RESTORATION PRINCIPLES AND CRITERIA: SUPERFUND PROGRAM POLICY FOR CLEANUP AT RADIATION CONTAMINATED SITES

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The Environmental Protection Agency (EPA) Office of Superfund Remediation and Technology Innovation (OSRTI) is responsible for implementing the long-term (non-emergency) portion of a key U.S. law regulating cleanup: the Comprehensive Environmental Response, Compensation and Liability Act, CERCLA, nicknamed "Superfund." The purpose of the Superfund program is to protect human health and the environment over the long term from releases or potential releases of hazardous substances from abandoned or uncontrolled hazardous waste sites. The focus of this paper is on Superfund, including how radiation is addressed by the Superfund program.

This paper provides a brief overview of the approach used by EPA to conduct Superfund cleanups at contaminated sites, including those that are contaminated with radionuclides, to ensure protection of human health and the environment. The paper addresses how EPA Superfund determines if a site poses a risk to human health and the framework used to determine cleanup levels. The theme emphasized throughout the paper is that within the Superfund remediation framework, radioactive contamination is dealt with in a consistent manner as with chemical contamination, except to account for the technical differences between radionuclides and chemicals. This consistency is important since at every radioactively contaminated site being addressed under Superfund's primary program for long-term cleanup, the National Priorities List (NPL), chemical contamination is also present.

Introduction: Superfund based on Protection of Human Health

The Superfund program is dedicated to cleaning up hazardous waste sites and protecting public health and the environment. EPA has worked closely with the Agency for Toxic Substances and Disease Registry (ATSDR) in evaluating the impacts of Superfund sites on public health. Studies conducted by the ATSDR show a variety of health effects associated with some Superfund sites, including birth defects, cardiac disorders, changes in pulmonary function, impacts on the immune system, infertility, and increases in chronic lymphocytic leukemia. In addition, hundreds of drinking water wells across the country have been shut down due to contamination.

Superfund is one of the United States' most ambitious and complex environmental programs. Since it was launched, the Superfund program has maintained two bedrock principles: protection of human health and the environment is foremost, and polluters must pay for cleanup of the contamination they create.

Superfund arose out of the need to protect citizens from the dangers posed by abandoned or uncontrolled hazardous waste sites. In the wake of the discovery that a residential district had been

built atop an abandoned chemical dump at a town called "Love Canal" in New York State, the American public demanded that its government take action.

The enactment of Superfund gave the federal government broad authority to respond to hazardous substance emergencies, and to develop long-term solutions for the United States' most serious hazardous waste problems like Love Canal. It also enabled the United States Federal government to recover the costs from responsible parties, or to force them to clean up the hazardous site at their own expense.

When CERCLA or Superfund was enacted, the challenge of what was assumed to be a few hundred discrete, land-based cleanups appeared relatively straightforward. Furthermore, the Congress created a $1.6 billion Trust Fund to ensure that funding would prove no obstacle. Things have not worked out as smoothly as that, however. The problem of neglected hazardous waste sites has revealed itself to be far more complex and widespread than anyone at first realized.

While every Superfund site is unique, and thus cleanups must be tailored to the specific needs of each site, there are two requirements that must be met at every site. CERCLA requires that all remedial actions at Superfund sites must be protective of human health and the environment. Therefore, cleanup actions are developed with a strong preference for remedies that are highly reliable, provide long-term protection and provide treatment of the principle threat to permanently and significantly reduce the volume, toxicity, or mobility of the contamination. In addition, EPA believes that site cleanups should protect ground waters that are current or potential sources of drinking water to drinking water standards whenever practicable. In addition, CERCLA specifically requires Superfund actions to attain or waive the standards and requirements found in other State and Federal environmental laws and regulations. This mandate is known as compliance with "applicable or relevant and appropriate requirements" or ARARs.

Remedy Selection

A comprehensive regulation known as the National Oil and Hazardous Substances Pollution Contingency Plan or NCP contains the guidelines and procedures for implementing the Superfund program. The NCP reiterates CERCLA's goal of selecting remedies that protect human health and the environment, that maintain protection over time, and that minimize untreated waste. The NCP sets forth nine criteria for selecting Superfund remedial actions. These evaluation criteria are the standards by which all remedial alternatives are assessed and are the basis of the remedy selection process. The criteria can be separated into three levels: threshold, balancing, and modifying. The first two criteria are known as "threshold" criteria. They are a reiteration of the CERCLA mandate that remedies must (1) at a minimum assure protection of human health and the environment and (2) comply with (or waive) requirements of other Federal environmental laws, more stringent State environmental laws and State facility-siting laws. They are the minimum requirements that each alternative must meet in order to be eligible for selection as a remedy.

After the threshold criteria are applied, EPA considers a number of other evaluation criteria. Five of the criteria are known as the "balancing" criteria. These criteria are factors with which tradeoffs between alternatives are assessed so that the best option will be chosen, given site-specific data and conditions. The criteria balance long-term effectiveness and permanence; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; and cost. The final two criteria are called "modifying" criteria: new information or comments from the State or the community may modify the preferred remedial action alternative or cause another alternative to be considered.

EPA believes the "modifying" criteria concerning new information or comments from the community is important. In many instances, communities are able to provide valuable information on local history, citizen involvement, and site conditions. To ensure community participation, EPA specifically requires the party conducting the cleanup to conduct a number of activities. For example, EPA conducts community interviews and develops a community relations plan to help EPA determine the community's level of interest in the site, major concerns and issues. EPA creates an information repository and administrative record for every site and makes it available to community members. EPA also develops a document specifically for the community which explains the various clean up options being considered, holds at least one meeting to explain the options and invites the community to submit comments on them. EPA also make funding available to eligible community members so they may obtain technical assistance to better understand the often complex issues associated with cleaning up a Superfund site. By identifying the public's concerns, EPA is able to fashion a response that more effectively addresses the community's need.

Risk Assement

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 releases (both radiological and nonradiological), EPA 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 the EPA's estimate of the likelihood and magnitude of health problems occurring if no cleanup action is taken at a site. Specifically, the risk assessment provides:

- an analysis of baseline risks to help determine the need for action at sites;
- a basis for determining levels of hazardous substances that can remain onsite and still be adequately protective of public health;
- a basis for comparing potential health impacts of various remedial alternatives; and
- a consistent process for evaluating and documenting public health threats at sites nationwide.

The results of a risk assessment are critical in determining whether responses to protect human health and the environment are justified, and in establishing an appropriate cleanup level. The risk assessment also helps EPA identify potential risks associated with a particular remedy and evaluate risks remaining at a site after cleanup is completed.

Cleanup levels for radioactive contamination at CERCLA sites are generally expressed in terms of risk levels, rather than millirem or millisierverts, as a unit of measure. CERCLA guidance recommends the use of slope factors in the EPA Health Effects Assessment Summary tables when estimating cancer risk from radioactive contaminants. Many of you are probably more familiar with estimating millirem or millisieverts using dose conversion factors, rather than basing cleanup on site-specific risk assessment.

Risk-based Cleanup Levels

Compliance with the requirements of other laws, ARARs, is often the determining factor in establishing cleanup levels at CERCLA sites. However, where ARARs are not available or are not sufficiently protective, EPA generally sets site-specific remediation levels for: 1) carcinogens at a level that represents an upper-bound lifetime cancer risk to an individual of between 10^{-4} to 10^{-6}; and for 2) non-carcinogens such that the cumulative risks from exposure will not result in adverse effects to human populations (including sensitive sub-populations) that may be exposed during a lifetime or

part of a lifetime, incorporating an adequate margin of safety. Such is the case for the non-carcinogenic risks of uranium. The specified cleanup levels account for exposures from all potential pathways, and through all media (e.g. soil, ground water, surface water, sediment, air, structures, biota).

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, EPA prefers cleanups achieving the more protective end of the range (i.e. 10^{-6}). EPA uses 10^{-6} as a point of departure and establishes Preliminary Remediation Goals (PRGs) at 1 x 10^{-6}. EPA has developed a Preliminary Remediation Goals (PRGs) for Radionuclides electronic calculator which may be found at: http://epa-prgs.ornl.gov/radionuclides/.

To assess the potential for cumulative noncarcinogenic effects posed by multiple contaminants, EPA has developed a hazard index (HI). The HI is derived by adding the noncancer risks for site contaminants with the same target organ or mechanism of toxicity. When the HI exceeds 1.0, there may be concern for adverse health effects due to exposure to multiple contaminants. Radioisotopes of uranium are generally the only radionuclides for which EPA will evaluate the HI for at a CERCLA site.

While cleanups will generally achieve a risk level within 10^{-4} to 10^{-6} for carcinogenic risk, risks of greater than 1 x 10^{-4} may be acceptable under appropriate circumstances. CERCLA guidance states that "the upper boundary of the risk range is not a discrete line at 1 x 10^{-4}, although EPA generally uses 1 x 10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions." Other EPA regulatory programs have developed a similar approach to determining acceptable levels of cancer risk.

EPA's risk range of 10^{-4} to 10^{-6} represents EPA's opinion on what are generally acceptable levels. This has been a consistent EPA position under CERCLA and other programs for many years. Congress did not define protectiveness in CERCLA and also did not change EPA's risk management approach during its very thorough consideration of the Superfund program prior to amending the CERCLA law in 1986.

Radiological Contamination included in Risk-based Cleanup Levels

CERCLA defines radiation as a hazardous substance subject to actions conducted under CERCLA. In particular, radionuclides are designated generically as hazardous air pollutants by Clean Air Act section 112, and CERCLA section 101(14)(E) defines the term "hazardous substance" to include Clean Air Act hazardous air pollutants.

EPA policy requires that cleanup of radionuclides are governed by the risk range for all carcinogens established in the NCP when ARARs are not available or are not sufficiently protective. Remedial actions under CERCLA must be protective, i.e. generally within the cancer risk range of 10^{-4} to 10^{-6} for all exposure pathways in all contaminated media.

Compliance with Environmental Laws

Compliance with (or waiver of) requirements of other Federal environmental laws, more stringent State environmental laws and State facility-siting laws is a cornerstone of CERCLA. Cleanups conducted under the Superfund program must comply with these laws unless a waiver is justified. These laws, as well as ARARs, assist EPA in identifying preliminary remediation goals and

alternatives. Complying with ARARs both during the implementation and upon completion of an action helps the lead agency define the ways in which the activity can be carried out in a manner that is protective of human health and the environment.

Because the diverse characteristics of Superfund sites preclude the development of prescribed ARARs, it is necessary to identify ARARs on a site-by-site basis. There are many radiation standards that are likely to be used as ARARs to establish cleanup levels or to conduct remedial actions. Some of the radiation standards most frequently used as ARARs at Superfund sites are the soil cleanup and indoor radon standards developed to address contamination at sites that are subject to the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). When used as an ARAR at Superfund sites, the soil cleanup level for radium 226 and radium 228 combined, or thorium 230 and thorium 232 combined, is 5 picoCuries per gram (pCi/g) *[0.2 becquerals per gram (Bq/g)]* above background, while the indoor radon level is 0.02 working levels inclusive of background.

For a list of "Likely Federal Radiation Applicable or Relevant and Appropriate (ARARs)", see Attachment A of EPA's guidance "Establishment of Cleanup Levels for CERCLA sites with Radioactive Contamination." This document and others providing additional guidance on compliance with ARARs at radioactively contaminated CERCLA sites, go to the following webpage: http://www.epa.gov/superfund/resources/radiation/radarars.htm.

Groundwater

One extremely important ARAR that should be noted are Maximum Contaminant Levels (MCLs) that are established under the United States law for drinking water standards, called the Safe Drinking Water Act. Over 85% of the sites designated for long-term cleanup by the Superfund program have some groundwater contamination. Ground water contamination is generally more difficult to detect and clean up than contamination in other environmental media. Ground water generally moves slowly; velocities are usually in the range of 5 to 50 feet per year. Large quantities of a particular contaminant can enter an aquifer and remain undetected until reaching a point of use, such as a water well or surface water body. Moreover, contaminants in ground water, unlike those in other environmental media such as air or surface water, generally move with relatively little mixing or dispersion, so concentrations can remain relatively high. These plumes of concentrated contaminants move slowly through aquifers and may be present for many years, sometimes for decades or longer, making the resource potentially unusable for extended periods of time. Slow migration over an extended period can cause a large area to become contaminated, and will increase the potential for exposure to those contaminants. All of these factors favor prevention of contaminated ground water where possible, and remediation of chemical and radioactive materials in other media (e.g. soil) to prevent future contamination of ground water.

EPA believes contaminated ground water should be restored to beneficial use, whenever practicable. This means that sites where the contaminated ground water is a potential or current source of drinking water should be remediated to concentrations corresponding to drinking water standards (e.g. concentrations corresponding to MCLs or more stringent State drinking water standards). The Superfund program requires MCLs be met within the aquifer, not at the tap. EPA's phased approach to addressing contaminated groundwater at CERCLA sites is discussed in "Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance, which may be found at: http://www.epa.gov/superfund/resources/gwguide/index.htm.

EPA's policy is to defer to State determinations of ground-water use when such determinations are based on a Comprehensive State Ground Water Protection Program (CSGWPP) that has 1) been endorsed by EPA and 2) allows such determinations to be made at specific sites. In the absence of a

CSGWPP, EPA considers other state classification schemes and EPA's classification guidelines which uses criteria defining ground waters of sufficient quantity and quality to supply the needs of a single family household. EPA's us of CSGWPP's at CERCLA sites is discussed in "The Role of CSGWPPs in EPA Remediation Programs" which may be found at:
http://www.epa.gov/superfund/resources/csgwpp/role.pdf.

The current MCLs for radionuclides are set at 4 mrem/yr to the whole body or an organ for the sum of the doses from beta particles and photon emitters, 15 picoCuries per liter (pCi/l) *[0.6 becquerals per liter (Bq/l)]* for gross alpha, and 5 pCi/l *[0.2 Bq/l]* combined for radium-228 and radium-226, and 30 micrograms per liter of uranium. EPA has published concentration tables for each radionuclide that correspond to the 4 mrem/yr MCL in "The Final Implementation Guidance for Radionuclides and Appendices" (see page I-3) which may be found at:
http://www.epa.gov/safewater/rads/implement.html.

MCLs are developed using health, technological, and cost information. EPA establishes Maximum Contaminant Level Goals (MCLGs) at a level of a contaminant in drinking water at which there is no known or anticipated health threat from that contaminant to a person who consumes the water. EPA has established MCLGs for carcinogens, including radionuclides, at zero since scientists do not know if any level of exposure, no matter how small, might cause cancer. MCLs are established as close as possible to the MCLG, taking into account the technological and cost considerations for public water systems in achieving various concentration levels. EPA does use a target risk range of 10^{-4} to 10^{-6} when establishing MCLs for carcinogens. An MCL can be set outside the range if it is not feasible to achieve a specific level.

Other Criteria, Advisories and Guidance

Many Federal and State environmental and public health agencies develop criteria, advisories, guidance, and proposed standards that are not legally enforceable but contain information that would be helpful in carrying out selected remedies, or in determining their protectiveness. These materials are meant to complement the use of ARARs, not to compete with or replace them. Because they are not ARARs, their identification and use are not mandatory. These are known as to-be-considered (TBC) material. However, it is EPA's policy that dose-based (millirem) recommendations should generally not be used as TBCs.

In conjunction with the completion of the baseline risk assessment, where no ARARs address a particular situation, or the existing ARARs do not ensure sufficient protectiveness, these advisories, criteria or guidelines are used to set cleanup targets. This information may be invaluable in deciding how to carry out a particular remedy. Many ARARs have broad performance criteria but do not provide specific instructions for implementation. Often those instructions are contained in supplemental program guidance. Sometimes the Superfund program develops guidance on interpreting a particular ARAR to assist site decision makers. For example, at UMTRCA sites the standard for subsurface soil is 15 pCi/g *[0.6 Bq/g]*, averaged over a 15 cm thick layer of soil more than 15 cm below the surface. This standard for subsurface soil was derived as a tool for use in locating and remediating discrete deposits of high activity tailings found in subsurface locations at UMTRCA sites (typically 300-1,000 pCi/g). Since this range of radioactive contamination differs from that typically found at Superfund sites which contain the full range of radioactive contamination including lower levels, 15 pCi/g *[0.6 Bq/g]* wouldn't necessarily be an ARAR. However, since the subsurface soil standard was used as a finding tool for any contamination above 5 pCi/g *[0.2 Bq/g]*, EPA has interpreted the cleanup level as 5 pCi/g *[0.2 Bq/g]* (combined for radium-226 and radium-228 or thorium-230 and thorium-232) for purposes of ARAR compliance. This information is found in the

Superfund guidance document entitled "Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA sites."

Land Use/Institutional Controls

The concentration levels for various media that correspond to the acceptable risk level established for cleanup will depend in part on land use at the site. Land uses that will be available following completion of a response action are determined as part of the remedy selection process considering the reasonably anticipated land use or uses along with other remedy selection factors. EPA's policies for how to determine a sites reasonably anticipated land use is discussed in "Land Use in the CERCLA Remedy Selection Process", which may be found at:
http://www.epa.gov/superfund/resources/landuse.pdf.

Institutional controls are generally included as a supplemental component to cleanup alternatives, not as a substitute for treatment or containment. Institutional controls are non-engineering measures – usually, but not always legal controls – intended to affect human activities in a way that prevents or reduces exposure to hazardous substances. Institutional controls usually restrict land use to prevent unanticipated changes in use that could result in unacceptable exposures to residual contamination. At a minimum, institutional controls are intended to alert future users to the residual risks and the need to monitor for any changes in use.

EPA's CERCLA policy states that if a site cannot be cleaned up to a protective level (i.e. generally within the 10^{-4} to 10^{-6} risk range) for the "reasonably anticipated future land use" because it is not cost-effective or practicable, then a more restricted land use should be chosen that will meet a protective level.

Where waste is left on-site at levels that would require limited use and restricted exposure to ensure protectiveness, EPA will conduct reviews at least once every five years to monitor the site for any changes including changes in land use. Such reviews need to analyze the implementation and effectiveness of any institutional controls with the same degree of care as other parts of the remedy. Should land use change in spite of land use restrictions, it will be necessary to evaluate the implications of that change for the selected remedy, and whether the remedy remains protective.

Site Examples

Two examples of radioactively contaminated Superfund sites that have been addressed are the Glen Ridge and Montclair/West Orange sites in New Jersey. These two nearby sites were similar enough that they were addressed jointly. Over 700 properties were contaminated with radioactive waste materials suspected to have originated from radium-processing facilities located nearby during the early 1900's. Some of the radium contaminated soil was used as fill in low lying areas or was mixed with cement for sidewalks and foundations. Carcinogenic risks to residents posed by site-related indoor radon were estimated to range as high as 4×10^{-1}, while the maximum carcinogenic risks from radium contaminated soil were estimated at 1×10^{-2}. The remedy for these two sites included the excavation of highly contaminated soil and debris material for offsite disposal. The primary contaminant of concern in soil was Radium 226 with decays to radon gas. The ARAR used for radium was soil cleanup standards for uranium millings under 40 CFR 192 (5 pCi/g *[0.2 Bq/g]* over background). For radon, the ARAR used was indoor radon standards under 40 CFR 192 (0.02 working levels, inclusive of background).

Closing

Actions under Superfund must result in the protective cleanup of sites. The CERCLA framework for addressing hazardous sites ensures that risks from radiological contamination will be addressed in a manner consistent with risks from non-radiological contamination, except to account for technical differences posed by radionuclides, and that cleanups for all contaminants will achieve protection of human health and the environment. The same set of principles and decision making criteria apply equally to both chemical and radioactive hazards. The goal is to provide lasting, protective site restoration while taking into account the cost and achievability of different approaches to attaining these protective goals.

For more information and copies of EPA guidance documents for addressing radioactively contaminated CERCLA sites, see the EPA's Superfund Radiation webpage at:
http://www.epa.gov/superfund/resources/radiation/index.htm.

For more information and copies of EPA guidance documents for developing cleanup levels for long-term CERCLA sites, see EPA's Remedy Decisions webpage at:
http://www.epa.gov/superfund/action/guidance/remedy/index.htm.

Both of these webpages contain numerous OSWER Directives, which are EPA's official guidance for the Superfund program, and other material that is useful for cleaning up CERCLA sites.