US EPA Superfund Radiation Risk Assessment Update: New, Revised, and Upcoming Tools – 15350

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ABSTRACT

The U.S. EPA Superfund remedial program is finishing up a significant number of revisions to its guidance for the risk assessment process at radioactively contaminated Superfund sites. The six Preliminary Remediation Goal (PRG) and Dose Compliance Concentration (DCC) internet based calculators for risk and dose assessment at Superfund sites are being revised to reflect better science, revisions to existing exposure scenarios and new scenarios, and changes to match up more closely with the EPA chemical regional screening level calculator. A comprehensive set of revisions to the PRG calculator will be finished in November 2014. A revised version of the 1999 guidance document that provides an overview for the Superfund risk assessment process at radioactively contaminated sites, "Radiation Risk Assessment At CERCLA Sites: Q & A" [1] was issued on June 13, 2014 reflects Superfund recommended guidance and other technical documents issued over the past 15 years. Also on June 13, 2014 EPA issued a new toolkit comprised of 22 fact sheets that was developed to help the general public understand more about EPA's risk assessment process used at radioactively contaminated Superfund sites.

INTRODUCTION

The primary purpose of the introduction is to provide the information that the reader needs to understand your documented results and discussion. The level of explanation needed will depend on the level of knowledge that you assume in your audience, which will in turn depend on the complexity of your subject matter. At times the introduction serves to provide readers with the background information that underlies your efforts. Many authors prefer to keep introduction and background as separate sections.

To help meet the Superfund program's mandate to protect human health and the environment from current and potential threats posed by uncontrolled hazardous substance (both radiological and non-radiological) pollutant or contaminant) releases, the Superfund program has developed a human health evaluation process as part of its remedial response program. The process of gathering and assessing human health risk information is adapted from well-established chemical risk assessment principles and procedures. The Superfund Baseline Risk Assessment provides an estimate of the likelihood and magnitude of health problems occurring if no cleanup action is taken at a site.

Cleanup levels for radioactive contamination at CERCLA sites are generally expressed in terms of risk levels (e.g., 10^{-4}), rather than millirem or millisierverts, as a unit of measure. CERCLA guidance recommends the use of slope factors when estimating cancer risk from radioactive

contaminants, rather than converting from millirem. Current slope factors are based on risk coefficients in Federal Guidance Report 13.

The 10^{-4} to 10^{-6} cancer risk range can be interpreted to mean that a highly exposed individual may have a one in 10,000 to one in 1,000,000 increased chance of developing cancer because of exposure to a site-related carcinogen. Once a decision has been made to take an action, the Superfund remedial program prefers cleanups achieving the more protective end of the range (i.e., 10^{-6}). The Superfund remedial program uses 10-6 as a point of departure and establishes Preliminary Remediation Goals (PRGs) at 1 x 10^{-6}.

Preliminary Remediation Goals (PRGs) are used for site "screening" and as initial cleanup goals if applicable. PRGs are not de facto cleanup standards and should not be applied as such. The PRG's role in site "screening" is to help identify areas, contaminants, and conditions that do not require further federal attention at a particular site.

PRGs not based on ARARs are risk-based concentrations, derived from standardized equations combining exposure information assumptions with EPA toxicity data. PRGs based on cancer risk are established at 1 x 10^{-6}. PRGs are identified early in the CERCLA process. PRGs are modified as needed based on site-specific information.

METHODS

Superfund Risk and Dose Soil and Water Models

EPA has developed a PRG for Radionuclides electronic calculator, known as the Rad PRG calculator [2]. This electronic calculator presents risk-based standardized exposure parameters and equations that should be used for calculating radionuclide PRGs for residential, commercial/industrial, and agricultural land use exposures, tap water and fish ingestion exposures. The calculator also presents PRGs to protect groundwater which are determined by calculating the concentration of radioactively contaminated soil leaching from soil to groundwater that will meet MCLs or risk-based concentrations. The Rad PRG calculator may be found at the EPA website (http://epa-prgs.ornl.gov/radionuclides/).

To address ARARs that are expressed in terms of millirem per year, an approach similar to that taken for calculation of PRGs was also used to calculate soil “compliance concentrations” based upon various methods of dose calculation in another EPA tool, the “Dose Compliance Concentrations”, or DCC calculator [3]. The DCC calculator equations are identical to those in the PRG for Radionuclides, except that the target dose rate (ARAR based) is substituted for the target cancer risk (1 x 10-6), the period of exposure is one year to indicate year of peak dose, and a dose conversion factor (DCF) will be used in place of the slope factor. The DCC calculator may be found at the EPA website(http://epa-dccs.ornl.gov/).

Superfund Decommissioning Models

The EPA Superfund remedial program has two risk assessment tools that are particularly relevant to decommissioning activities conducted under CERCLA authority. The Preliminary Remediation Goals for Radionuclides in Buildings (BPRG) electronic calculator [4] was developed to help standardize the evaluation and cleanup of radiologically contaminated buildings at which risk is being assessed for occupancy. BPRGs are radionuclide concentrations in dust, air and building materials that correspond to a specified level of human cancer risk. The BPRG calculator may be found at the EPA website (http://epa-bprg.ornl.gov/).

The Preliminary Remediation Goals for Radionuclides in Outside Surface (SPRG) electronic calculator [5] addresses hard outside surfaces such as building slabs, outside building walls, sidewalks and roads. SPRGs are radionuclide concentrations in dust and hard outside surface materials. The BPRG and SPRG calculators include both residential and industrial/commercial exposure scenarios. The SPRG calculator may be found at the EPA website (http://epa-sprg.ornl.gov/).

To facilitate compliance with dose-based ARARs while conducting decommissioning activities under CERCLA, EPA developed two electronic calculators. These are the Radionuclide Building Dose Cleanup Concentrations (BDCC) [6] and the Radionuclide Outside Hard Surfaces Dose Cleanup Concentrations (SDCC) [7] electronic calculators. Both of these ARAR dose calculators are set up in a similar manner to the BPRG and SPRG calculators. They include the same exposure scenarios. Also, the equations in the scenarios are essentially the same except the ARAR dose calculators use: dose conversion factors instead of slope factors, and a year of peak dose instead of risk over a period of exposure such as 30 years. The BDCC calculator may be found at: http://epa-bdcc.ornl.gov/. The SDCC calculator may be found at the EPA website (http://epa-sdcc.ornl.gov/).

Superfund Ecological Risk Model

The EPA Superfund remedial program is also developing the “Radionuclide Ecological Benchmark” electronic calculator [8]. This calculator provides biota concentration guides (BCGs), also known as ecological screening benchmarks, for use in ecological risk assessments at CERCLA sites. This calculator is intended to develop ecological benchmarks as part of the Superfund remedial guidance "Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments." The calculator will develop ecological benchmarks for ionizing radiation based on cell death only.

Superfund Radiation Risk Assessment Q&A Guidance

The EPA previously issued “Radiation Risk Assessment At CERCLA Sites: Q&A” (OSWER No. 9200.4-31P, December 1999) [9]. The 1999 Risk Q&A provided an overview of the then current EPA guidance for risk assessment and related topics for radioactively contaminated CERCLA sites. This guidance provided answers to several commonly asked questions regarding risk assessments at radioactively contaminated CERCLA sites. In addition, it recommended that dose

assessments only be conducted under CERCLA where necessary to demonstrate compliance with Applicable or Relevant and Appropriate Requirements (ARARs).

Community Involvement Tools

The Superfund remedial program has developed two tools to facilitate public involvement at radioactively contaminated Superfund sites which may be found at the following webpage:

http://www.epa.gov/superfund/health/contaminants/radiation/radcomm.htm.

The first is a booklet entitled "Common Radionuclides Found at Superfund Sites" [10] The information in this booklet is intended to help the general public understand more about the various common radionuclides found at Superfund sites. The booklet contains 12 radionuclide-specific fact sheets that 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?, and What recommendations has EPA made to protect human health from the radionuclide?

The second is a video entitled "Superfund Radiation Risk Assessment and How You Can Help, an Overview" [11]. This 19 minute video describes the Superfund risk assessment process for radioactive contamination: what it is, how it works, and most importantly, how members of the public can be involved.

DISCUSSIONS

Revisions to Risk and Dose Models

All six of the PRG and DCC calculators will include a baseline risk or dose assessment feature. When developing risk based PRG or dose based DCC concentrations, the user will be able to input the existing contamination levels at the same time to get isotope specific and overall risk and dose estimates. Some of the default input parameters are being changed to reflect new information on the US population in the EPA Exposure Factors Handbook. New slope factors and dose conversion factors will be used based on information in ICRP 107.

There are a number of revisions that will apply only to the PRG and DCC calculators. A recreator scenario has been added that includes a swimmer, park user, and a game eater. In the tap water scenario, the external route of exposure from bathing and showering is added to the existing ingestion and volitization exposure routes. The farmer scenario is now broken into separate soil and water subscenarios which assume all of the contamination is solely within that media. There is a new feature for accounting for clean soil on top of contaminated soil. Also new transfer factors have been adopted from the IAEA for addressing uptake into plants and animals.

Several additional features such as accounting for gamma fields in different size construction ditches and gamma shielding factors based on different housing material are underway and will be able to be discussed in greater detail when WM 2015 occurs.

Risk Q&A Updates

In June of 2014 EPA issued a revised version of the Q&A that provides context to how these calculators and other new guidance fit within the overall Superfund risk assessment process. This revised Q&A includes a consultation process for EPA regions with EPA Headquarters (OSRTI) when considering the use of guidance documents or models not discussed in the Q&A.

The Q&A stresses that risk assessments for radiological contamination should be done consistently with those done for chemical contamination. This includes the use of the PRG calculators for risk assessment and the use of a consistent survey approach (e.g., area averaging vs. not to exceed) depending upon land use.

In addition, to demonstrate compliance with indoor UMTRCA ARAR of 0.02 Working Levels (WL), the revised Risk Q&A provides pCi/l levels that users may assume that correlates to the 0.02 WL ARAR. Because indoor radon guidelines for homes are expressed in pCi/l rather than WL, there are many more available survey methods utilizing pCi/l.

Also new guidance is provided on the protectiveness level of some dose-based ARARs, with 12 mrem/yr EDE now being the maximum level a dose-based ARAR can be and be considered protective under CERCLA.

Community Involvement Tool Updates

Below is an overview of the 22 fact sheets that make up the new Toolkit “Superfund Radiation Risk Assessment: A Community Toolkit” [12].

The first two fact sheets were developed by the EPA to help the general public understand more about the risk assessment process that may be used at Superfund sites to assess and address radioactive contamination. The “Superfund Radiation” fact sheet provides an overview of the Superfund remedial program and how and why it addresses radioactive contamination. The “Superfund Radiation Risk Assessment” fact sheet provides an overview of how EPA conducts risk assessments at radioactively contaminated Superfund sites.

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.

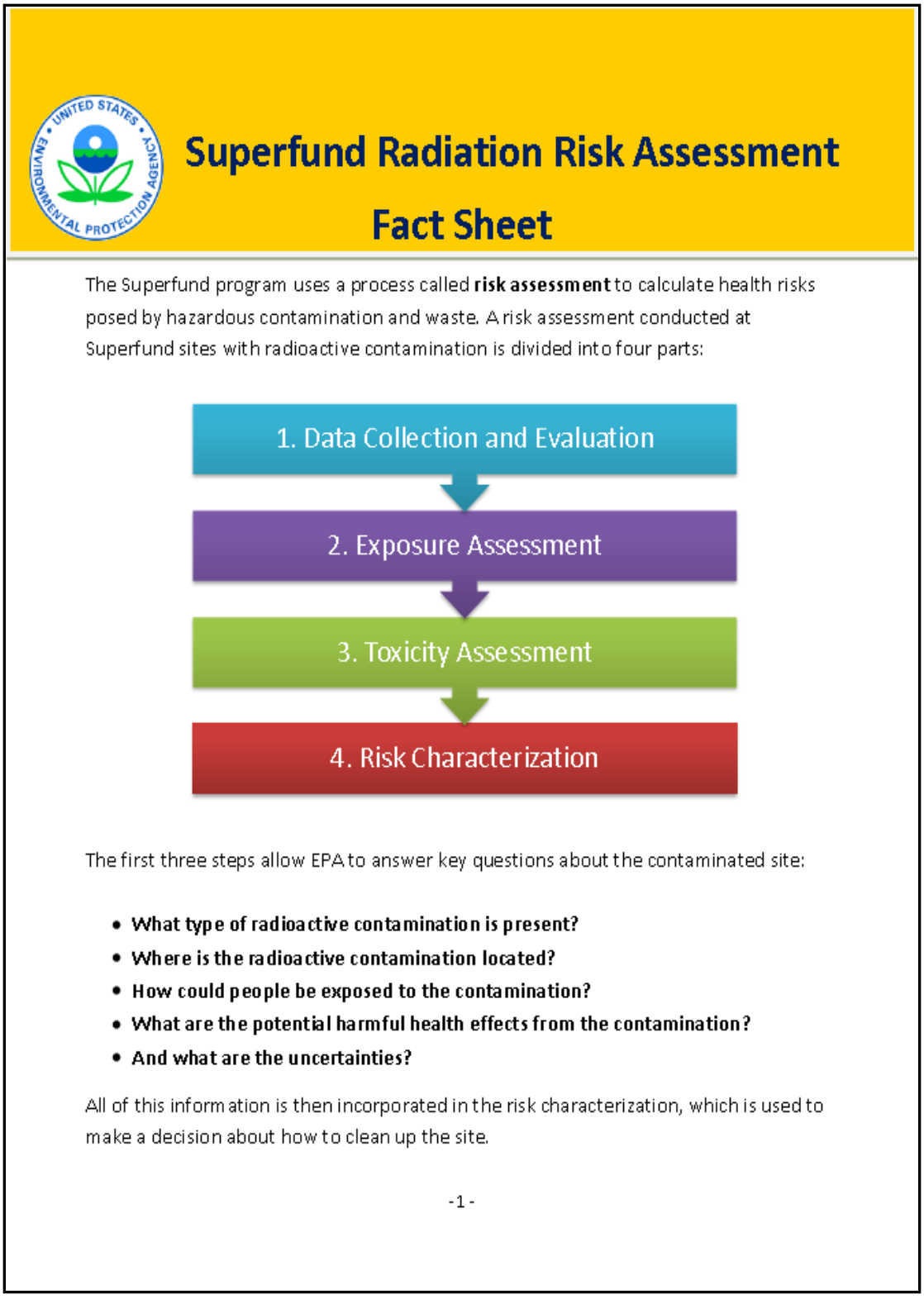
Superfund was established in 1980 by an act of Congress, giving EPA the funds and authority to clean up polluted sites

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.



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.

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Fig 1. Superfund Radiation and Risk Assessment Process Fact Sheets

Attachment A: Compendium of Information on the Preliminary Remediation Goal (PRG) and Dose Compliance Concentration (DCC) Calculators includes fact sheets for 6 calculators that were developed by EPA to assess radioactive contamination in soil, water, air, buildings, sidewalks, and streets at designated Superfund sites. The information in these fact sheets is intended to help the general public understand more about the each of these calculators that may be used at Superfund sites.

These fact sheets answer questions such as:

- What is PRG or DCC?
- How does the calculator work?, and
- What are the types of radioactive exposures does the calculator assess?

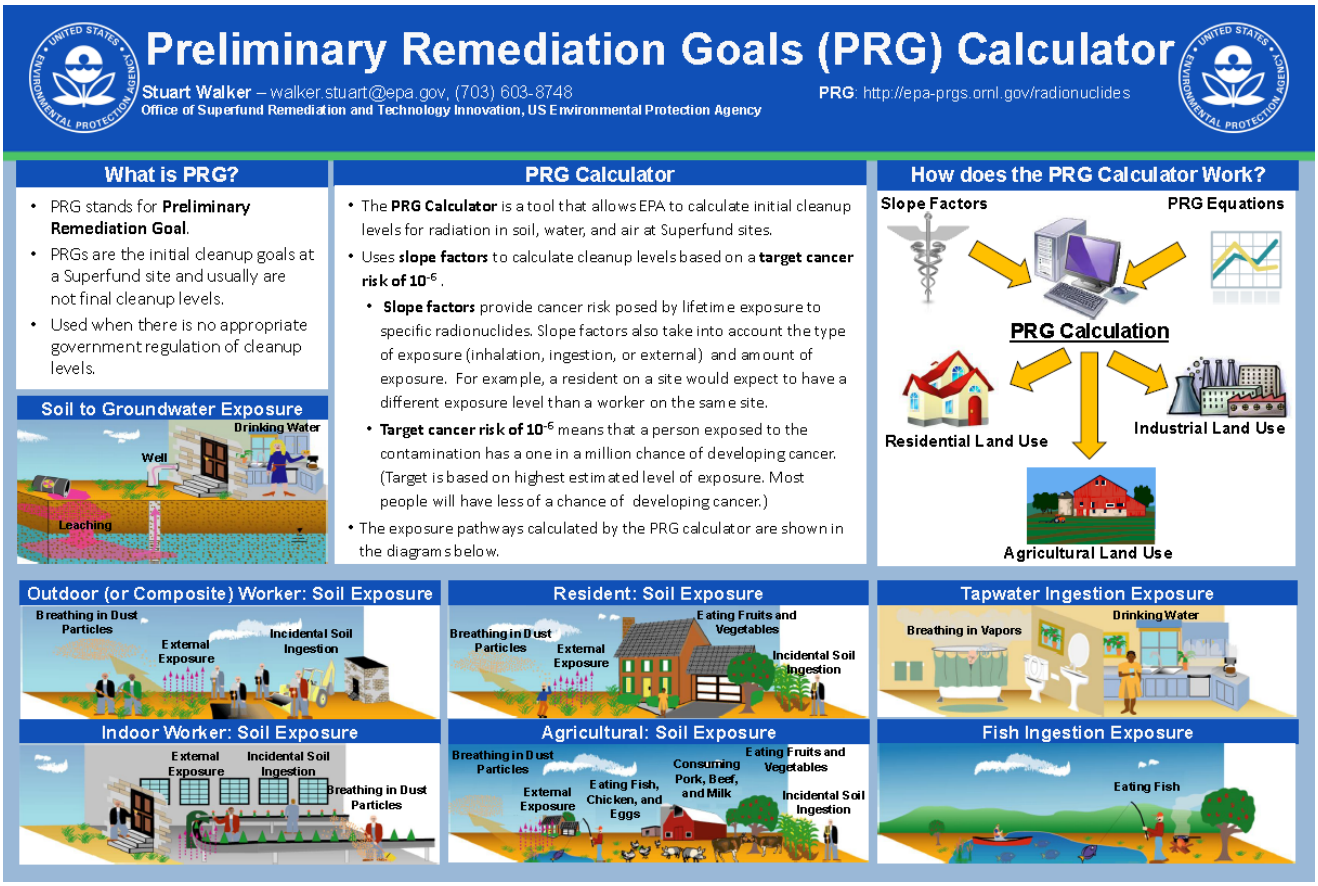

Figure 2. PRG calculator Fact Sheet

In addition to the calculator fact sheets, Attachment A includes a "Primer on PRG and DCC Calculators" fact sheet which provides general information about cleanup levels for radioactively contaminated Superfund sites, and an explanation of some of the terms that appear in each of the calculator fact sheets. Attachment B: "Compendium of Information on Radionuclides Commonly Found at Superfund Sites" includes 12 facts sheets on radionuclides are the most frequently

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

- amercium-241
- cesium-137
- cobalt-60
- iodine
- plutonium
- radium
- radon
- strontium
- technetium-99
- thorium
- tritium
- uranium

These fact sheets answer questions such as:

- How can a person be exposed to the radionuclide?
- How can it affect human health?
- How does a radionuclide enter and leave the body?
- What levels of exposure result in harmful health effects?, and
- What recommendations has EPA made to protect human health from the radionuclide?

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/

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Fig 3. Cesium Fact Sheet

In addition to the radionuclide fact sheets, the "Primer on Radionuclides Commonly Found at Superfund Sites"" fact sheet provides general information about cleanup levels for radioactively contaminated Superfund sites, and an explanation of some of the terms that appear in each of the radionuclide fact sheets.

The fact sheets in Attachment B replace the EPA previously issued booklet "Common Radionuclides Found at Superfund Sites."

CONCLUSIONS

The changes to the Superfund PRG and DCC models and the Risk Q&A guidance will facilitate the risk assessment process at radioactively contaminated Superfund sites. The revised Risk Q&A by incorporating the guidance developments that have occurred since 1999 in one location will enhance regional consistency in Superfund decision-making and stakeholder understanding of current Superfund policy. The "Superfund Radiation Risk Assessment: A Community Toolkit" should facilitate the cleanup of radioactively contaminated Superfund sites by helping to improve public confidence in the cleanup process by enhancing the involvement of the public in the cleanup process. The toolkit helps the public better understand the risk assessment process and therefore the selection of cleanup levels.

REFERENCES

1. "Radiation Risk Assessment at CERCLA Sites: Q&A". Office of Superfund Remediation and Technology Innovation. Directive 9200.4-40. EPA 540-R-012-13. June 13, 2014. http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/Rad%20Risk%20QA%20with%20transmit%20memo_June_13_2014.pdf

2. "Radionuclide Preliminary Remediation Goals (PRGs) for Superfund" electronic calculator. http://epa-prgs.ornl.gov/radionuclides/

3. "Radionuclide ARAR Dose Compliance Concentrations (DCCs) for Superfund" electronic calculator. http://epa-dccs.ornl.gov/

4. "Preliminary Remediation Goals for Radionuclides in Buildings (BPRG)" electronic calculator. http://epa-bprg.ornl.gov/

5. "Preliminary Remediation Goals for Radionuclides in Outside Surface (SPRG)" electronic calculator. http://epa-sprg.ornl.gov/

6. "Radionuclide Building Dose Cleanup Concentrations (BDCC)" electronic calculator. http://epa-bdcc.ornl.gov/

7. “Radionuclide Outside Hard Surfaces Dose Cleanup Concentrations (SDCC)” electronic calculator. http://epa-sdcc.ornl.gov/

8. “Radionuclide Ecological Benchmark” electronic calculator. Draft.

9. “Radiation Risk Assessment At CERCLA Sites: Q&A” (OSWER No. 9200.4-31P, December 1999). http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/riskqa.pdf

10. “Common Radionuclides Found at Superfund Sites” booklet. Superceded.

11. “Superfund Radiation Risk Assessment and How You Can Help, an Overview” video. http://www.epa.gov/superfund/health/contaminants/radiation/radvideo.htm

12. “Superfund Radiation Risk Assessment: A Community Toolkit.” http://www.epa.gov/superfund/health/contaminants/radiation/radtoolkit.htm