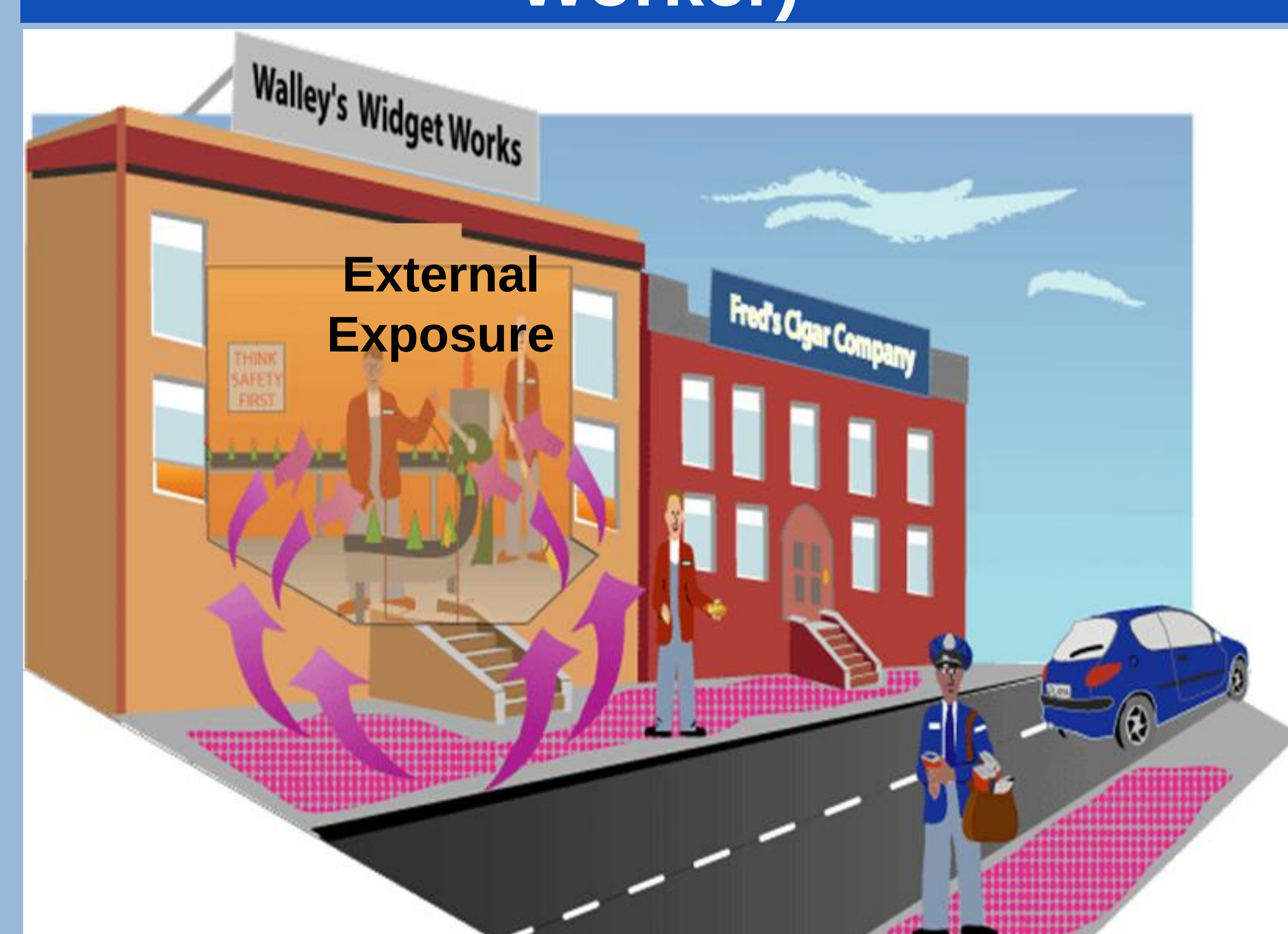


2D Exposure to Fixed Settled Dust on Finite Slabs (Outdoor Worker)



Settled Dust (Resident)

3D Exposure to Fixed Settled Dust on Outdoor Surfaces (Indoor Worker)



3D Exposure to Fixed Contaminated Building Materials (Outdoor Worker)

2D Exposure to Fixed Contaminated Finite Slabs (Resident)

Attachment B

Compendium of Information on

Radionuclides Commonly Found at Superfund Sites

Primer on Radionuclides Commonly Found at Superfund Sites

What is the purpose of these fact sheets?

The information in these fact sheets is intended to help the public understand more about the various radionuclides commonly found at Superfund sites.

What information is in these fact sheets?

These fact sheets answer questions such as:

- How can a person be exposed to the radionuclide?
- How can it affect human health?
- How does it enter and leave the body?
- What levels of exposure result in harmful effects?
- What recommendations has the U.S. Environmental Protection Agency (EPA) made to protect human health from exposure to radionuclides?

How does EPA calculate risks to human health from radiation exposure at Superfund sites?

EPA assesses the health effects of radiation by calculating **excess cancer risk** caused by radioactive contamination. Excess cancer risk is the probability that a person exposed to the contamination will develop cancer over a lifetime.

EPA considers excess cancer risk to be any risk above the **protective range**. The protective range is a probability that a person exposed to radioactive and chemical contaminants will have between a one in 10,000 and a one in a million chance of developing cancer, known as the 10^{-4} to 10^{-6} cancer risk range.

It is important to note that even in the protective range, most people will have less of a chance of developing cancer than these numbers would indicate. The actual change is lower because EPA uses assumptions about exposure levels that are higher than most people's actual exposure.

EPA may also calculate health risk from exposure to radiation in dose per year, measured in **millirems per year**. Some regulations at Superfund sites are based on what EPA has calculated to be acceptable dose limits per year.

What is an Applicable or Relevant and Appropriate Requirement (ARAR)?

An ARAR is an environmental law or regulation from the federal government or a state government that addresses conditions or a particular cleanup technology at a Superfund site.

All actions to clean up contamination at Superfund sites must be protective of human health and the environment and comply with ARARs, unless a waiver is justified. ARARs are often the deciding factor in establishing cleanup levels at Superfund sites.

What radionuclides are listed in these fact sheets?

The following radionuclides are those most frequently encountered at EPA Superfund sites and are described in a series of EPA fact sheets.

Americium-241

Cesium-137

Cobalt-60

Iodine isotopes

Plutonium isotopes

Radium isotopes

Radon

Strontium-90

Technetium-99

Thorium isotopes

Tritium

Uranium isotopes

What if I want More Information?

If you have questions about the radionuclides described in this document, you can contact Stuart Walker of EPA by e-mail at walker.stuart@epa.gov or by telephone at (703) 603-8748.

EPA Facts about Americium-241

What is americium-241?

Americium is a man-made radioactive metal. It is produced in nuclear reactors and during nuclear weapons tests when plutonium absorbs neutrons.

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

What are the uses of americium-241?

Americium is commonly used in very small amounts in smoke detectors. It is blended with the element beryllium and is used as a neutron source to measure the quantity of water present in soil, as well as moisture and density for quality control in highway construction. Americium is also used as a source of radiation in medical research and in medical diagnostic devices.

How does americium-241 change in the environment?

Americium-241 is introduced into the environment by the decay of plutonium that is a contaminant from nuclear weapons production and testing and potentially by certain types of nuclear reactors. Americium-241 is an unstable isotope. Therefore, 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 the stable element 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 required for a radioactive substance to lose 50 percent of its radioactivity by decay is known as the half-life. The half-life of americium-241 is about 432 years.

How are people exposed to americium-241?

Most americium that has been released into the environment has come from atmospheric testing of nuclear weapons. Some americium has also been released through nuclear weapons production, but this amount is small compared with the amount released during atmospheric testing.

Nuclear weapon sites, certain types of nuclear reactors, and industries that manufacture smoke detectors are potential sources of exposure to americium-241. Potential pathways of exposure include ingestion, inhalation, and external exposure from gamma radiation.

How does americium-241 get into the body?

Americium can enter the body when it is inhaled or swallowed. When it is inhaled, the amount of americium that remains in the lungs depends on the size of the particle and the chemical form of the americium compound. Some americium compounds dissolve easily. These compounds are absorbed through the lungs and enter 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 un-dissolved material that stays in the body goes to the bones, where it can remain for decades.

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

Yes, 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 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?

Americium poses a significant risk if enough is swallowed or inhaled because americium emits alpha particles. 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 exposure may eventually increase a person's chance of developing cancer, but these cancer effects may not become apparent for several years. Americium, however, also can pose a risk from direct external exposure through gamma ray emissions.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including americium-241, are summarized in the fact sheet "Primer on Radionuclides Commonly Found at Superfund Sites."

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 is covered under this MCL.

For more information about how EPA addresses americium-241 at Superfund sites *Contact Stuart Walker of EPA:*
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA's Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/

EPA Facts about Cesium-137

What is cesium-137?

Radioactive cesium-137 is produced spontaneously when other radioactive materials, such as uranium and plutonium, absorb neutrons and undergo fission. Fission is the process in which the nucleus of a radionuclide splits into smaller parts. Cesium-137 is a common radionuclide produced when nuclear fission 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 in food sterilization, including wheat, spices, flour, and potatoes. Cesium-137 is 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. 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. The time required for a radioactive substance to lose 50 percent of its radioactivity by decay is known as the half-life. Cesium-137 is significant because of its prevalence, relatively long half life (30 years), and its potential effects on human health. Barium-137, the daughter product of cesium-137 decay, has a half-life of 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, barium-137m, can pass through the human body, delivering radiation exposure 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 worldwide.

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 operation of nuclear reactors, spent fuel reprocessing plants, and nuclear accidents such as Chernobyl and Fukushima. Cesium-137 is also a component of low-level radioactive waste at hospitals, radioactive source manufacturing, and research facilities.

How does cesium-137 get into the body?

Cesium-137 can enter the body when it is inhaled, ingested, or absorbed through the skin. 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. 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 taking 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 cause cancer. 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 in Western Europe exposed to fallout from the accident at Chernobyl.

The magnitude of the health risk would depend on exposure conditions for scenarios involving nuclear accidents or waste materials, such as:

- Types of radioactivity encountered,
- Nature of exposure, and
- Length of exposure.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including cesium-137, are summarized in the fact sheet "Primer on Radionuclides Commonly Found at Superfund Sites."

EPA has established a Maximum Contaminant Level (MCL) of 4 millirems 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 millirems per year, is 200 picoCuries per liter (pCi/L). If other radionuclides that emit beta particles and photon radioactivity are present in addition to cesuim-137, the sum of the annual dose from all the radionuclides cannot exceed 4 millirems/year.

For more information about how EPA addresses cesium-137 at Superfund sites

Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA's Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/

EPA Facts about Cobalt-60

What is cobalt-60?

The most common radioactive form of cobalt is cobalt-60. It 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 source of radiation. Medical use consists primarily of cancer radiotherapy. Industrial uses include testing welds and castings and a large variety of measurement and test instruments, such as 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 required for a radioactive substance to lose 50 percent of its radioactivity by decay is known as the half-life. The half-life of cobalt-60 is about 5.3 years.

How are people exposed to cobalt-60?

Most exposure to cobalt-60 takes place intentionally during medical tests and treatments. These 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 a 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 collecting 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. Health risks increase with the amount of cobalt-60, duration of exposure, distance from the source (for external exposure), and whether the cobalt-60 was ingested or inhaled.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including cobalt-60, are summarized in the fact sheet "Primer on Radionuclides Commonly Found at Superfund Sites."

EPA has established a Maximum Contaminant Level (MCL) of 4 millirems 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 that is assumed to yield 4 millirems per year is 100 picoCuries per liter (pCi/L). If other radionuclides that emit beta particles and photon radioactivity are present in addition to cobalt-60, the sum of the annual dose from all the radionuclides cannot exceed 4 millirems/year

For more information about how EPA addresses cobalt-60 at Superfund sites

Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA's Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/

EPA Facts about Iodine

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 is used 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 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 iodine-131 is relatively short, at 8 days, while the half life of iodine-129 is much longer, at more than 15 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 testing and the Chernobyl and Fukushima nuclear power plant accidents; however, the current level of iodine 131 in the environment is very low. The reason is that 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 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 is 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 after 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 that 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. This health effect is of particular concern for children and pregnant women. High doses of iodine are used to treat thyroid cancer. Lower doses of radioactive iodine will result in reducing the activity of the thyroid gland, which in turn will result in lower hormone production in the gland. There is a fine balance when treating thyroid problems with radioactive iodine. These treatments are administered only when the benefits outweigh the risks. As with any radioactive material, there is an incremental chance that a cancer can result from that incremental exposure to radioactive materials.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including iodine-131, are summarized in the fact sheet "Primer on Radionuclides Commonly Found at Superfund Sites."

EPA has established a Maximum Contaminant Level (MCL) of 4 millirems 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 millirems per year, is 3 picoCuries per liter (pCi/L). If other radionuclides that emit beta particles and photon radioactivity are present in addition to iodine-131, the sum of the annual dose from all the radionuclides cannot exceed 4 millirems/year.

For more information about how EPA addresses iodine at Superfund sites
Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA's Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation

EPA Facts about Plutonium

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 source of heat 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 common 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. 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; however, internal exposure to alpha radiation is a concern. 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 required for a radioactive substance to lose 50 percent of its radioactivity by decay is known as the half-life. Plutonium-238, plutonium-239, and plutonium-240 are isotopes of plutonium, and have half-lives of 87 years for plutonium-238, 24,065 years for plutonium-239, and 6,537 years for plutonium-240.

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 is very small 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 from these isotopes is minimal. When mixed in soil on the ground, these plutonium isotopes pose a potential risk that is predominantly from inhalation and ingestion.

How does plutonium get into the body?

Plutonium can enter the body when it is inhaled or swallowed. Once it is inhaled, the amount of plutonium that remains in the lungs depends on 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-241 and 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 these cancer effects may not become apparent for several years.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including plutonium, are summarized in the fact sheet "Primer on Radionuclides Commonly Found at Superfund Sites."

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 is covered under this MCL.

For more information about how EPA addresses plutonium at Superfund sites

Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA's Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/

EPA Facts about Radium

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 1900s, radium was wrongly 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. The use of radium for these purposes was discontinued because of the health hazards from these types of exposures. Radium has also been widely used in radiation treatment of cancer, 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 lightning 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 particles, 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. The time required for a radioactive substance to lose 50 percent of its radioactivity by decay is known as the half-life. The half lives are 3.5 days for radium-224, 1,600 years for radium-226, and 6.7 years for radium-228, the most common isotopes of radium, 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 continuously produces radon, which can diffuse into nearby homes.

An individual can be exposed to radium through contact with waste from ore at former radium processing facilities, former radium dial facilities, or radium dials. In addition, exposure to radium can occur if radium is released into the air from burning 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 as a result of 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 percent) will promptly leave the body in the feces. The other 20 percent 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?

Urinalysis and bone biopsy tests are sometimes used to determine if individuals have ingested 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 its direct decay product radon. Radon has been shown to cause lung cancer.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including radium, are summarized in the fact sheet "Primer on Radionuclides Commonly Found at Superfund Sites."

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 cleanup of soil in the top 15 centimeters. These regulations under 40 Code of Federal Regulations (CFR) Part 192.12 are often Applicable or Relevant and Appropriate Requirements (ARARs) at Superfund sites. The EPA document "Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA Sites" provides guidance to EPA staff regarding when the use of 5 picoCuries per gram (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. This document is available online at: http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/umtrcagu.pdf.

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 be an ARAR at the same site. Criterion 6(6) requires that the level of radiation, called a "benchmark dose," that an individual would receive be estimated 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 document "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 to EPA staff 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 in estimating a benchmark dose. This document is available online at: http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/part40.pdf.

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 is covered under this MCL.

For more information about how EPA addresses radium at Superfund sites

Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA's Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/

EPA Facts about Radon

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 groundwater 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 groundwater. 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 groundwater flowing through rock or sand. Radon undergoes radioactive decay, when 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 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 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 picoCuries per liter [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, more than 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 groundwater that contains radon. Radon gas escapes from the water and goes into the air when water that contains radon is used in the home for showering, washing dishes, and cooking. Radon in domestic water generally contributes only a small proportion (about 1 to 2 percent) of the total radon in indoor air. Radon levels in air and groundwater 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 percent of these cancer deaths are caused by lung cancer from inhalation of radon released to indoor air from the water, and about 11 percent are a result of cancers of internal organs, mostly stomach cancers, from ingestion of radon in water.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including radon, are summarized in the fact sheet “Primer on Radionuclides Commonly Found at Superfund Sites.”

EPA has established a limitation to exposure to radon-222 and radon-220 decay products of less than 0.02 Working Levels (WL) for uranium mill tailings sites, where radon poses the major health threat. These regulations under 40 Code of Federal Regulations (CFR) Part 192.12(b) are often Applicable or Relevant and Appropriate Requirements (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 pCi/L, EPA’s national voluntary action level. EPA and the Surgeon General also recommend that schools nationwide be tested for radon. (Exposure to 5 pCi/L of radon-222, or 7.5 pCi/L of radon-220, 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/pubs/index.html.

There is currently a proposed Maximum Contaminant Level (MCL) for radon in drinking water from community water systems using groundwater. The Safe Drinking Water Act directs EPA to set both an MCL for radon in drinking water, as well a higher alternative maximum contaminant level 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 visit EPA’s web site at http://water.epa.gov/drink/index.cfm.

For more information about how EPA addresses radon at Superfund sites

Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA’s Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/

EPA Facts about Strontium-90

What is strontium-90?

Radioactive strontium-90 is produced when uranium and plutonium undergo fission. Fission is the process in which the nucleus of a radionuclide breaks into smaller parts. 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 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. Additionally, strontium-90 is used in electron tubes, radioluminescent markers, 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.

The time required for a radioactive substance to lose 50 percent of its radioactivity by decay is known as the half-life. 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 (such as research reactors and nuclear power plants).

Accidents involving nuclear reactors such as Chernobyl and Fukushima have released strontium into the atmosphere, which ultimately settles to the earth’s surface as fallout.

Chernobyl contributed the largest worldwide amount of strontium-90 contamination, and a substantial portion of the strontium-90 released was deposited in the former Soviet Republics, with the rest being spread as fallout worldwide.

How does strontium-90 get into the body?

Ingestion, usually through swallowing 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 digestive tract, while the rest is excreted through feces. Of the portion absorbed, virtually all (99 percent) of the strontium is deposited in the bones or skeleton.

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 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 of strontium-90 in air, water, and soil. At higher exposures, such as those associated with the Chernobyl accident, the cancer risks may be elevated. The magnitude of this health risk would depend on exposure conditions, such as the amount ingested.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including strontium-90, are summarized in the fact sheet "Primer on Radionuclides Commonly Found at Superfund Sites."

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

For more information about how EPA addresses strontium-90 at Superfund sites

Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA's Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/

EPA Facts about Technetium-99

What is technetium-99?

Technetium-99 (Tc-99) is a radioactive metal. Most technetium-99 is produced artificially, but some also occurs naturally in very small amounts in the earth's crust. Technetium-99 was first obtained from the element molybdenum, but it 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 technetium-99 and technetium-99m.

In addition to being produced during nuclear reactor operation, technetium-99 is produced in atmospheric nuclear weapons tests. Metastable technetium-99 (technetium-99m), the shorter-lived form of technetium-99, is also a component of gaseous and liquid effluent from nuclear reactors. Technetium-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?

Technetium-99 is an excellent superconductor at very low temperatures. In addition, technetium-99 has anti-corrosive properties. Five parts of technetium per million will protect carbon steels from corrosion at room temperature. Technetium-99m is used in medical therapy in brain, bone, liver, spleen, kidney, and thyroid scanning and for blood flow studies. Technetium-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 technetium-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 is 210,000 years for technetium-99 and 6 hours for technetium-99m.

How are people exposed to technetium-99?

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

In the natural environment, technetium-99 is found at very low concentrations in air, sea water, soils, plants, and animals. The behavior of technetium-99 in soils depends on many factors. Organic matter in soils and sediments plays a significant role in controlling the mobility of technetium-99. In soils rich in organic matter, technetium-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 technetium-99. Technetium-99 can also transfer from seawater to animals.

How does technetium-99 get into the body?

At radioactively contaminated sites with technetium-99 contamination, the primary routes of exposure to an individual are from the potential use of contaminated drinking water and ingestion of contaminated plants. Exposure may occur to persons working in research laboratories that conduct experiments using technetium-99 and technetium-99m. Patients undergoing diagnostic procedures may receive controlled amounts of technetium-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 technetium-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 administered 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, technetium-99 concentrates in the thyroid gland and the gastrointestinal tract. The body, however, constantly excretes technetium-99 once it is ingested. As with any other radioactive material, there is an increased chance that cancer or other adverse health effects can result from exposure to radiation.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including technetium-99, are summarized in the fact sheet "Primer on Radionuclides Commonly Found at Superfund Sites."

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

For more information about how EPA addresses technetium-99 at Superfund sites

Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA's Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/

EPA Facts about Thorium

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 that 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 naturally 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 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 thorium-232 is very long at about 14 billion years. As a result of 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-232 is typically present with its decay product radium-224, which will produce radon-220 gas, also known as thoron, and its decay products that result in lung exposure. 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-226 decay products, lung exposure from radon-222 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 administered 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 to take special X-rays. Bone cancer is also a potential health effect through the storage of thorium in the bone.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including thorium, are summarized in the fact sheet "Primer on Radionuclides Commonly Found 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 cleanup of the top 15 centimeters of soil. Since thorium decays into radium, these regulations for radium under 40 Code of Federal Regulations (CFR) Part 192.12 have often been used as Applicable or Relevant and Appropriate Requirements (ARARs) at Superfund sites for thorium-contaminated soil. The EPA document "Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA Sites" provides guidance to EPA staff regarding when 5 pCi/g of thorium is an ARAR or otherwise recommended cleanup level for any 15 centimeters of subsurface soil contaminated by thorium other than the first 15 centimeters. This document is available online at: http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/umtrcagu.pdf.

If regulations under 40 CFR Part 192.12 are an ARAR for radium in soil at a Superfund site, then Nuclear Regulatory Commission (NRC) regulations for uranium mill tailing sites under 10 CFR Part 40 Appendix A, I, Criterion 6(6), may be an ARAR at the same site.

Criterion 6(6) requires that the level of radiation, called a "benchmark dose," that an individual would receive be estimated 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 document "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. This document is available online at: http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/part40.pdf.

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 is covered under this MCL.

For more information about how EPA addresses thorium at Superfund sites

Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA's Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/

EPA Facts about Tritium

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 (such as EXIT signs). Tritium is used as a tracer for biochemical research, animal metabolism studies, and groundwater 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. As a result, 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 complex and slow.

The time required for a radioactive substance to lose 50 percent of its radioactivity by decay is known as the half-life. 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 that generate electricity. Other sources of tritium include government plants that have reprocessed reactor fuels. Individuals can also be exposed to tritium via 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, the risk to the average person from tritium is typically not significant since current world-wide levels of tritium in the environment from man-made and natural sources are low. 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 depends 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. Therefore, tritium dilutes through the body as ordinary water. Tritium concentration in soft tissue and the associated dose to these tissues is generally uniform and depends on the water content of the tissue. Tritium is rapidly cleared from tissues because the water content in the body turns over frequently.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including tritium, are summarized in the fact sheet "Primer on Radionuclides Commonly Found at Superfund Sites."

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

For more information about how EPA addresses tritium at Superfund sites

Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA's Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/

EPA Facts about Uranium

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 Facts 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 time required for a radioactive substance to lose 50 percent of its radioactivity by decay is known as the half-life. 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 the uranium-238, uranium-234, and uranium-235 are extracted and chemically separated during processing. 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 cleanup of these sites. Potential individual exposure at these sites may be from different pathways, but the groundwater pathway is of particular concern because of the mobility of uranium.

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 noncancer 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 depends on the level of uranium concentration.

What recommendations has the U.S. 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 at Superfund sites (the 10^{-4} to 10^{-6} cancer risk range), which cover all radionuclides including uranium, are summarized in the fact sheet “Primer on Radionuclides Commonly Found at Superfund Sites.”

EPA has established a Maximum Contaminant Level (MCL) of 30 micrograms per liter (µg/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 document "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 Applicable or Relevant and Appropriate Requirement (ARAR) at Superfund sites. This document is available online at: http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/9283_1_14.pdf.

Also 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. These regulations under 40 Code of Federal Regulations (CFR) Part 192.12 are often ARARs at Superfund sites. The EPA document “Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA Sites” provides guidance to EPA staff regarding when 5 pCi/g is an ARAR or otherwise recommended cleanup level for any 15 centimeters of subsurface soil contaminated by radium other than the first 15 centimeters. This document is available online at: http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/umtrcagu.pdf.

If regulations under 40 CFR Part 192.12 are an ARAR for radium in soil at a Superfund site, then Nuclear Regulatory Commission (NRC) regulations for uranium mill tailing sites under 10 CFR Part 40 Appendix A, I, Criterion 6(6), may 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 the level of radiation, called a “benchmark dose,” that an individual would receive be estimated 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 could be exposed to from all radionuclides, except radon, in both the soil and buildings at the site. The EPA document “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. This document is available online at: http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/part40.pdf.

For more information about how EPA addresses uranium at Superfund sites

Contact Stuart Walker of EPA:
(703) 603-8748 or walker.stuart@epa.gov,
or visit EPA’s Superfund Radiation Webpage:
http://www.epa.gov/superfund/resources/radiation/