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Nuclear Cleanup: The Standards Conflict

Committee to Bridge the Gap

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NUCLEAR CLEANUP

THE STANDARDS CONFLICT

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ABSTRACT

The U.S. Department of Energy has recently violated a longstanding Joint DOE-EPA Policy which commits DOE to clean up all its nuclear facilities nationwide to the Environmental Protection Agency (EPA) Superfund (CERCLA) standards. The focal point of this conflict between DOE and EPA cleanup standards is the Santa Susana Field Laboratory (SSFL), a 2800-acre facility on the Los Angeles-Ventura County line in Southern California. Ten reactors, a plutonium fuel facility, and a "hot laboratory" for cutting up irradiated nuclear fuel were operated at the facility, which opened in the 1940s when it was remote from populated areas. Now large numbers of people live nearby.

One of the reactors suffered a partial meltdown in 1959; two others experienced damage in 1964 and 1969 to 80% and 35% of their fuel, respectively. In 1989, DOE found widespread chemical and radioactive contamination at the site, and a cleanup program commenced. In 1995, DOE and EPA entered into a Joint Policy to assure that all DOE sites, whether or not they were on the National Priority List (Superfund), would be cleaned up consistent with EPA's CERCLA standards.

In March of 2003, DOE reversed course and, while claiming to still follow the 1995 Policy, announced it would not clean the site up to the EPA standards. It would remove only 1% of the contaminated soil and then release the site for unrestricted residential use. In December 2003, EPA issued findings that the site was not being cleaned up consistent with the 1995 Joint Policy and that under the circumstances, so much radioactivity could be left in place that residential use would be unsafe and the only safe use would be restricted dayhikes with limitations on picnicking.

To date no detailed study has been done comparing the DOE and EPA cleanup standards. This report, supported by a grant from the Citizens' Monitoring and Technical Assistance Fund, performs that analysis.

The evaluation demonstrates that DOE's decision not to comply with EPA's cleanup standards will result in radionuclide concentrations being permitted that are hundreds, thousands, tens of thousands, and in some cases, hundreds of thousands of times higher than EPA's primary cleanup goals. For most radionuclides, the associated risk exceeds even the uppermost permissible risk level of EPA under CERCLA. In some cases, those cancer risks rise to levels on the order of one cancer per ten people exposed, using the federal government's official radiation risk figures.

Should DOE proceed with acting in contravention of the 1995 DOE-EPA Joint Policy on cleaning up DOE sites consistent with CERCLA at SSFL, there would be significant ramifications for the DOE nuclear complex nationwide, and for public health.

NUCLEAR CLEANUP:

THE STANDARDS CONFLICT

Introduction

The Department of Energy (DOE) nuclear complex consists of approximately one hundred sites across the country, many of which face daunting cleanup challenges because of extensive radioactive and chemical contamination of soil, surface water and groundwater. Decades of accidents, spills, and other releases have left behind a legacy of pollution which poses significant risks if not adequately remediated.

All DOE nuclear sites are supposed to be cleaned up in accordance with the standards and procedures of the Environmental Protection Agency (EPA) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund. DOE facilities are brought under CERCLA in two primary ways. Some DOE sites are on the National Priority List (NPL), i.e., they are Superfund sites, and automatically must comply with CERCLA requirements. All other DOE sites must also be cleaned up consistent with EPA's CERCLA guidance, as a result of a 1995 Joint DOE-EPA "Policy on Decommissioning Department of Energy Facilities Under CERCLA."[1]

[1] The Joint Policy is included herein as an attachment.

That Joint Policy requires that all DOE sites, irrespective of whether they are on the NPL, shall be cleaned up consistent with EPA's CERCLA standards, guidance, procedures, and methods. This includes the use of EPA's Preliminary Remediation Goals (PRGs) as the starting point for determining acceptable levels of contaminants that can remain after decommissioning the facilities, methods of calculating acceptable contaminant levels in a site-specific way in terms of appropriate inputs to models, and public participation procedures.

Recently, DOE, while still claiming to follow the 1995 Policy, has begun to resist complying with its requirement to be consistent with EPA's CERCLA standards. The facility where this conflict between DOE and EPA standards is being fought out most clearly is the Santa Susana Field Laboratory (SSFL), located on the boundary between Los Angeles and Ventura Counties in Southern California.

This report examines the conflict between the DOE and EPA cleanup standards, focusing on SSFL as a case study, with significant implications for the DOE nuclear complex nationwide.

SSFL

Founded in the 1940s as a government facility for development and testing of nuclear reactors, in addition to testing rockets, SSFL was designed as a remote field laboratory to conduct work too dangerous to be performed in more populated areas. However, in the more than half a century since it was founded, Southern California's population has mushroomed, and large numbers of people now live within a few miles of the site. 2800 acres, SSFL is situated on top of the Simi hills, overlooking Simi Valley to the north, Chatsworth, Canoga Park, and West

Hills to the east, Agoura, Calabasas and Woodland Hills to the south, and Thousand Oaks to the west.

Over the years, approximately ten nuclear reactors operated at SSFL, in addition to several "critical facilities," a plutonium fuel fabrication facility, a uranium carbide fuel fabrication facility, and a "hot lab" in which irradiated fuel shipped in from around the country was decladded and examined. The reactors had no containment structures, i.e., were built without the large concrete domes surrounding modern power reactors.

Numerous accidents occurred at the site. In July 1959, the Sodium Reactor Experiment (SRE) suffered a power excursion, in which power rose out of control. With significant effort, the reactor was shut down; but, inexplicably, a few hours later it was started up again, without having been able to determine the cause of the incident. The reactor continued to operate for several more weeks, with high radiation readings and other signs of problems, until it was shut down at the end of the month.

At that point, the reactor operators discovered that a significant fraction of the fuel had suffered melting. Tetralin, a coolant used for the pump seals, had leaked into the sodium coolant of the reactor; carbonaceous material formed, blocking the coolant channels, causing the fuel to overheat and melt. Approximately one-third of the fuel experienced melting. A photograph of some of the melted fuel is found on the next page.

Radioactive gases were released from the reactor into holding tanks and then bled into the atmosphere over a period of weeks. The extent of the radioactive releases remains uncertain to this date. Some monitors went off scale; few measurements of the sodium coolant were taken, and these were contradictory; and the ratios of volatile radionuclides found in the coolant suggest significant releases from the coolant to the environment may have occurred.

In 1964 and again in 1969, two other reactors suffered significant core damage. The System for Nuclear Auxiliary Power (SNAP) 8ER reactor operated for a year without its operators realizing the fuel was cracking. After shutdown, it was determined that 80% of the fuel had cracked. A few years later, the same type of accident occurred with the SNAP 8DR, with about a third of its fuel suffering damage.

The hot lab suffered fires resulting in spread of contamination. The sodium burn pit, an open-air pit for cleaning sodium-contaminated components, got contaminated when radioactively- and chemically-contaminated items were burned there, in contravention of safety requirements. Other spills and releases occurred as well over the decades of operations.

In 1989, a DOE investigation found widespread chemical and radioactive contamination on the property. Widely publicized in the local press, the revelations led to substantial concern among community members and elected officials, resulting in a challenge to and subsequent shutdown of continued nuclear activity at the site. Cleanup commenced, and EPA was brought in at the request of local legislators to provide oversight.

In 1995, DOE and EPA entered into the Joint Policy referenced above, committing that SSFL, and all other DOE sites, would be cleaned up consistent with EPA's CERCLA standards. In March 2003, however, DOE issued a final Environmental Assessment (EA) and Finding of No Significant Impact (FONSI), which set cleanup standards for SSFL that are at great variance from EPA's cleanup requirements. The EA conceded that there are approximately 405,000 cubic meters of soil contaminated above EPA's primary cleanup standard, but then chose as its preferred alternative to clean up only approximately 5000 cubic meters, intending to leave behind 99% of the soil it concedes is contaminated, and then release the land for unrestricted residential use.

In August 2003, the Senate Appropriations Committee issued a report on the Energy and Water Appropriations, urging DOE to live up to its commitments in the 1995 Joint Policy and clean up SSFL to EPA's CERCLA standards. Shortly thereafter, DOE responded to the Senate, claiming it was in fact consistent with both the Joint Policy and EPA's CERCLA standards. In December 2003, however, EPA issued formal findings that the cleanup was not consistent with CERCLA, that sufficient contamination would remain such that unrestricted residential use would not be appropriate, and that the only safe use under the circumstances would be restricted day hikes with limitations on picnicking.

A significant conflict thus exists between DOE and EPA standards for cleaning up DOE sites such as SSFL. We will now examine the differences.

The EPA CERCLA Standards

EPA cleanups are based on risk, not dose. EPA's primary remediation goals are set so as to not leave behind residual contamination sufficient to cause a more than one-in-a-million (10^{-6}) risk to an individual. If there are acceptable reasons why one cannot meet the 10^{-6} goal, one can request to be able to fall back from that cleanup goal somewhat, if one can show one meets the nine balancing criteria in CERCLA. One is then only permitted to increase the risk level the minimum amount necessary, and in no case to a risk in excess of approximately one in ten-thousand (10^{-4}).

The amount of a contaminant that will produce a certain risk is determined by use of various EPA models and input assumptions about exposure scenarios. For example, EPA sets acceptable inputs for such things as breathing rates, soil resuspension, backyard garden vegetable usage, and so on, which can then be adjusted for site-specific factors.

EPA bases these calculations on the exposure scenario that would produce the highest risk and which is reasonably foreseeable. For example, if a site is zoned rural residential, then the rural residential pathway is employed if it produces the highest risk for the same amount of contaminant in soil.

All contaminants – chemical and radioactive – must be summed and the collective risk must meet the overall risk goal. For example, if a site has both chemical and radioactive

contamination, it would be impermissible under EPA guidance to ignore the chemical contamination and set radioactive cleanup goals at the upper limit of the risk range.

EPA has published Preliminary Remediation Goals (PRGs) which set default concentrations of scores of radionuclides in environmental media such as soil for various exposure scenarios.[2] If there are strong site-specific reasons, one can alter the inputs into the model with the use of EPA's PRG calculator.

The DOE SSFL Cleanup Standards

DOE, despite its commitment in the 1995 Joint Policy to follow EPA's CERCLA guidance, has instead adopted cleanup standards that are in general orders of magnitude more lax than EPA's PRGs.

DOE has set cleanup standards for approximately twenty-five radionuclides.[3] It has done so based on its model, RESRAD, and its inputs thereto, rather than EPA's PRGs and PRG calculator. Furthermore, DOE has restricted its model to the suburban residential exposure pathway, rather than the rural residential pathway for which the site is currently zoned and which produces higher doses for the same concentration of radioactivity. EPA's CERCLA guidance

[2] The most recent EPA PRGs for radionuclides, dated August 2004, are included here as an attachment. The concentrations are in pico-curies of radioactivity per gram of soil (pCi/g). The column marked "Residential Soil" is for the suburban residential scenario; "Agricultural Soil" is for the rural residential scenario.

[3] See attached table, identifying the radionuclides, their symbols, and half-lives.

requires the use of the exposure scenario that produces the highest risk, if that end-land-use is contemplated by current zoning.

DOE sets its SSFL criteria based on the concentration that its model indicates would produce a 15 millirem/year dose to a member of the public. EPA bars the use of dose in cleanup standards for CERCLA. 15 millirem per year is the equivalent of getting an unnecessary chest X-ray every 5 months you are exposed; over a lifetime it is approximately equivalent to 175 additional chest X-rays. Over a lifetime, exposure at the DOE standard is estimated – by DOE and all other federal agencies – as producing a cancer in about one in every thousand people exposed.[4] Even if one assumes only a 30-year exposure period, this is four to four hundred times higher than the EPA standard (10^{-6} cleanup goal, with a risk range permitted to go up to no higher than 10^{-4}).

However, EPA guidance does not use dose, but rather risk, in making cleanup decisions. That is because, radionuclide by radionuclide, there are substantial differences. As will be seen below, DOE's cleanup standards for SSFL result for some radionuclides in risks as high as eight

[4] Federal Guidance Report 13 sets cancer risk from radiation at 8.46×10^{-4} cancers per rem of radiation received. In rough terms, there will be one cancer per thousand person-rems received. In other words, if 1000 people each get one rem, on average one of those people will get a cancer. 15 millirem per year over 70 years is a bit more than a rem.

EPA assumes only a 30 year exposure period rather than lifetime. Based on that shorter period, DOE's 15 millirem per year would produce a cancer risk of approximately 4×10^{-4}, still outside the upper end of EPA's risk range. (It probably isn't appropriate to use 30 years as the exposure period, as when one person moves out, another moves in, and the cancers keep getting generated. However, for the purposes of this study, we have used the less conservative EPA 30 year exposure period.)

cancers per ten people exposed (7.66×10^{-1}), using EPA's guidance. These risk levels are extraordinary and far outside of any acceptable risk range.

Comparison of DOE SSFL Cleanup Criteria with EPA's CERCLA Standards

The core of this study has been to compare, radionuclide by radionuclide, the cleanup criteria now adopted by DOE against the EPA PRGs; to estimate associated risk with the DOE cleanup standards for each radionuclide; and to provide an idea of the numbers of cancers those DOE standards would be expected to produce were SSFL permitted to have radioactive contamination remaining over the site at those levels.

A couple of provisos are in order. First, we have used the EPA PRGs as the point of comparison. The PRGs represent the Preliminary Remediation Goals, the default cleanup levels, as it were. As indicated above, if there are special circumstances, and one can meet the nine balancing criteria in CERCLA, one may fall back somewhat from the PRG, but in no case exceed it by more than approximately a factor of one hundred. DOE has made no argument that there are special circumstances at SSFL, nor has it attempted to show compliance with the nine balancing criteria. But even were it to do so, it would then fall back perhaps a factor of five for some radionuclides, ten for others, but in no case more than one hundred. All but three of the radionuclides of concern have DOE cleanup standards that are far more than one hundred times EPA's PRGs.

Secondly, the risk figures we have used are the official U.S. government figures for estimating cancer risk from radiation exposure. There is substantial evidence that those figures – derived largely from A-bomb survivor studies – may underestimate true risks, by an order of magnitude or more. A number of occupational epidemiological studies have found cancers in exposed populations being induced at roughly an order of magnitude higher level than the official government estimates would suggest. These studies include those by Wing *et al*. of Oak Ridge workers, Stewart *et al.* of Hanford workers, and Ritz and Morgenstern of the Santa Susana workers themselves. An explanation for the difference that was put forward by the late Dr. Alice Stewart is the "healthy survivor" effect – that the A-bomb survivors are an unrepresentative population in that they survived nuclear explosions. People with weaker immune systems died from the blast and other initial effects of the explosion, so the survivors do not necessarily represent a typical population. In addition, the same studies cited above found increased risks of radiation exposures for older adults than younger ones, an age effect not considered in government risk estimates.

However, for the purposes of this study we have used EPA's PRGs and the federal government's official guidance for estimating cancer risk from radiation exposure.

Results

The results are detailed in the attached tables and figures, and summarized in the summary graphs that immediately follow page 12. DOE's cleanup standards for SSFL exceed EPA's PRGs for the current zoning exposure scenario, in some cases by more than a hundred

thousand-fold. For several radionuclides, risks are in the range of several cancers per hundred people exposed to several per ten people exposed, extraordinary levels. For most radionuclides, DOE's cleanup standards not only exceed EPA's PRGs, they far exceed the upper end of EPA's acceptable risk range (10^{-4}, 1 in 10,000). Cancers per generation range up to hundreds, and in one case thousands, per generation, were SSFL to have contamination at those levels over the site.

For the suburban residential scenario, DOE's cleanup levels exceed EPA's PRGs by factors of up to a couple of thousand. Although the individual risks are somewhat lower than for the rural residential scenario, the total numbers of cancers per generation produced are comparable, because the population density is higher.[5]

The findings are summarized in the graphs that follow. The first set shows the cancer risk levels for DOE cleanup standards versus EPA's PRGs, radionuclide by radionuclide, summarized in a single graph for each exposure scenario (note that the summary graphs, which include all radionuclides on a single page, have a logarithmic scale). The differences between the standards are striking.

[5] It should be noted, as indicated above, that EPA CERCLA guidance requires that the cleanup goals for the exposure scenario that would produce the highest risk must be employed, if that end land-use is permitted, e.g., authorized under current zoning. In the SSFL case, the zoning is RA-5, rural residential, therefore it is those cleanup criteria which are to be met. We have here nonetheless calculated the differences between DOE and EPA standards also for a suburban residential scenario.

The second set of summary graphs shows the factor by which DOE's cleanup standards exceed EPA's PRG for each radionuclide. The third set of summary graphs shows the cancers per generation by radionuclide for the DOE standards.[6]

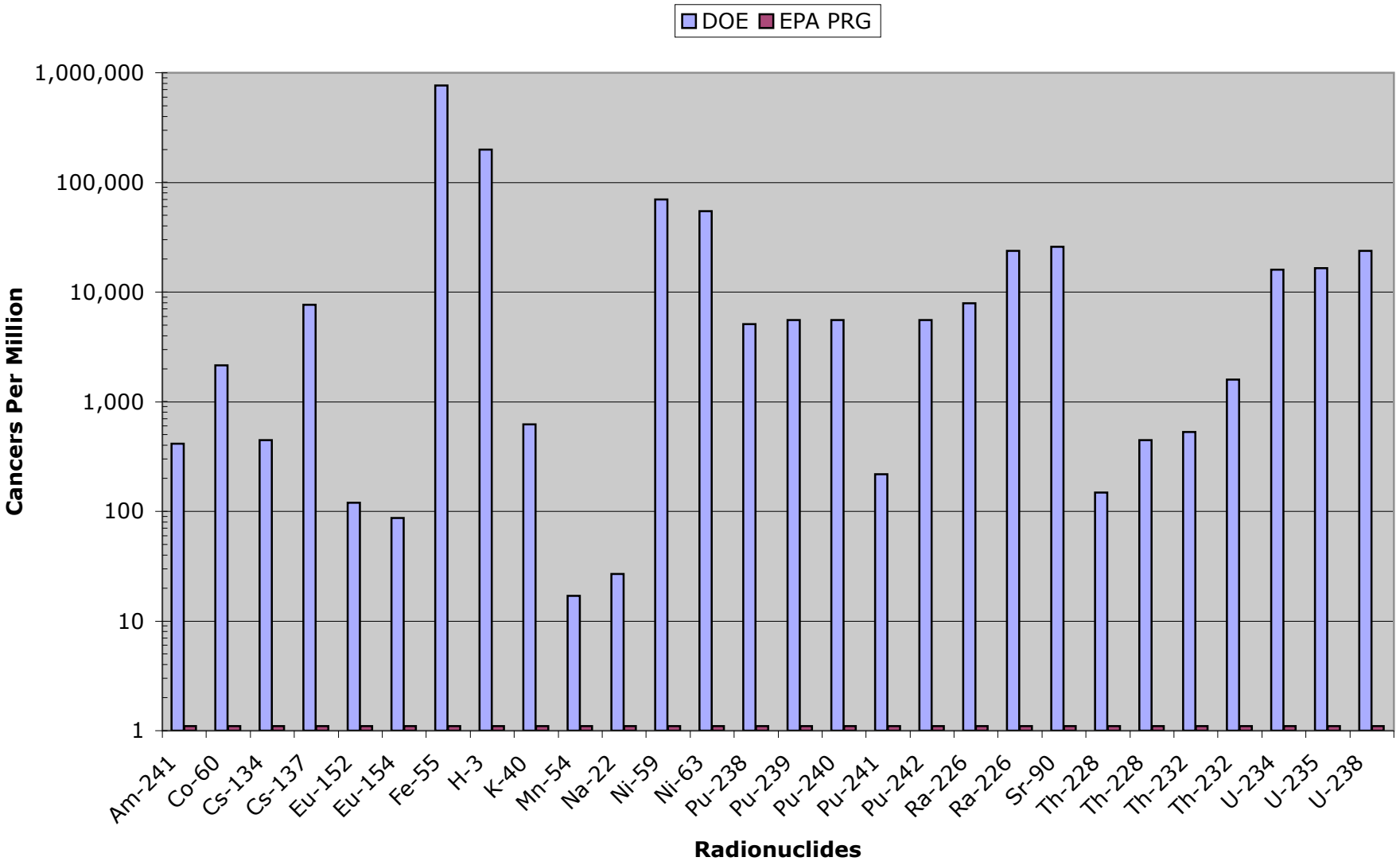
We have also provided in the attachments a more detailed set of comparison graphs, one for each radionuclide and for each exposure scenario.

Conclusion

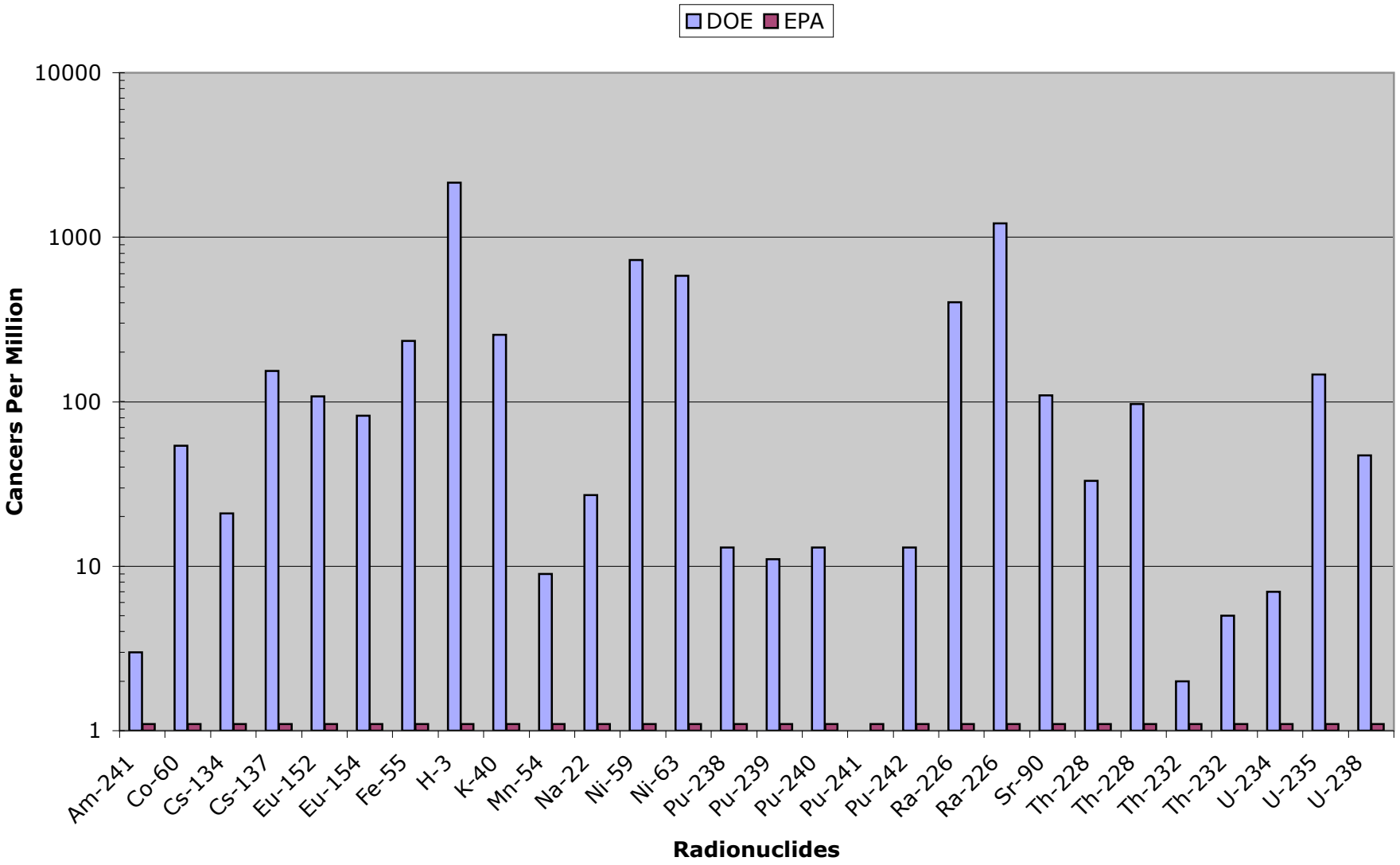
DOE's recent breach of its commitments under the 1995 DOE-EPA Joint Policy on Decommissioning DOE Facilities Under CERCLA results in extraordinarily higher radioactivity levels permitted to be left in place at SSFL, with associated very high risk factors, than EPA's CERCLA standards would permit, and with significant numbers of potential cancers among the public were the land indeed to be released for unrestricted use, as proposed by DOE. If not reversed, this may result in significantly elevated public health risks, and have important ramifications nationally for the cleanup of the DOE nuclear complex.

[6] Note that DOE has two sets of standards for radium-226, and thorium –228 and –232, depending on the depth from the surface at which the sample is taken. The graphs therefore show two entries for each of those radionuclides, the first being the 5 pico-curie per gram standard for the surface samples, the second being the 15 pico-curie per gram standard for samples taken beneath the surface. Note also that EPA's most recent revision of its PRGs has two entries for tritium, one in organic form, the other as vapor. No values are given for the latter form. DOE's SSFL cleanup criteria—and EPA's previous PRGs – have only a single value given for tritium, in any form.

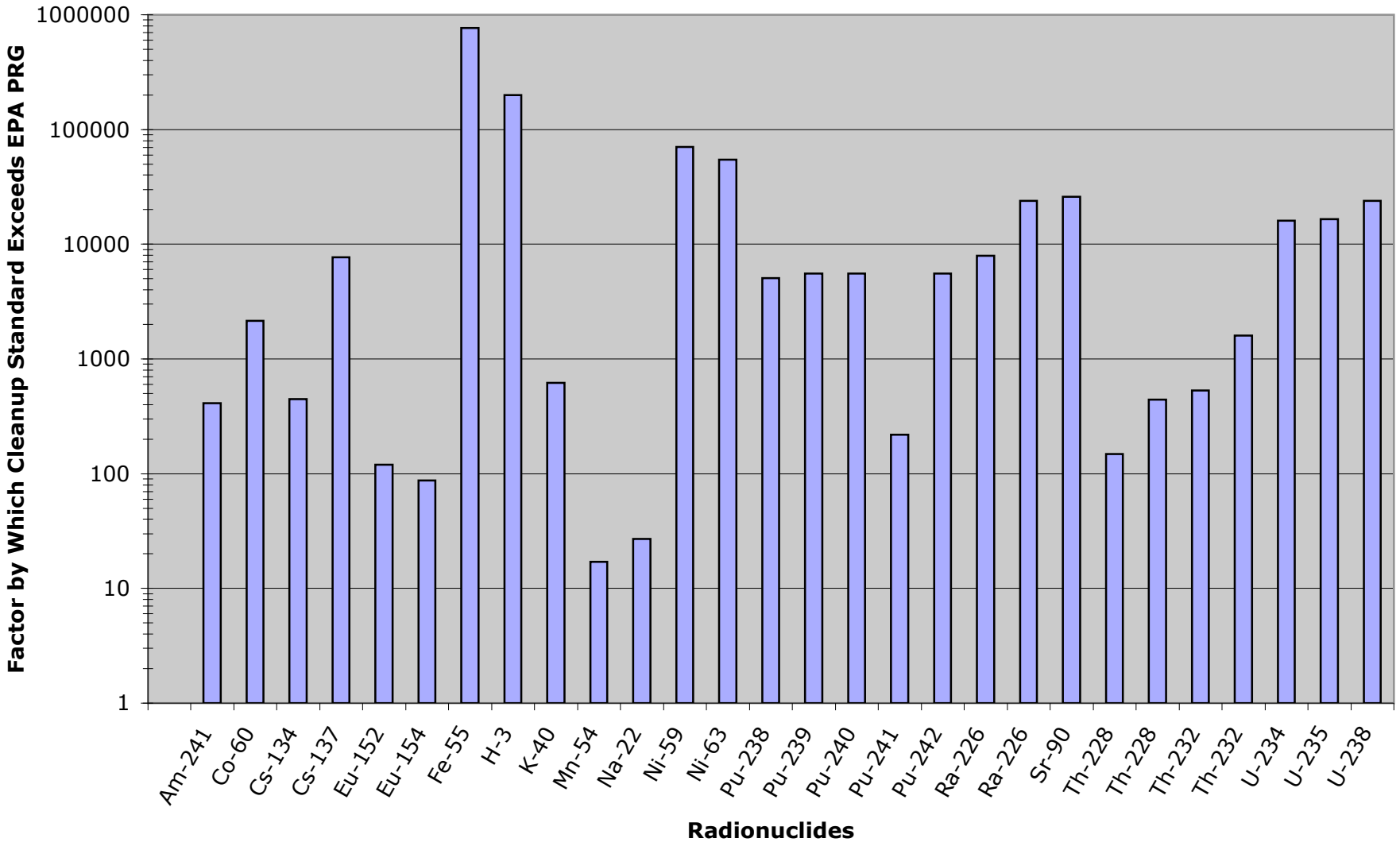
Cancer Risk Levels for Cleanup Standards: Rural Residential



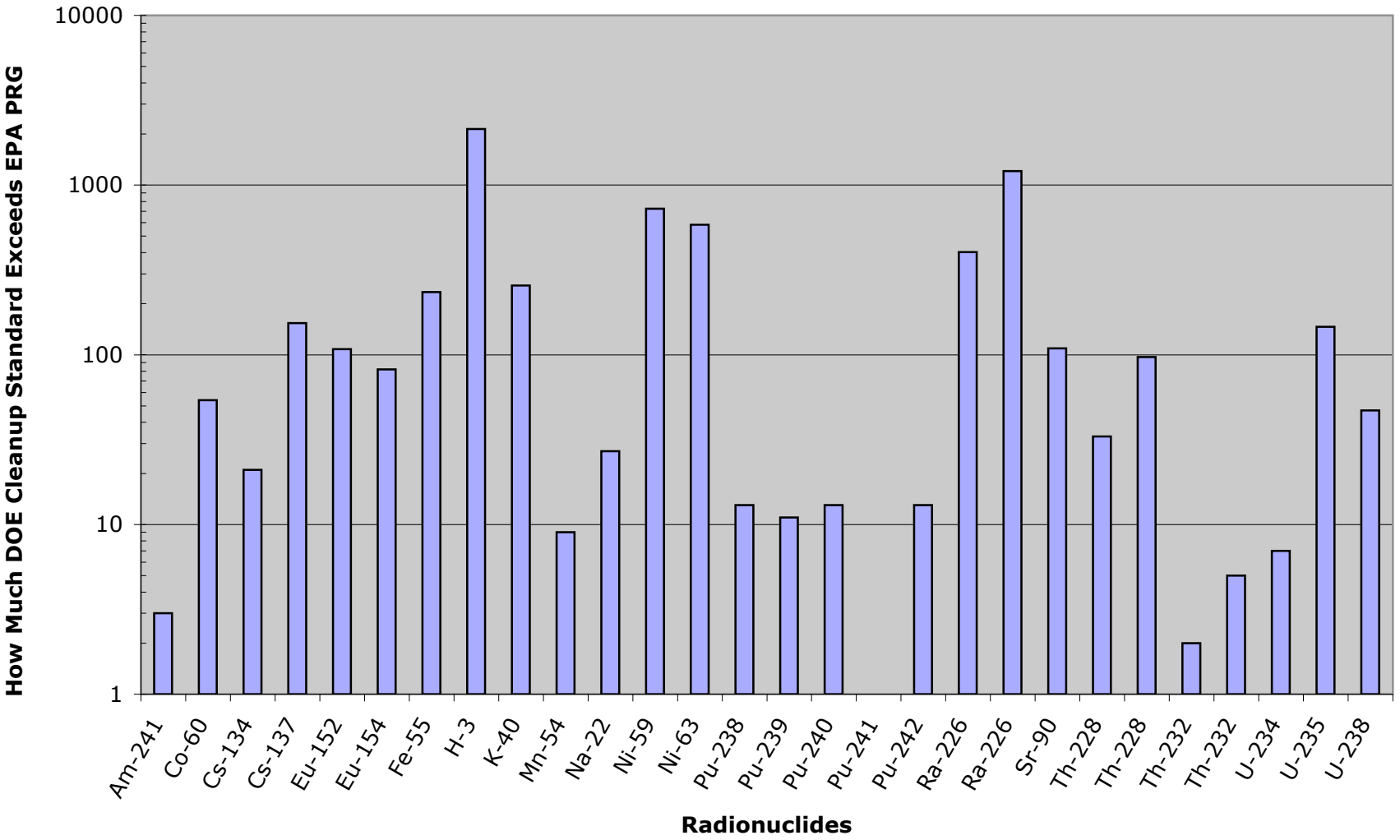
Cancer Risk Level for Cleanup Standards: Suburban Residential



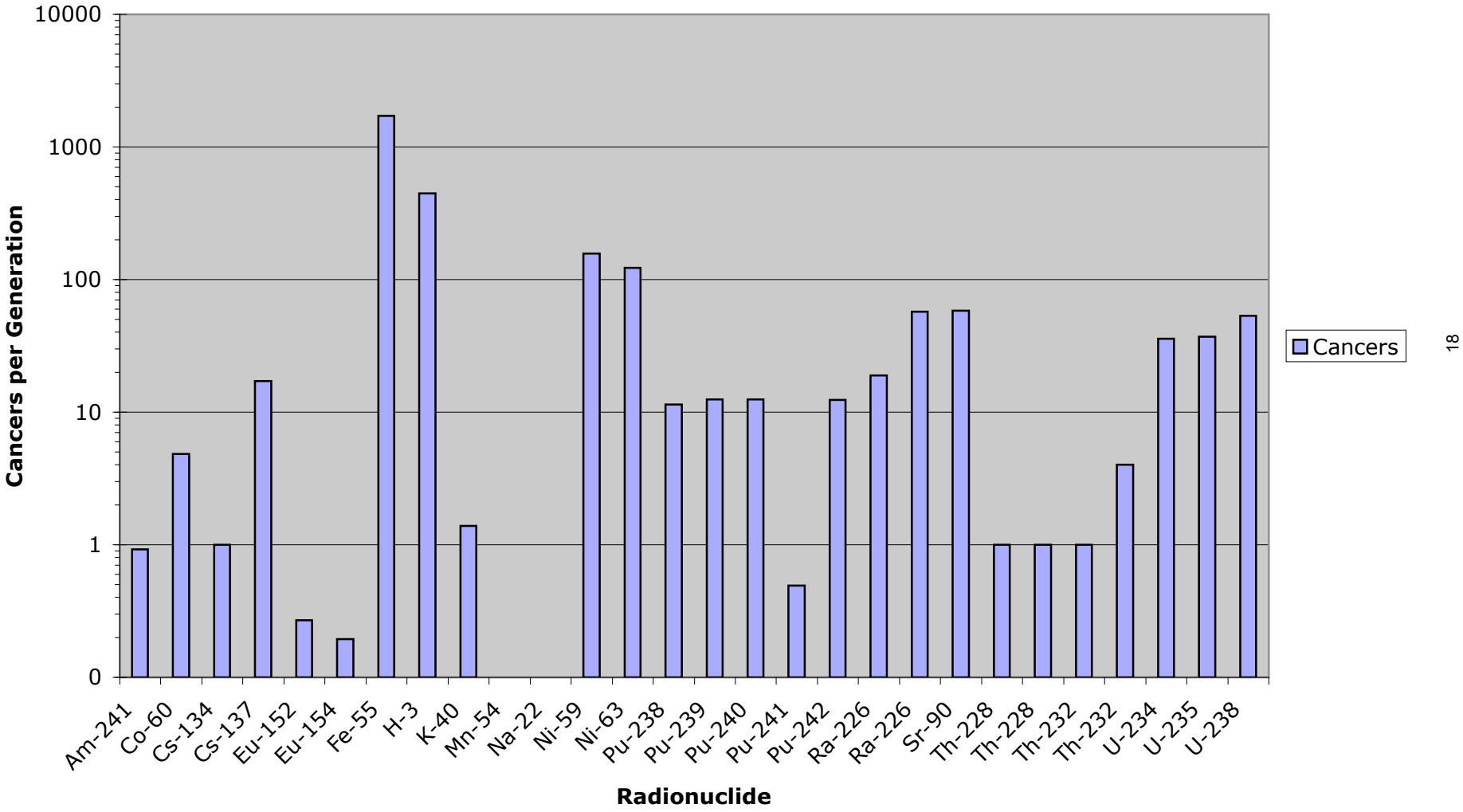
How Much DOE Cleanup Standards Exceed EPA's PRGs



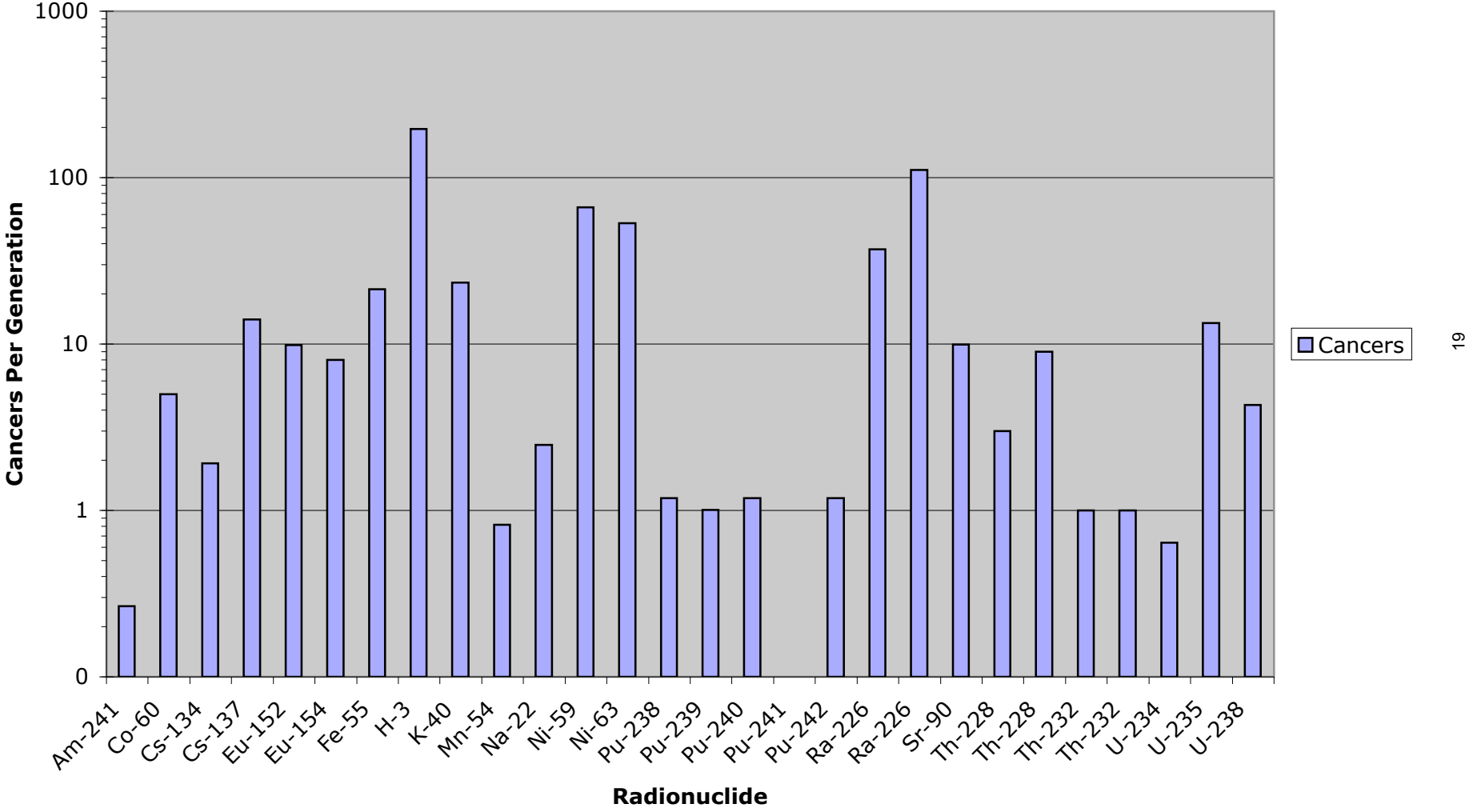
How Much DOE's Cleanup Standards Exceed EPA's PRGs



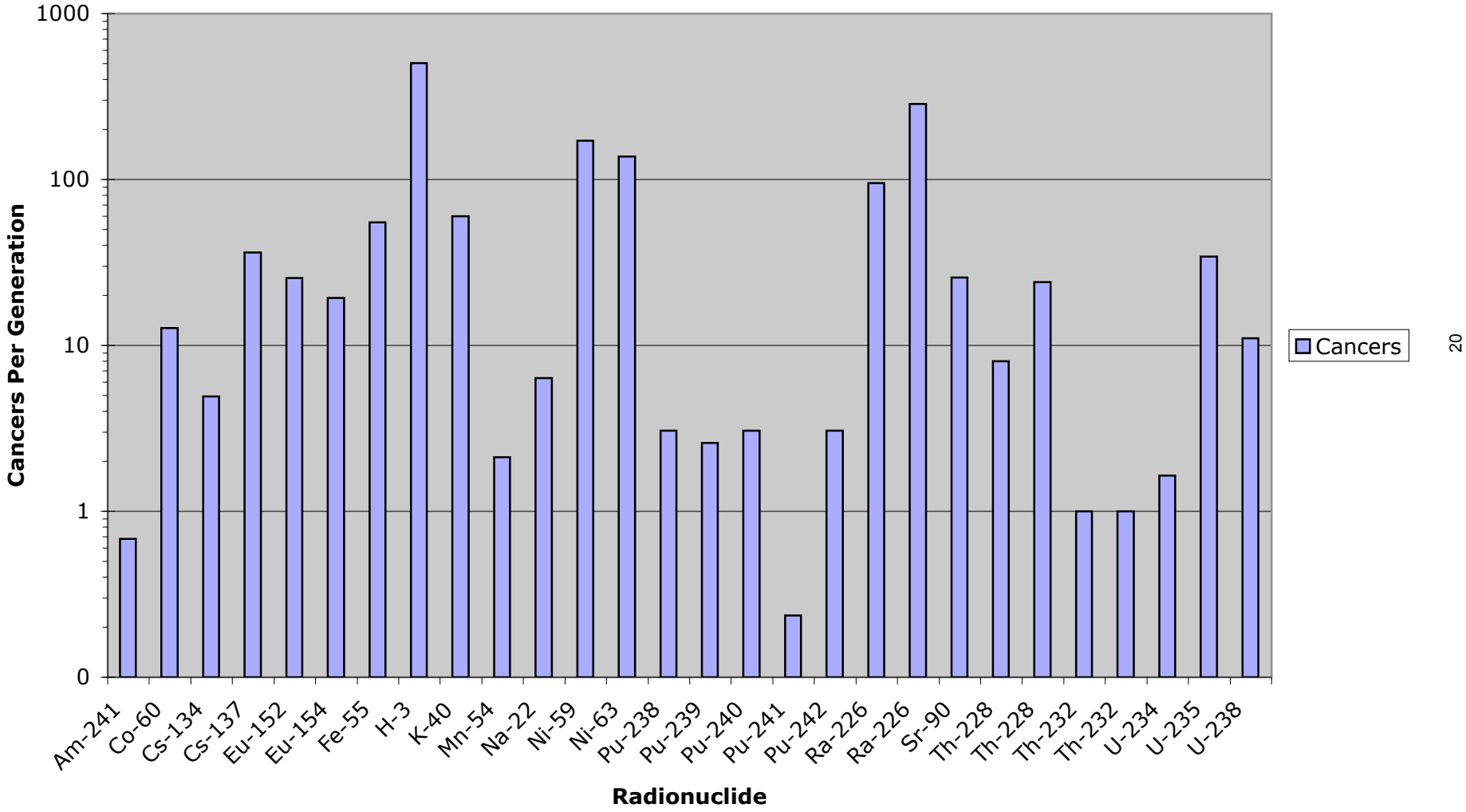
Cancers Per Generation - Rural Residential
DOE SSFL Cleanup Levels



Cancers Per Generation - Suburban Medium Density
DOE SSFL Cleanup Levels



Cancers Per Generation - High Density Suburban Residential
DOE SSFL Cleanup Levels



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TABLES

I. Radionuclides for Which DOE Has Set Cleanup Levels for the Santa Susana Field Laboratory

II. DOE SSFL Cleanup Levels vs. EPA Preliminary Remediation Goals (PRGs)

A. Rural Residential Exposure Scenario
B. Suburban Residential

Tables C & D are Identical to Tables A & B, but Employing Scientific Notation*

Note: When a value is given as, say, 4E-04, it means four times ten to the exponent minus four, or 4×10^{-4} (a chance of four in ten thousand of getting cancer from that particular exposure, or one chance in 2500).

Radionuclides for Which DOE Has Set Cleanup Levels for the Santa Susana Field Laboratory

Symbol	Radionuclide	Half-Life
Am-241	Americium-241	432.7 years
Co-60	Cobalt-60	5.27 years
Cs-134	Cesium-134	2.06 years
Cs-137	Cesium-137	30.0 years
Eu-152	Europium-152	13.3 years
Eu-154	Europium-154	8.8 years
Fe-55	Iron-55	2.73 years
H-3	Tritium	12.3 years
K-40	Potassium-40	1.28 billion years
Mn-54	Manganese-54	312 days
Na-22	Sodium-22	2.6 years
Ni-59	Nickel-59	75,000 years
Ni-63	Nickel-63	100 years
Pu-238	Plutonium-238	87.7 years
Pu-239	Plutonium-239	24,110 yars
Pu-240	Plutonium-240	6540 years
Pu-241	Plutonium-241	14.4 years
Pu-242	Plutonium-242	376,300 years
Ra-226	Radium-226	1600 years
Sr-90	Strontium-90	28.5 years
Th-228	Thorium-228	5.76 years
Th-232	Thorium-232	14.1 billion years
U-234	Uranium-234	245,400 years
U-235	Uranium-235	700 million years
U-238	Uranium-238	4.47 billion years

DOE SSFL Cleanup Levels vs. EPA PRGs

rural residential scenario
current zoning (RA5)

Radionuclide	DOE Cleanup Level for SSFL	Cancer Risk Level for DOE Cleanup Level	EPA PRG	DOE Cleanup Level /EPA PRG	Cancers per gen.
Am-241	5.44	**4.12E-04**	1.32E-02	**412**	**1**
Co-60	1.94	**2.15E-03**	9.01E-04	**2153**	**5**
Cs-134	3.33	**4.46E-04**	7.47E-03	**446**	**1**
Cs-137	9.2	**7.67E-03**	1.20E-03	**7667**	**17**
Eu-152	4.51	**1.20E-04**	3.76E-02	**120**	**0**
Eu-154	4.11	**8.71E-05**	4.72E-02	**87**	**0**
Fe-55	629,000	**7.66E-01**	8.21E-01	**766139**	**1716**
H-3	31,900	**1.99E-01**	1.60E-01	**199375**	**447**
K-40	27.6	**6.20E-04**	4.45E-02	**620**	**1**
Mn-54	6.11	**1.66E-05**	3.69E-01	**17**	**0**
Na-22	2.31	**2.71E-05**	8.52E-02	**27**	**0**
Ni-59	151,000	**7.02E-02**	2.15E+00	**70233**	**157**
Ni-63	55,300	**5.48E-02**	1.01E+00	**54752**	**123**
Pu-238	37.2	**5.09E-03**	7.31E-03	**5089**	**11**
Pu-239	33.9	**5.57E-03**	6.09E-03	**5567**	**12**
Pu-240	33.9	**5.56E-03**	6.10E-03	**5557**	**12**
Pu-241	230	**2.19E-04**	1.05E+00	**219**	**0**
Pu-242	35.5	**5.53E-03**	6.42E-03	**5530**	**12**
Ra-226	5 and 15	**7.937E-03 and 2.3809E-02**	6.32E-04	**7937 and 23809**	**19 and 57**
Sr-90	36	**2.59E-02**	1.39E-03	**25899**	**58**
Th-228	5 and 15	**1.48E-04 and 4.44E-04**	3.38E-02	**148 and 444**	**0 and 1**
Th-232	5 and 15	**5.31E-04 and 1.592E-03**	9.42E-03	**531 and 1592**	**1 and 4**
U-234	30	**1.60E-02**	1.87E-03	**16042.78075**	**36**
U-235	30	**1.66E-02**	1.81E-03	**16575**	**37**
U-238	35	**2.38E-02**	1.47E-03	**23810**	**53**

T2

based on EPA PRGs of 4 August 2004

DOE SSFL Cleanup Levels vs. EPA PRGs

Suburban Residential Scenario
Unrestricted Residential Use

Radionuclide	DOE Cleanup Level for SSFL (pCi/g)	Cancer Risk Level for DOE Cleanup Level (cancers per million people)	EPA PRG (pCi/g)	Factor by Which DOE Cleanup Level Exceeds EPA PRG	cancers per generation (HD*)	cancers per gen. (MD**)
Am-241	5.44	3	1.87	3	1	0
Co-60	1.94	54	0.04	54	13	5
Cs-134	3.33	21	0.16	21	5	2
Cs-137	9.2	154	0.06	154	36	14
Eu-152	4.51	108	0.04	108	25	10
Eu-154	4.11	82	0.05	82	19	8
Fe-55	629,000	234	2690.00	234	55	21
H-3	31,900	2141	2.28	13991	504	196
K-40	27.6	256	0.11	256	60	23
Mn-54	6.11	9	0.69	9	2	1
Na-22	2.31	27	0.09	27	6	2
Ni-59	151,000	726	208.00	726	171	66
Ni-63	55,300	583	94.80	583	137	53
Pu-238	37.2	13	2.97	13	3	1
Pu-239	33.9	11	2.59	13	3	1
Pu-240	33.9	13	2.60	13	3	1
Pu-241	230	1	406.00	1	0	0
Pu-242	35.5	13	2.73	13	3	1
Ra-226	5	403	0.01	403	95	37
Ra-226	15	1210	0.01	1210	285	111
Sr-90	36	109	0.23	156	26	10
Th-228	5	33	0.15	33	8	3
Th-228	15	97	0.15	97	24	9
Th-232	5	2	3.10		0	0
Th-232	15	5	3.10	5	1	0
U-234	30	7	4.01	7	2	1
U-235	30	146	0.20	154	34	13
U-238	35	47	0.74	47	11	4

T3

*HD=high density
**MD=medium density

based on EPA PRGs of 4 August 2004

DOE SSFL Cleanup Levels vs. EPA PRGs

rural residential scenario
current zoning (RA5)

Radionuclide	DOE Cleanup Level for SSFL	Cancer Risk Level for DOE Cleanup Level	EPA PRG	DOE Cleanup Level /EPA PRG	Cancers per gen.
Am-241	5.44	**4.12E-04**	1.32E-02	**412**	**1**
Co-60	1.94	**2.15E-03**	9.01E-04	**2153**	**5**
Cs-134	3.33	**4.46E-04**	7.47E-03	**446**	**1**
Cs-137	9.2	**7.67E-03**	1.20E-03	**7667**	**17**
Eu-152	4.51	**1.20E-04**	3.76E-02	**120**	**0**
Eu-154	4.11	**8.71E-05**	4.72E-02	**87**	**0**
Fe-55	629,000	**7.66E-01**	8.21E-01	**766139**	**1716**
H-3	31,900	**1.99E-01**	1.60E-01	**199375**	**447**
K-40	27.6	**6.20E-04**	4.45E-02	**620**	**1**
Mn-54	6.11	**1.66E-05**	3.69E-01	**17**	**0**
Na-22	2.31	**2.71E-05**	8.52E-02	**27**	**0**
Ni-59	151,000	**7.02E-02**	2.15E+00	**70233**	**157**
Ni-63	55,300	**5.48E-02**	1.01E+00	**54752**	**123**
Pu-238	37.2	**5.09E-03**	7.31E-03	**5089**	**11**
Pu-239	33.9	**5.57E-03**	6.09E-03	**5567**	**12**
Pu-240	33.9	**5.56E-03**	6.10E-03	**5557**	**12**
Pu-241	230	**2.19E-04**	1.05E+00	**219**	**0**
Pu-242	35.5	**5.53E-03**	6.42E-03	**5530**	**12**
Ra-226	5 and 15	**7.937E-03 and 2.3809E-02**	6.32E-04	**7937 and 23809**	**19 and 57**
Sr-90	36	**2.59E-02**	1.39E-03	**25899**	**58**
Th-228	5 and 15	**1.48E-04 and 4.44E-04**	3.38E-02	**148 and 444**	**0 and 1**
Th-232	5 and 15	**5.31E-04 and 1.592E-03**	9.42E-03	**531 and 1592**	**1 and 4**
U-234	30	**1.60E-02**	1.87E-03	**16042.78075**	**36**
U-235	30	**1.66E-02**	1.81E-03	**16575**	**37**
U-238	35	**2.38E-02**	1.47E-03	**23810**	**53**

T4

based on EPA PRGs of 4 August 2004

DOE SSFL Cleanup Levels vs. EPA PRGs

Suburban Residential Scenario
Unrestricted Residential Use

Radionuclide	DOE Cleanup Level for SSFL (pCi/g)	Cancer Risk Level for DOE Cleanup Level	EPA PRG (pCi/g)	DOE Cleanup Level /EPA PRG	cancers per gen. (HD*)	cancers per gen. (MD**)
Am-241	5.44	2.91E-06	1.87E+00	3	1	0
Co-60	1.94	5.37E-05	3.61E-02	54	13	5
Cs-134	3.33	2.12E-05	1.57E-01	21	5	2
Cs-137	9.2	1.54E-04	5.97E-02	154	36	14
Eu-152	4.51	1.08E-04	4.16E-02	108	25	10
Eu-154	4.11	8.24E-05	4.99E-02	82	19	8
Fe-55	629,000	2.34E-04	2.69E+03	234	55	21
H-3	31,900	1.40E-02	2.28E+00	13991	3291	1279
K-40	27.6	2.56E-04	1.08E-01	256	60	23
Mn-54	6.11	8.83E-06	6.92E-01	9	2	1
Na-22	2.31	2.67E-05	8.65E-02	27	6	2
Ni-59	151,000	7.26E-04	2.08E+02	726	171	66
Ni-63	55,300	5.83E-04	9.48E+01	583	137	53
Pu-238	37.2	1.25E-05	2.97E+00	13	3	1
Pu-239	33.9	1.31E-05	2.59E+00	13	3	1
Pu-240	33.9	1.30E-05	2.60E+00	13	3	1
Pu-241	230	5.67E-07	4.06E+02	1	0	0
Pu-242	35.5	1.30E-05	2.73E+00	13	3	1
Ra-226	5 and 15	4.03E-04 and 1.21E-03	1.24E-02	403 and 1,210	95 and 285	37 and 111
Sr-90	36	1.56E-04	2.31E-01	156	37	14
Th-228	5 and 15	3.25E-05 and 9.74E-05	1.54E-01	33 and 97	8 and 24	3 and 9
Th-232	5 and 15	1.61E-06 and 4.84E-06	3.10E+00	2 and 5	0 and 1	0 and 0
U-234	30	7.48E-06	4.01E+00	7	2	1
U-235	30	1.54E-04	1.95E-01	154	36	14
U-238	35	4.72E-05	7.42E-01	47	11	4

T5

*HD=high density
**MD=medium density

based on EPA PRGs of 14 August 2004

FIGURES

Comparison of DOE Cleanup Standards for SSFL with EPA's PRGs (25 separate graphs per set, one for each radionuclide)

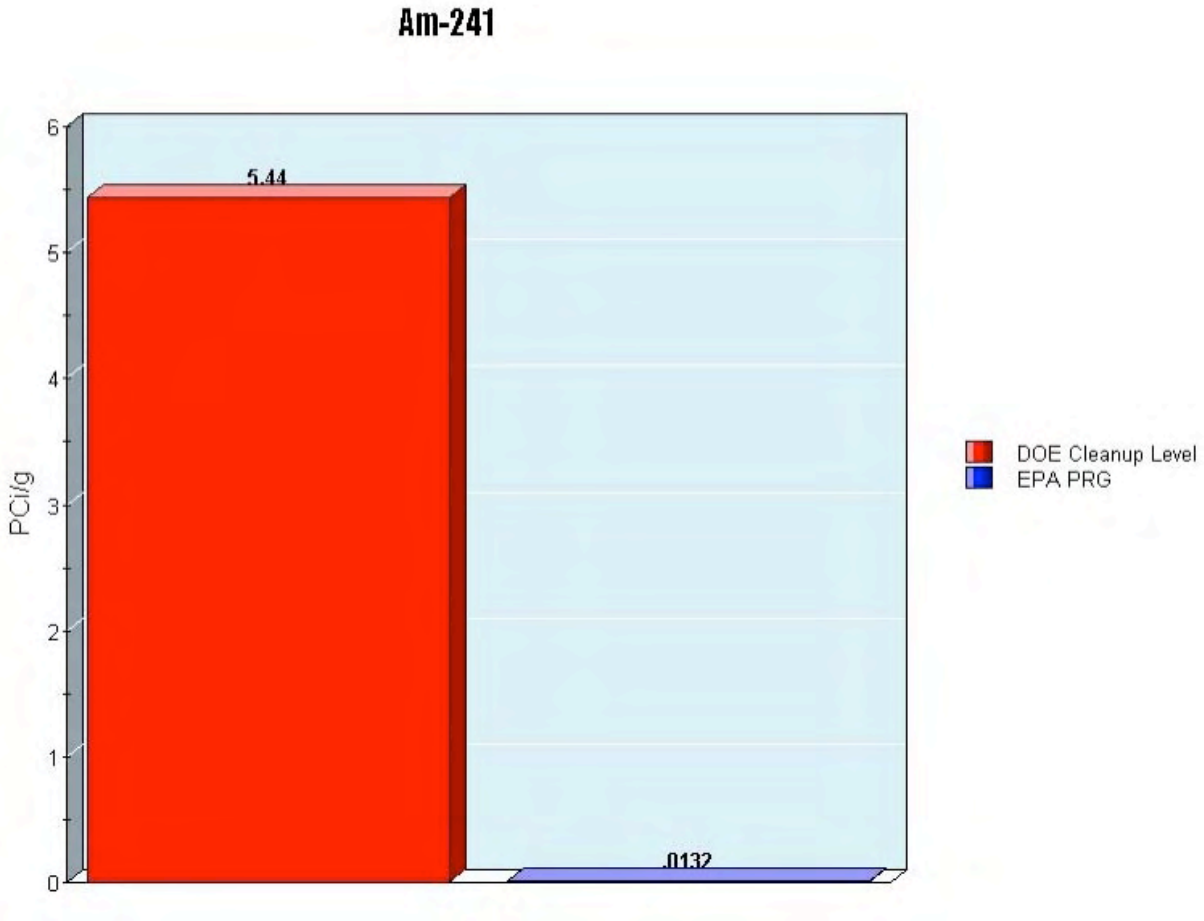
Set A. Rural Residential Exposure Scenario
Set B. Suburban Residential

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals

SET A

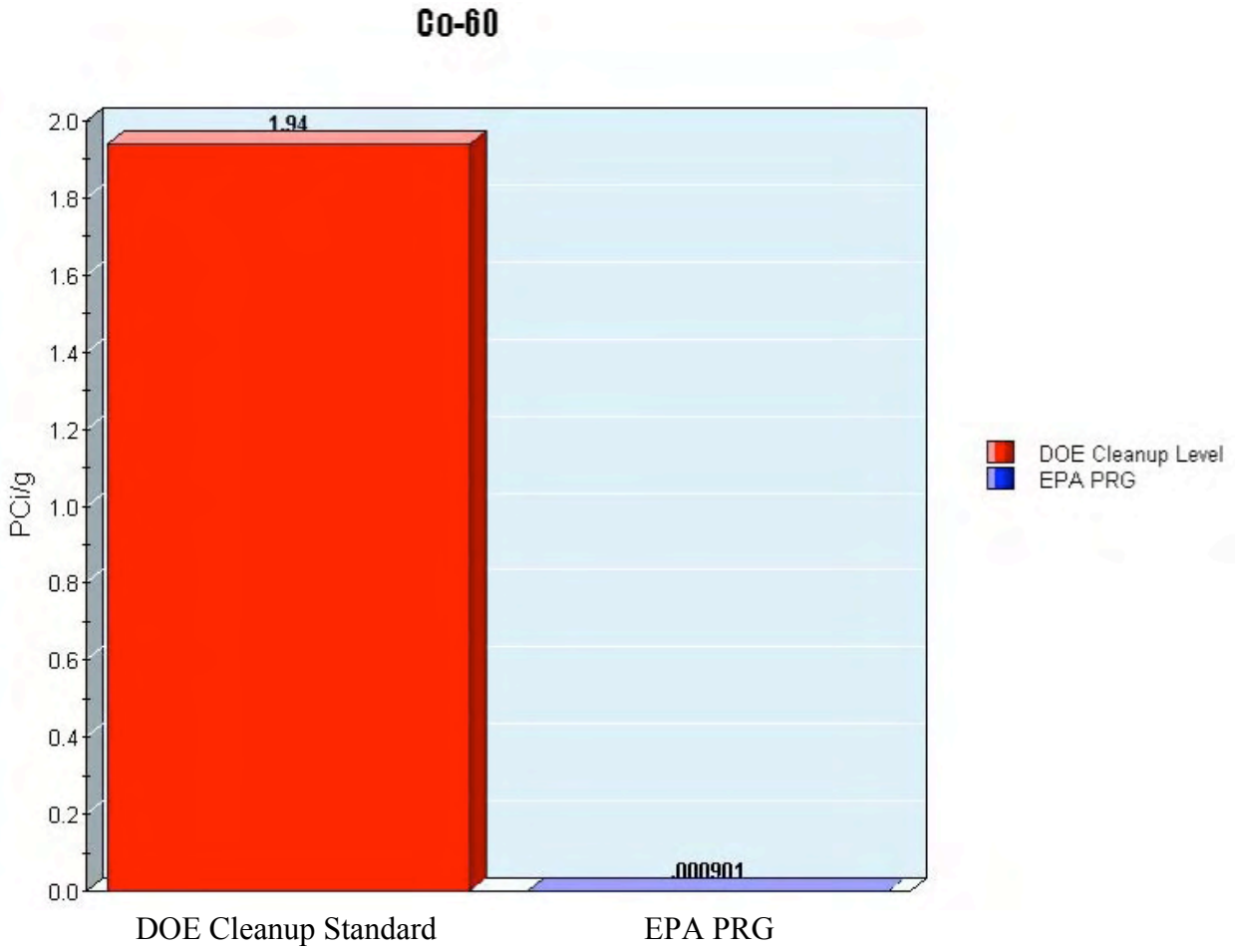
Rural Residential Exposure Pathway

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals

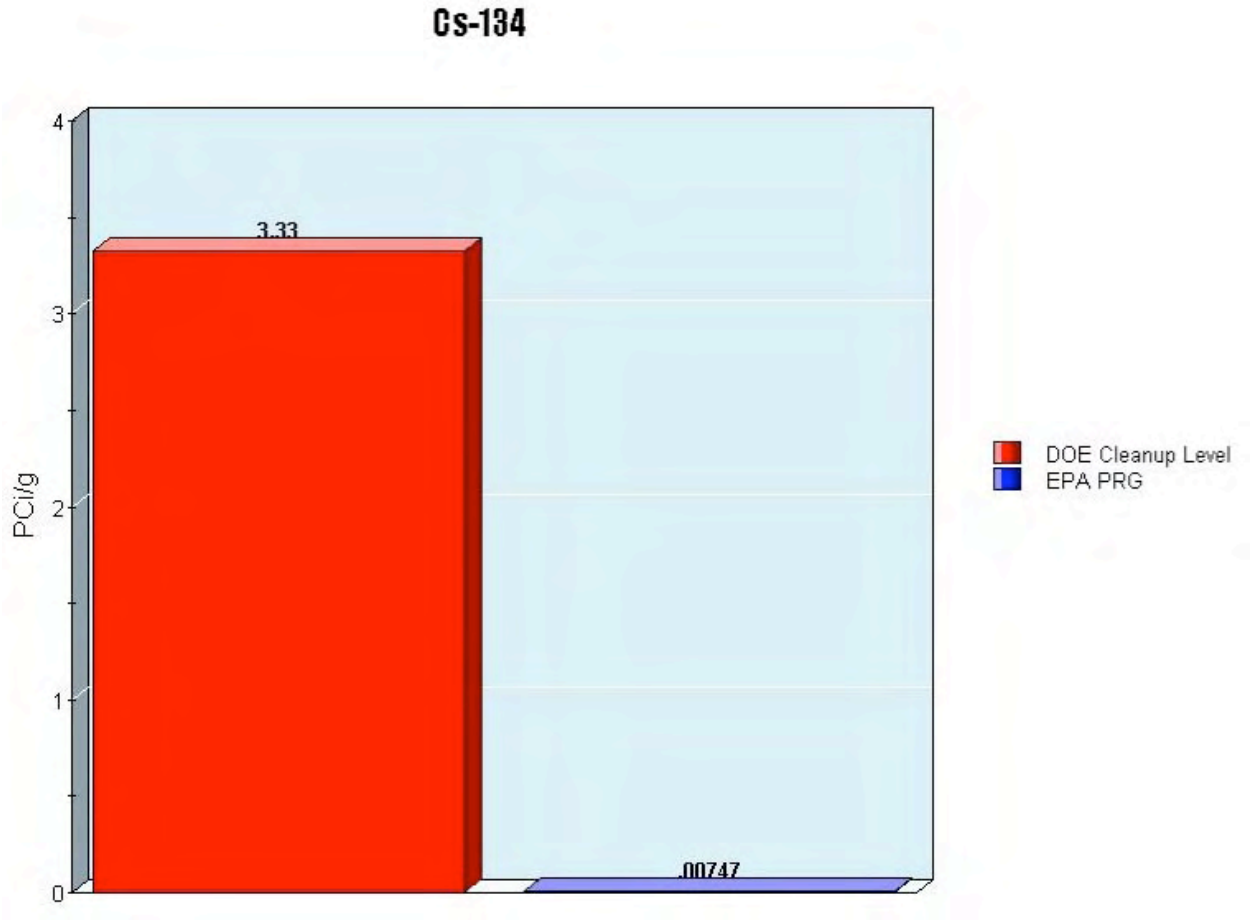


DOE Cleanup Standard EPA PRG

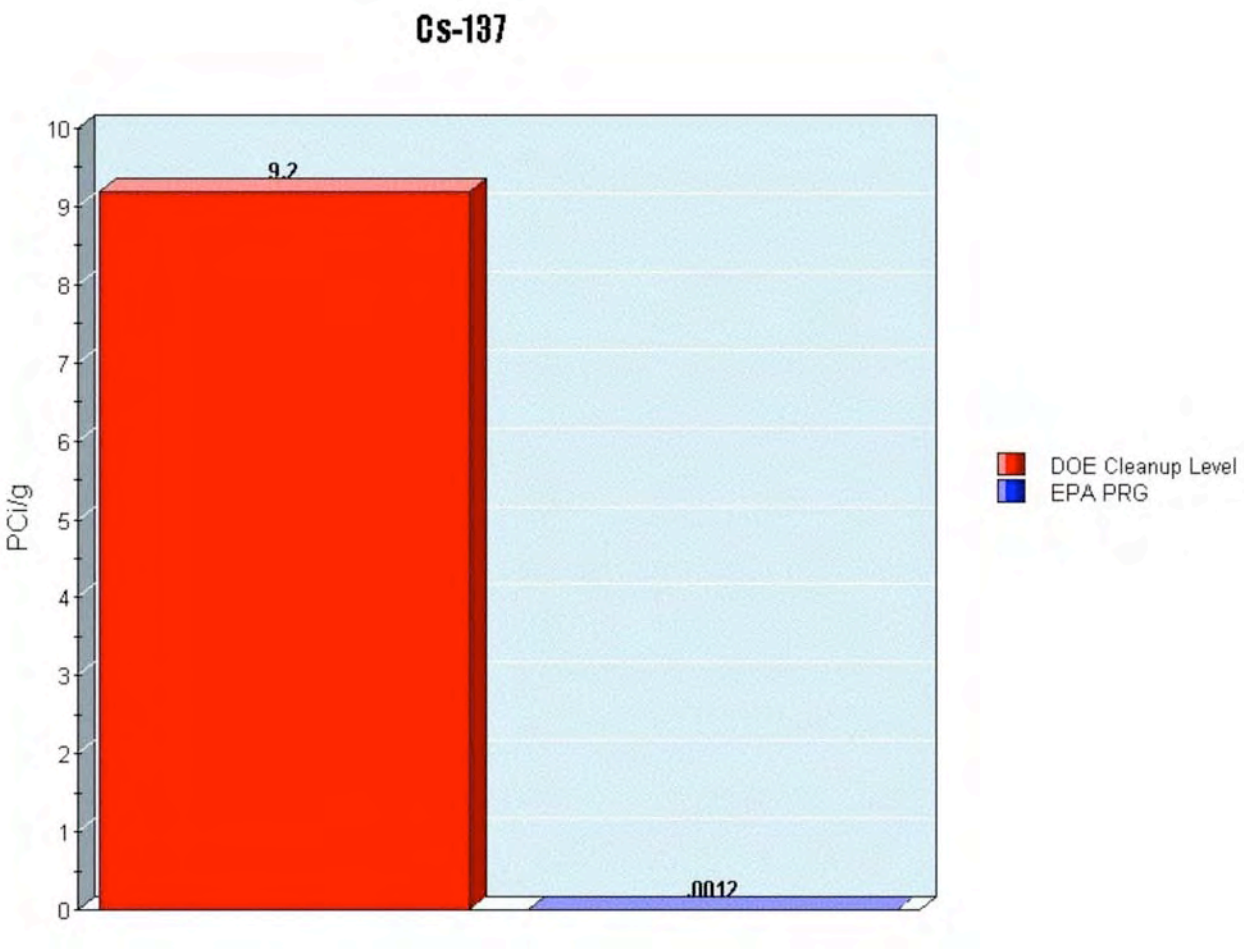
Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals

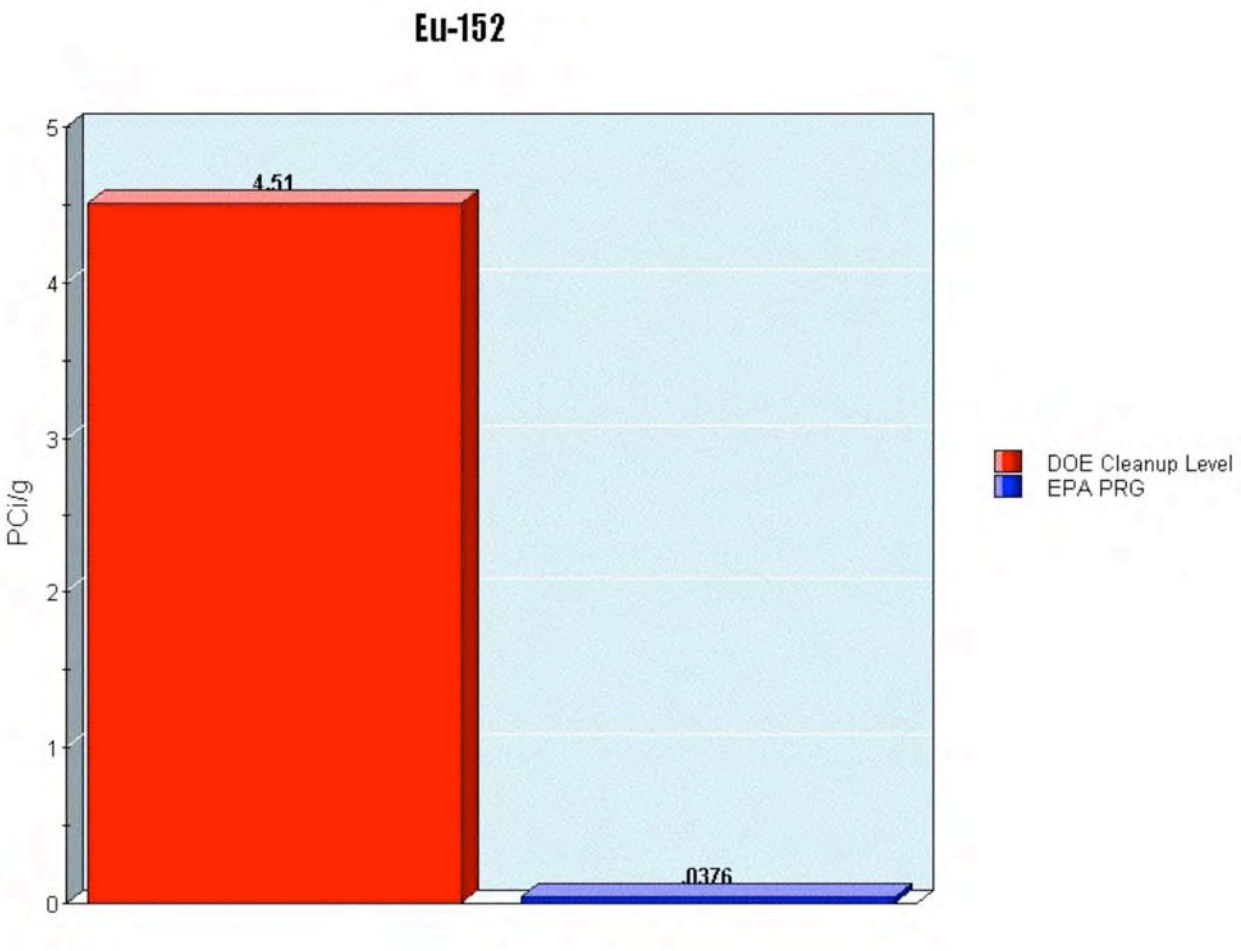


Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



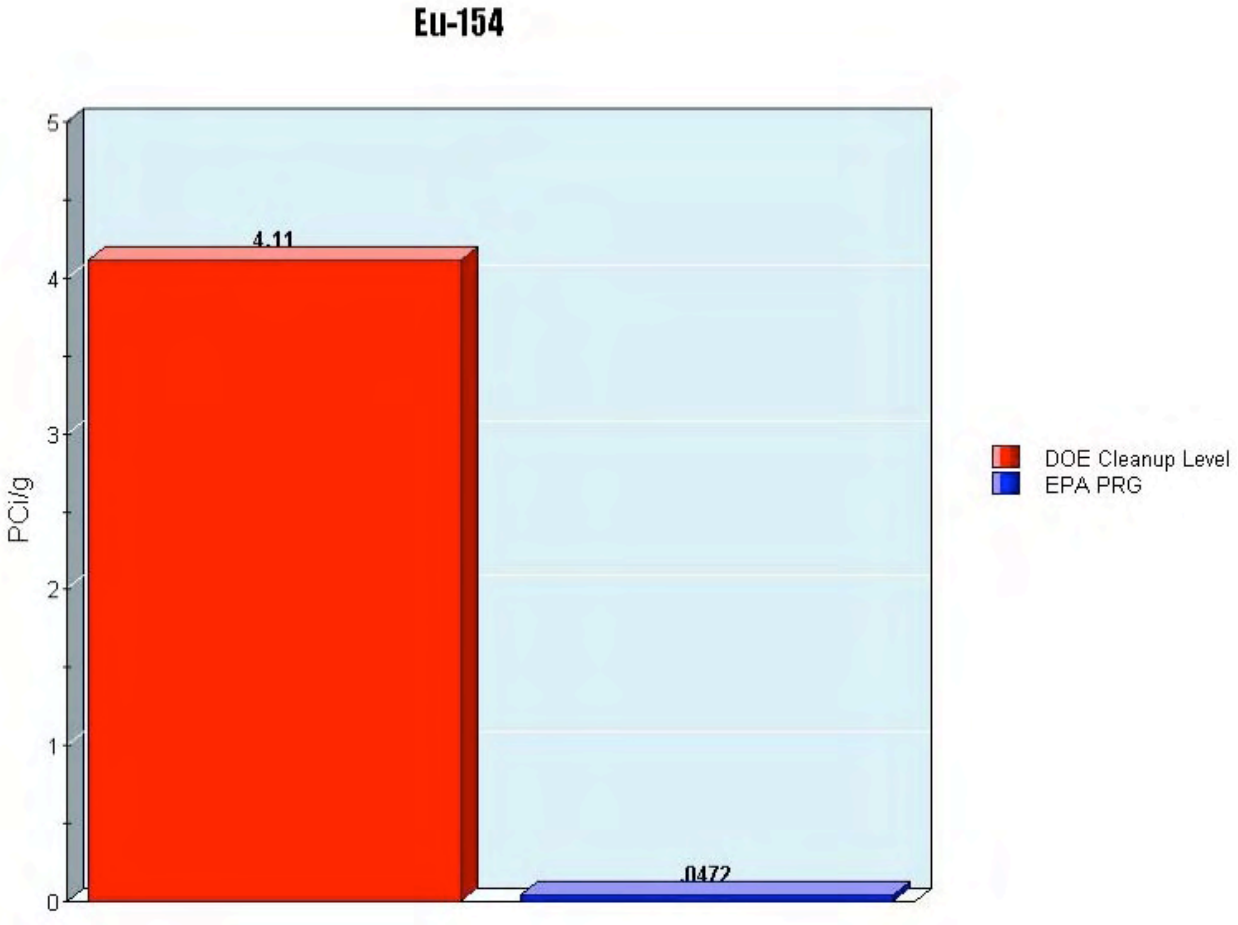
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



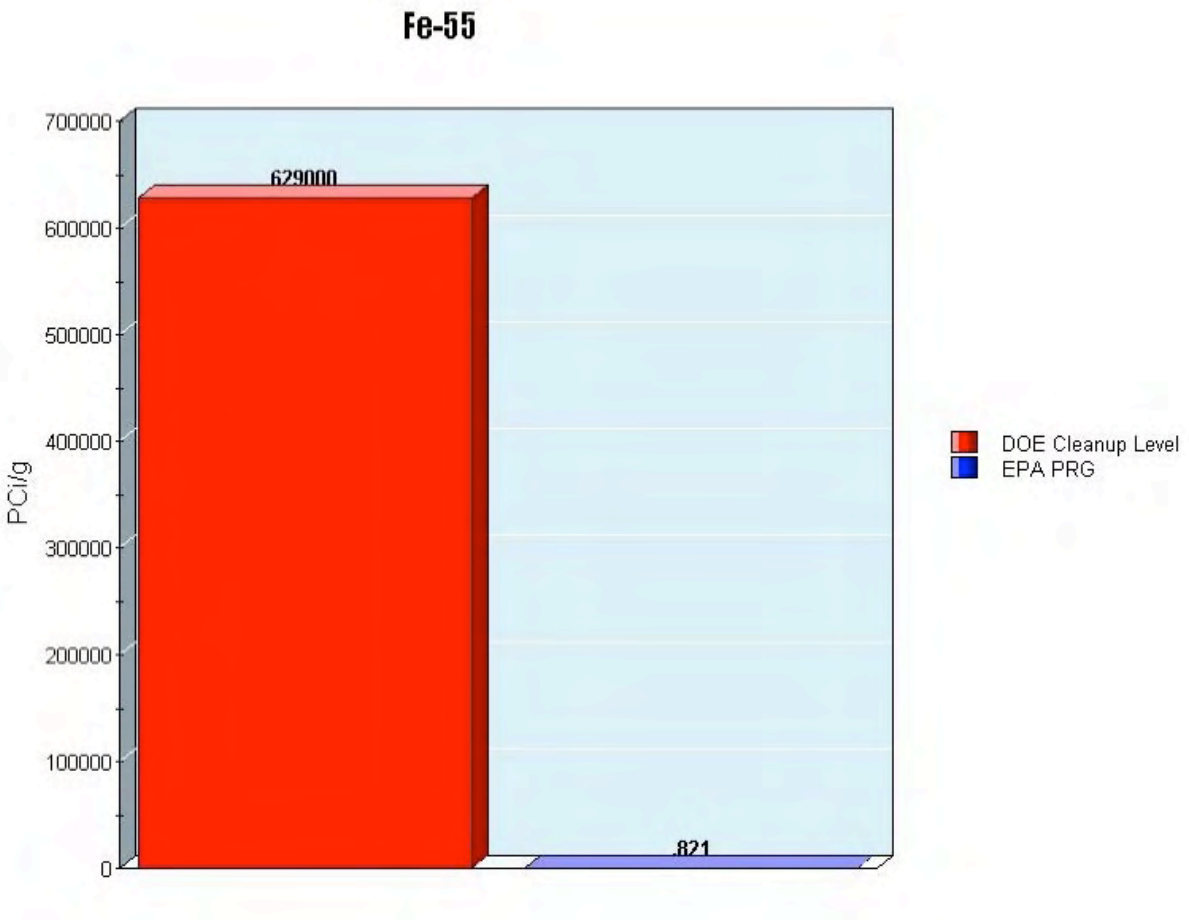
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



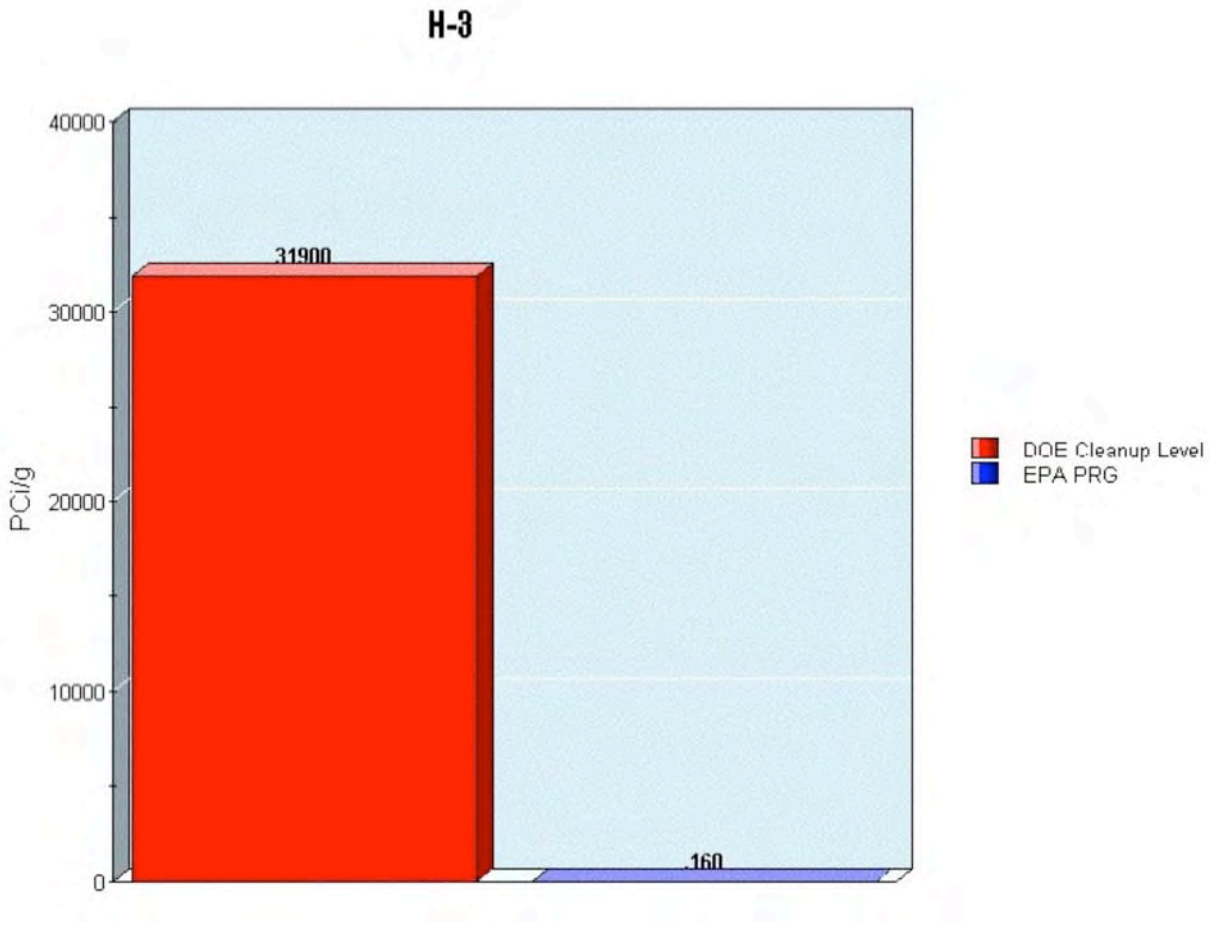
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



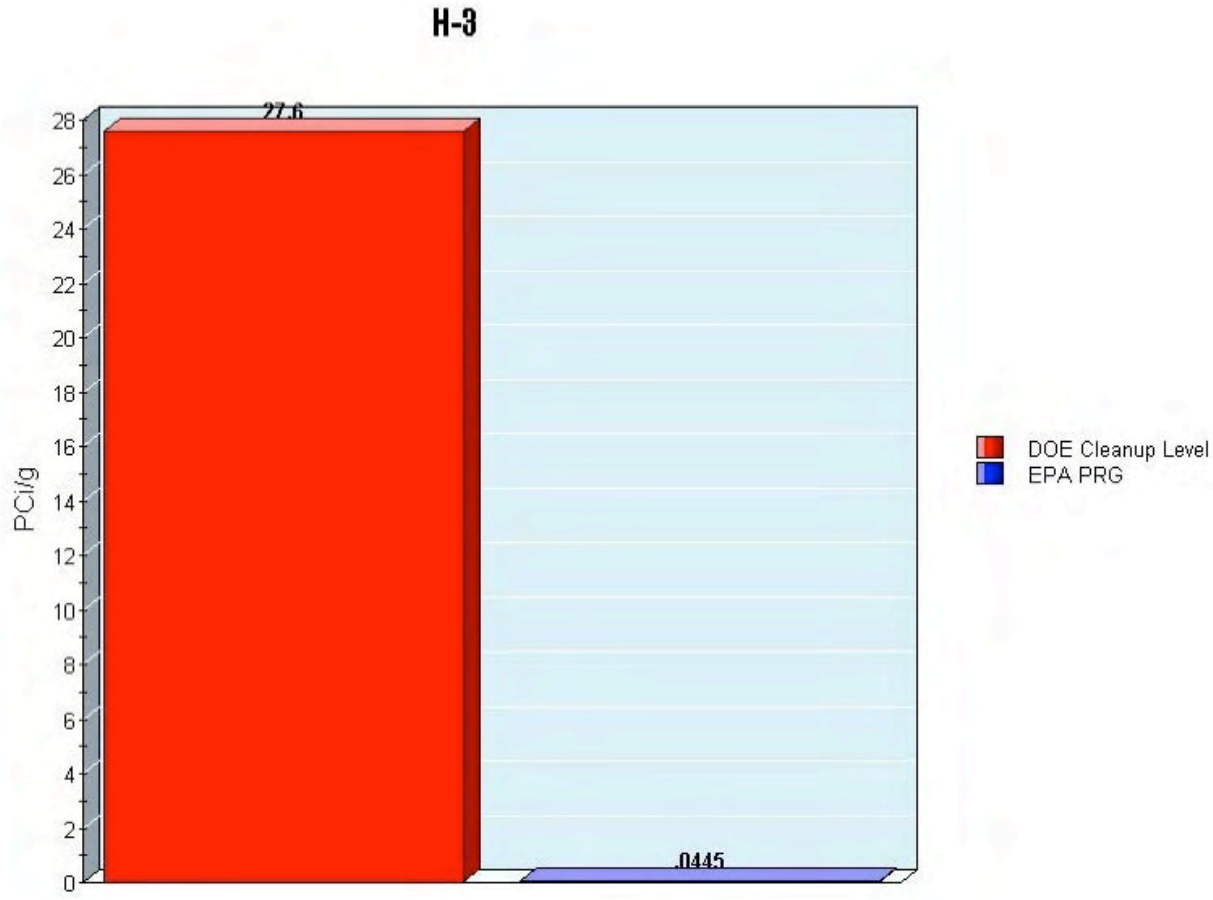
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



DOE Cleanup Standard EPA PRG

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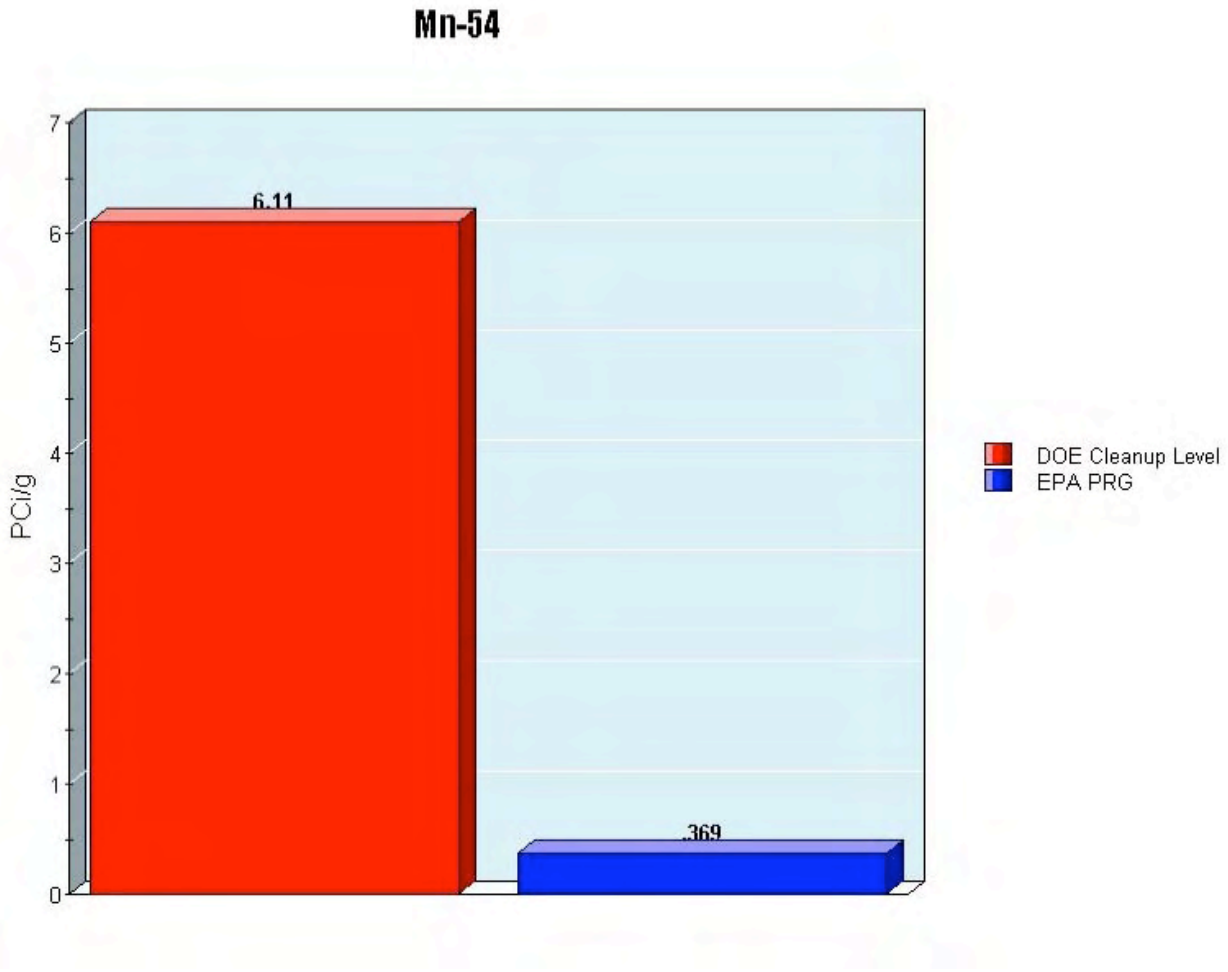
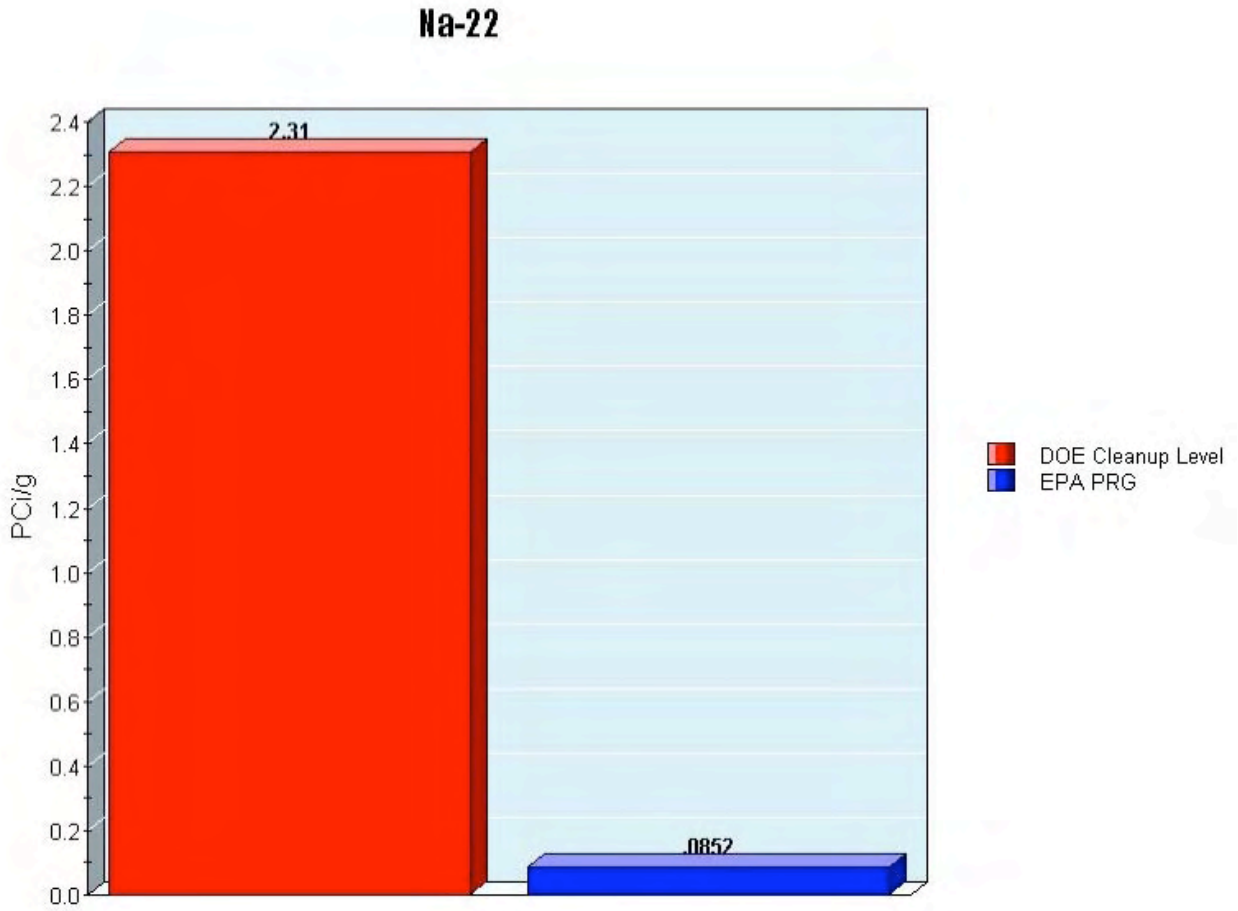


DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



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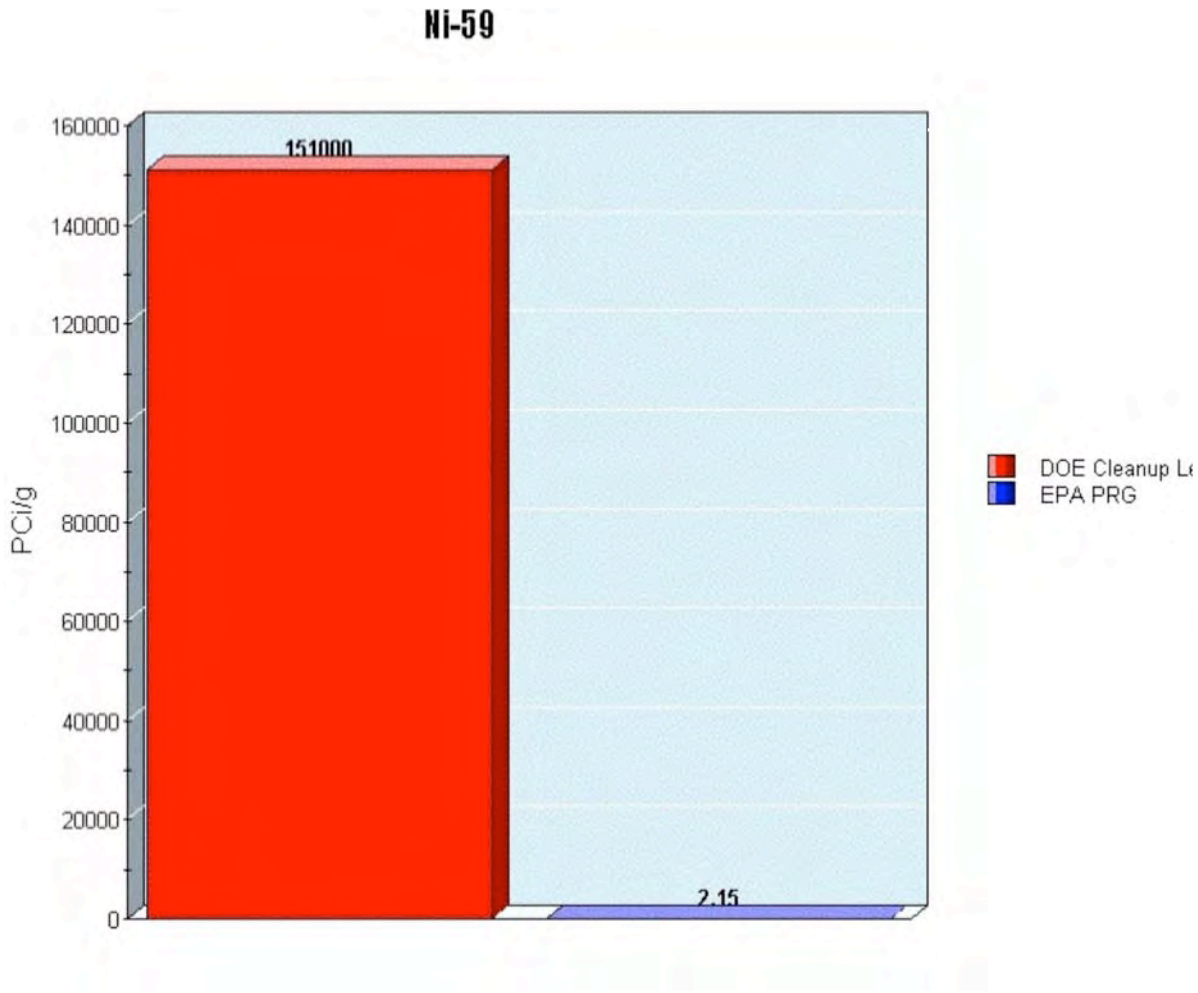
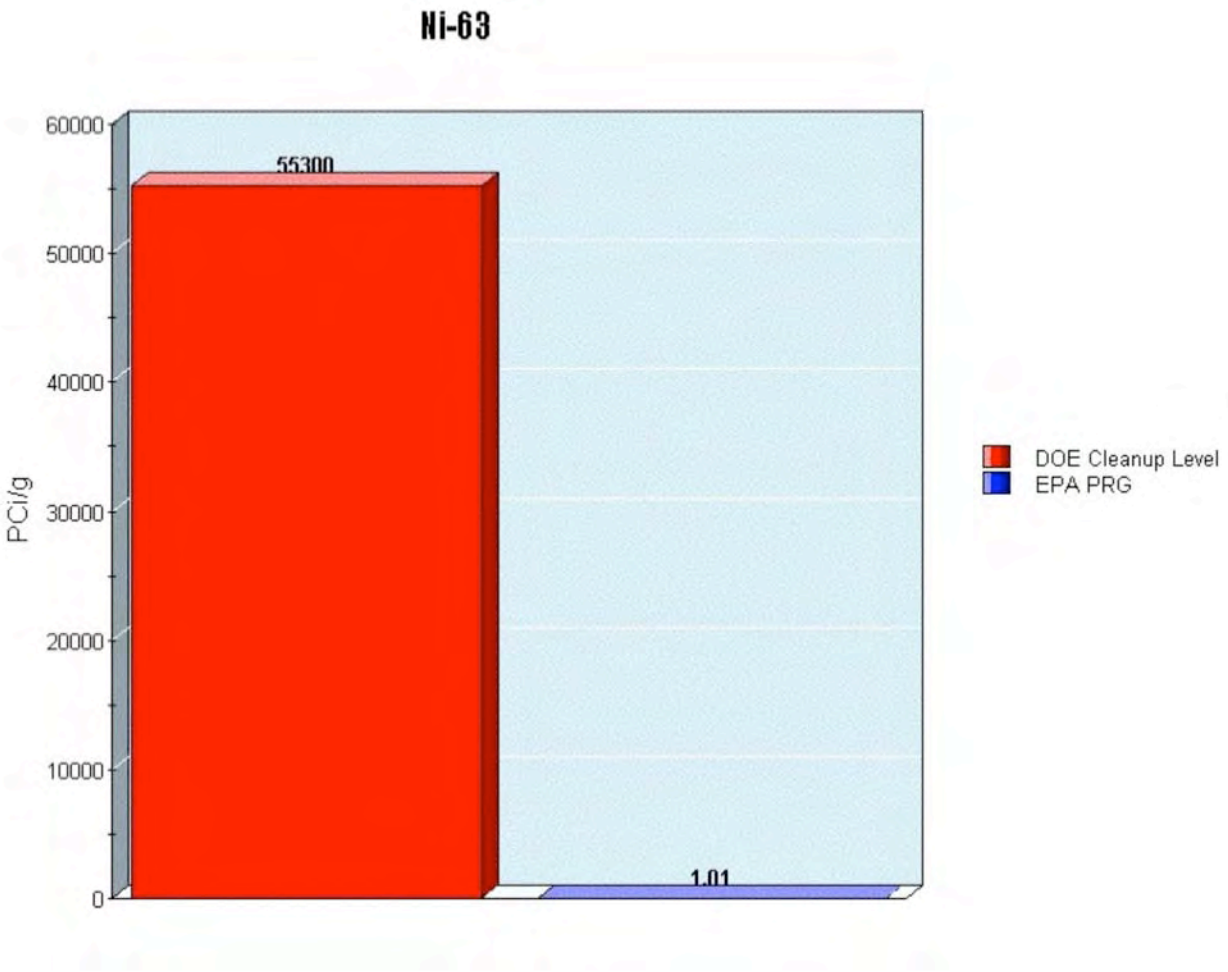


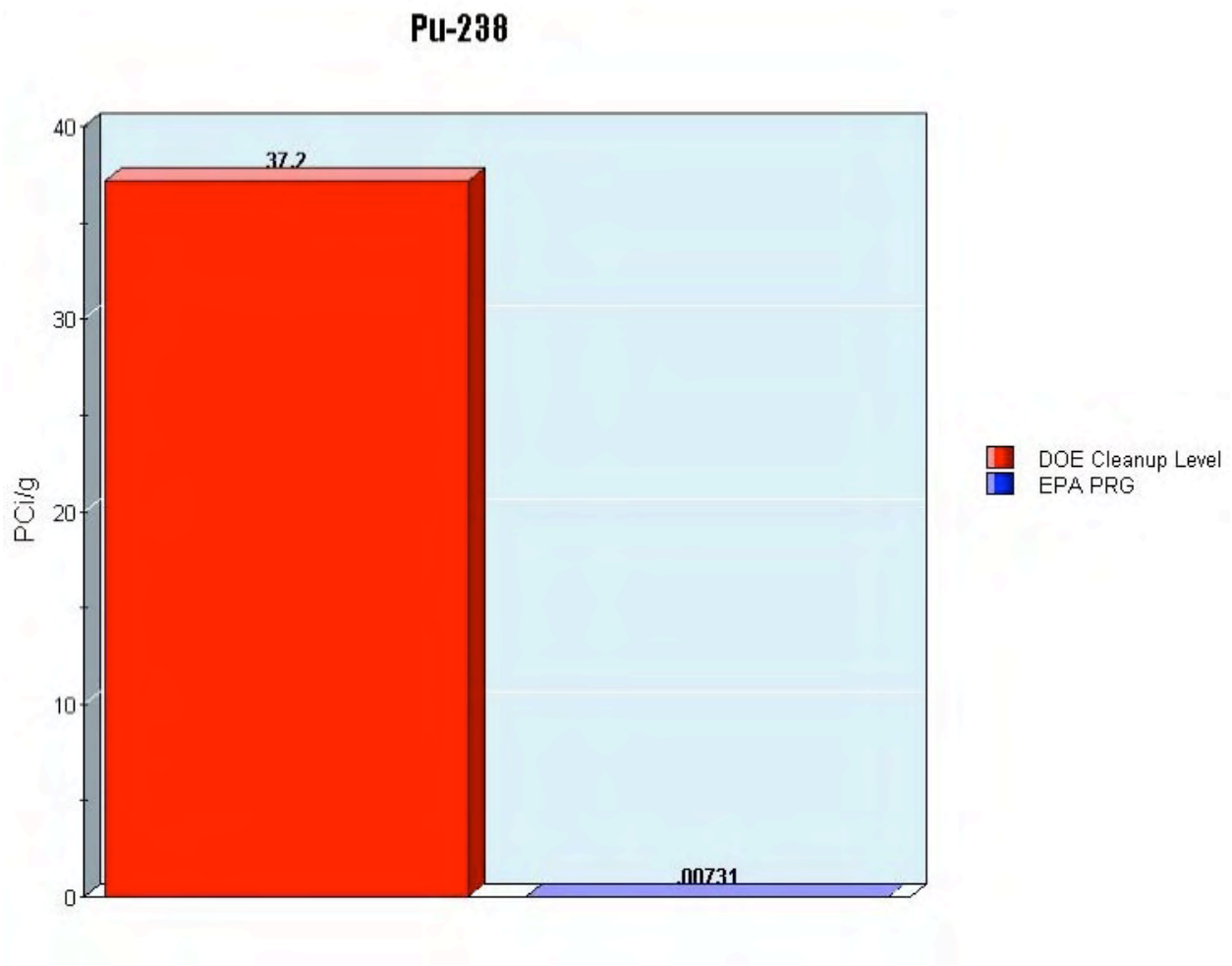
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



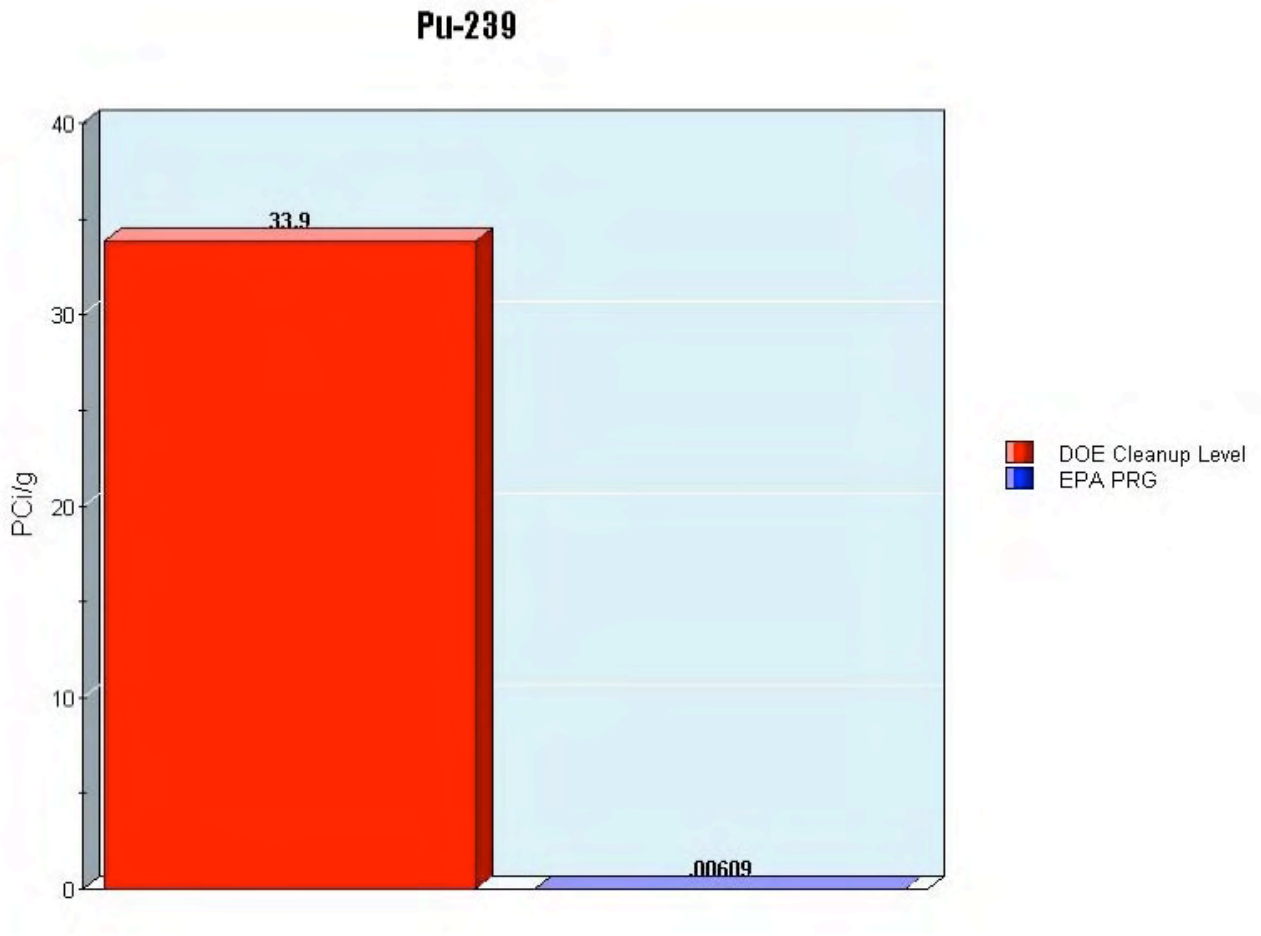
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



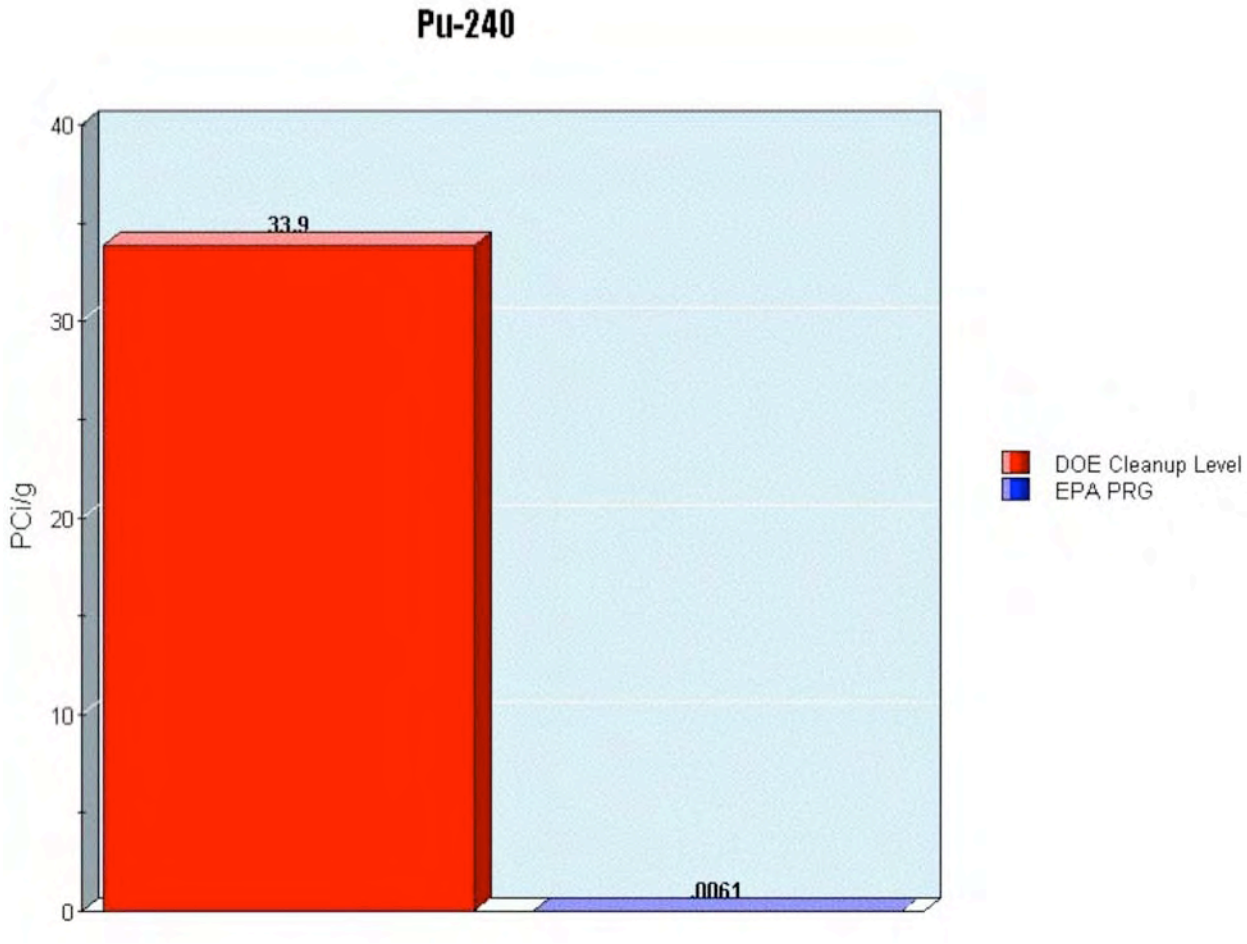
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



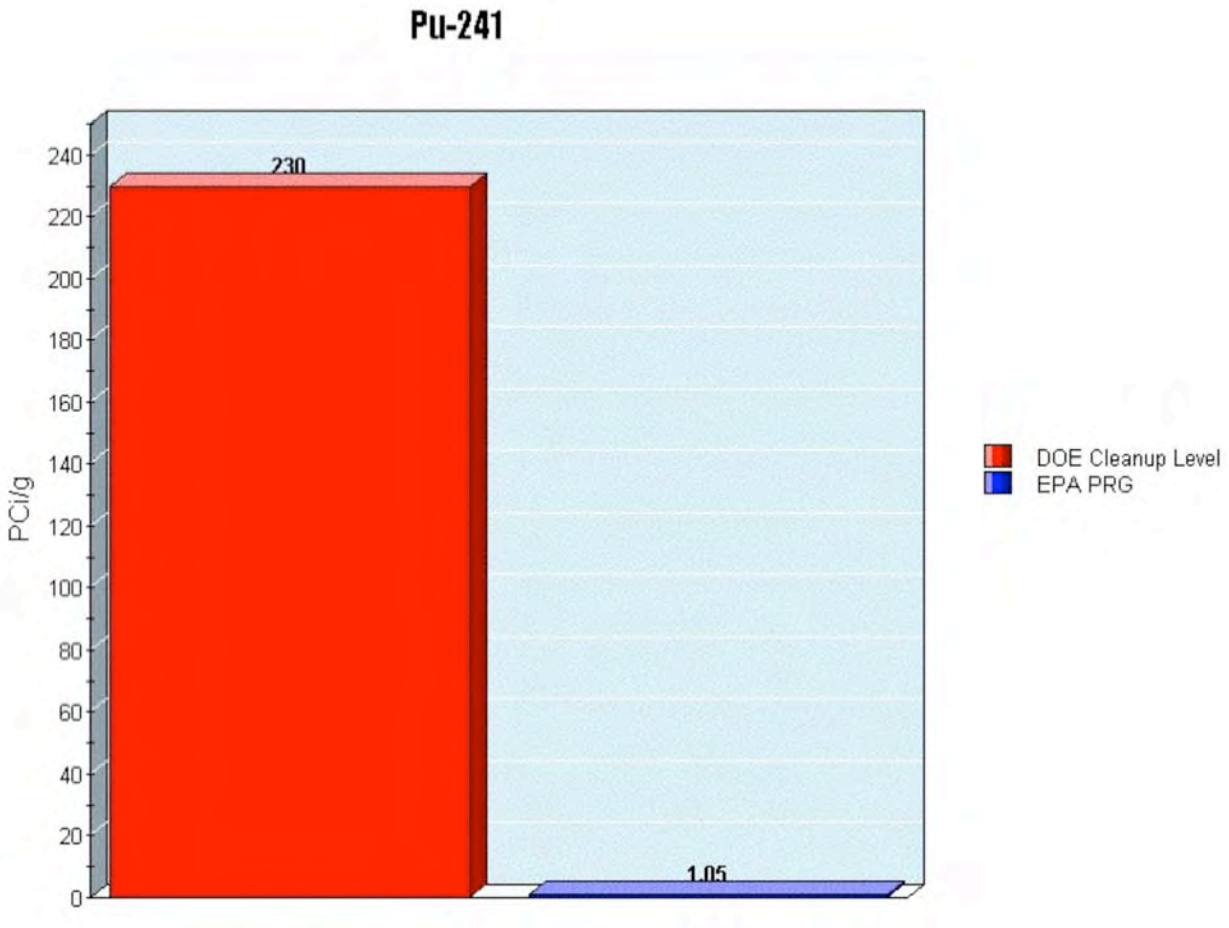
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



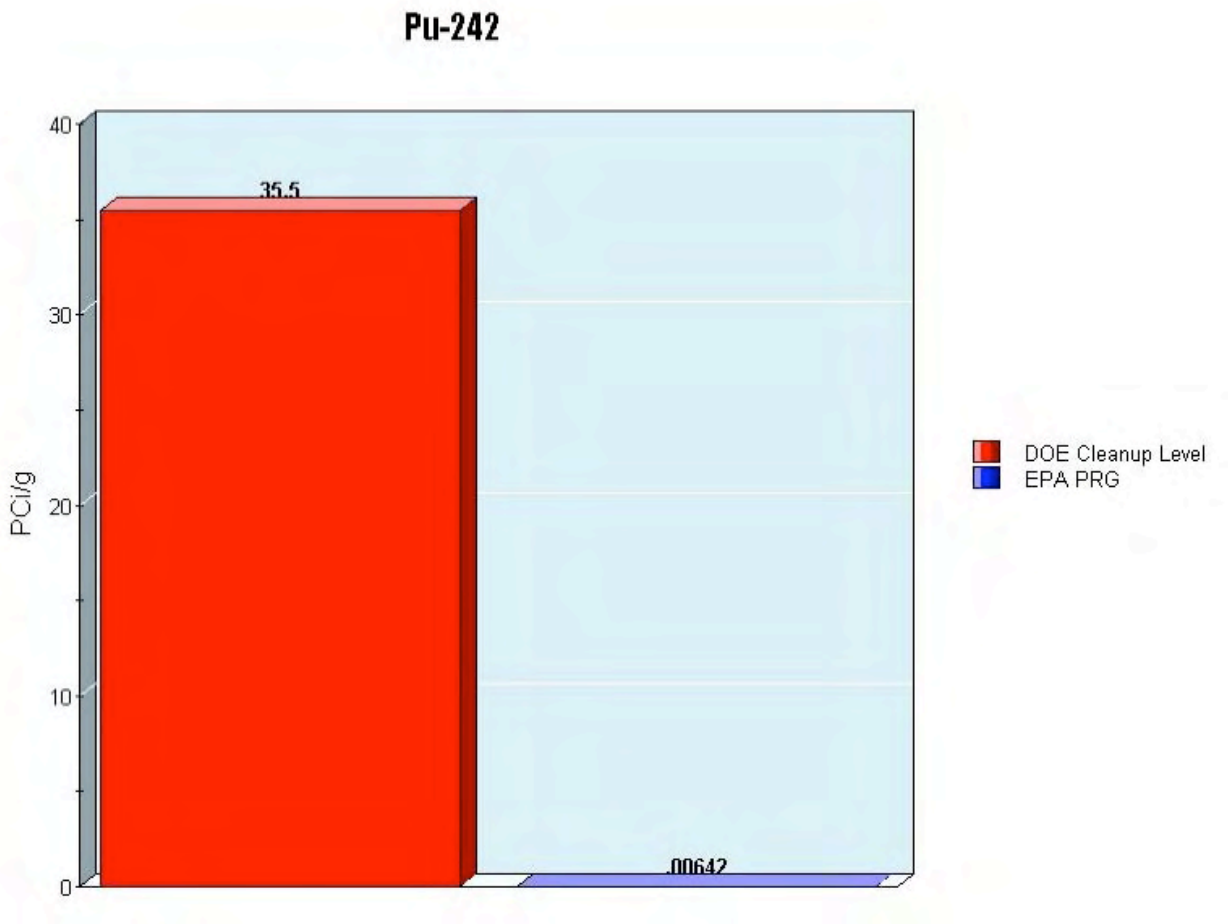
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



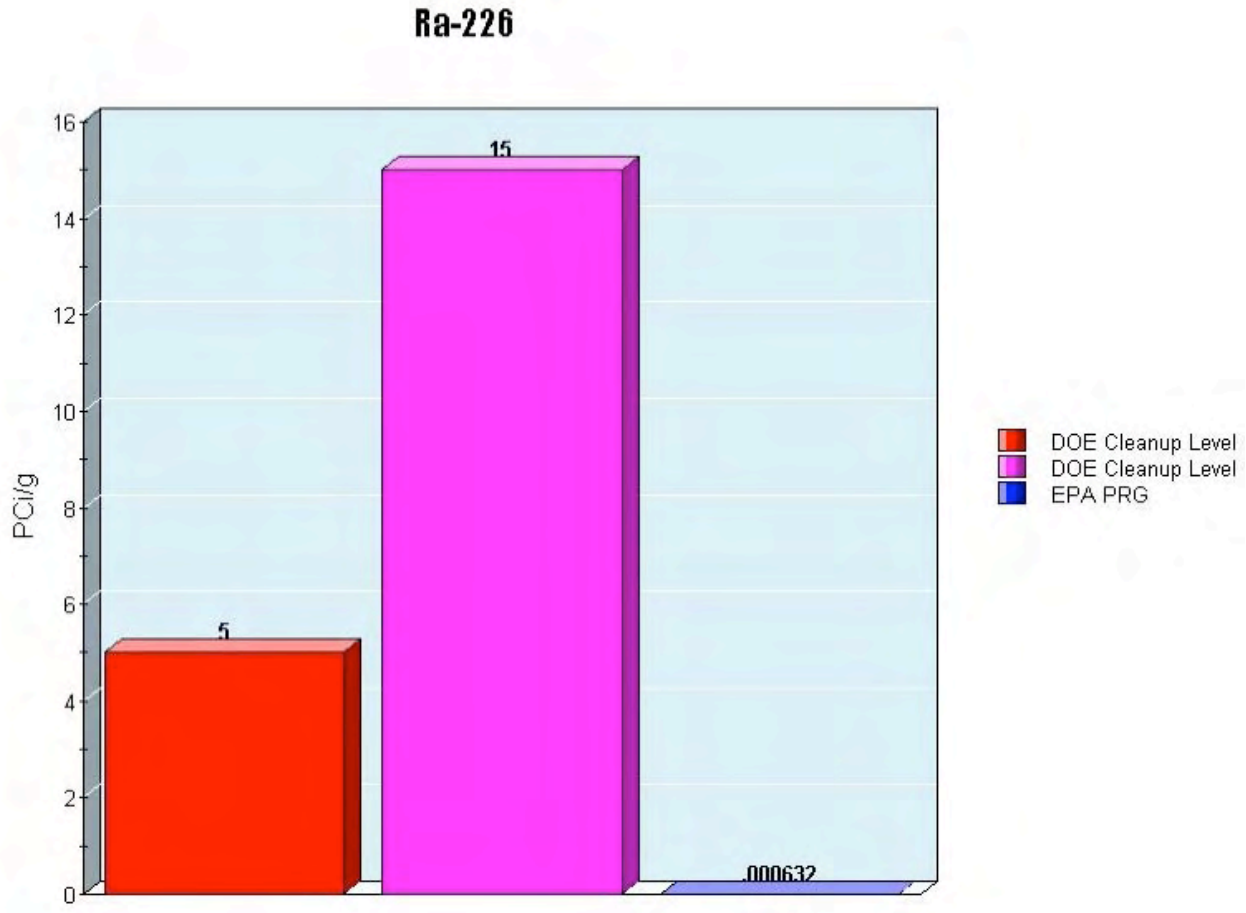
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



DOE Cleanup Standard EPA PRG

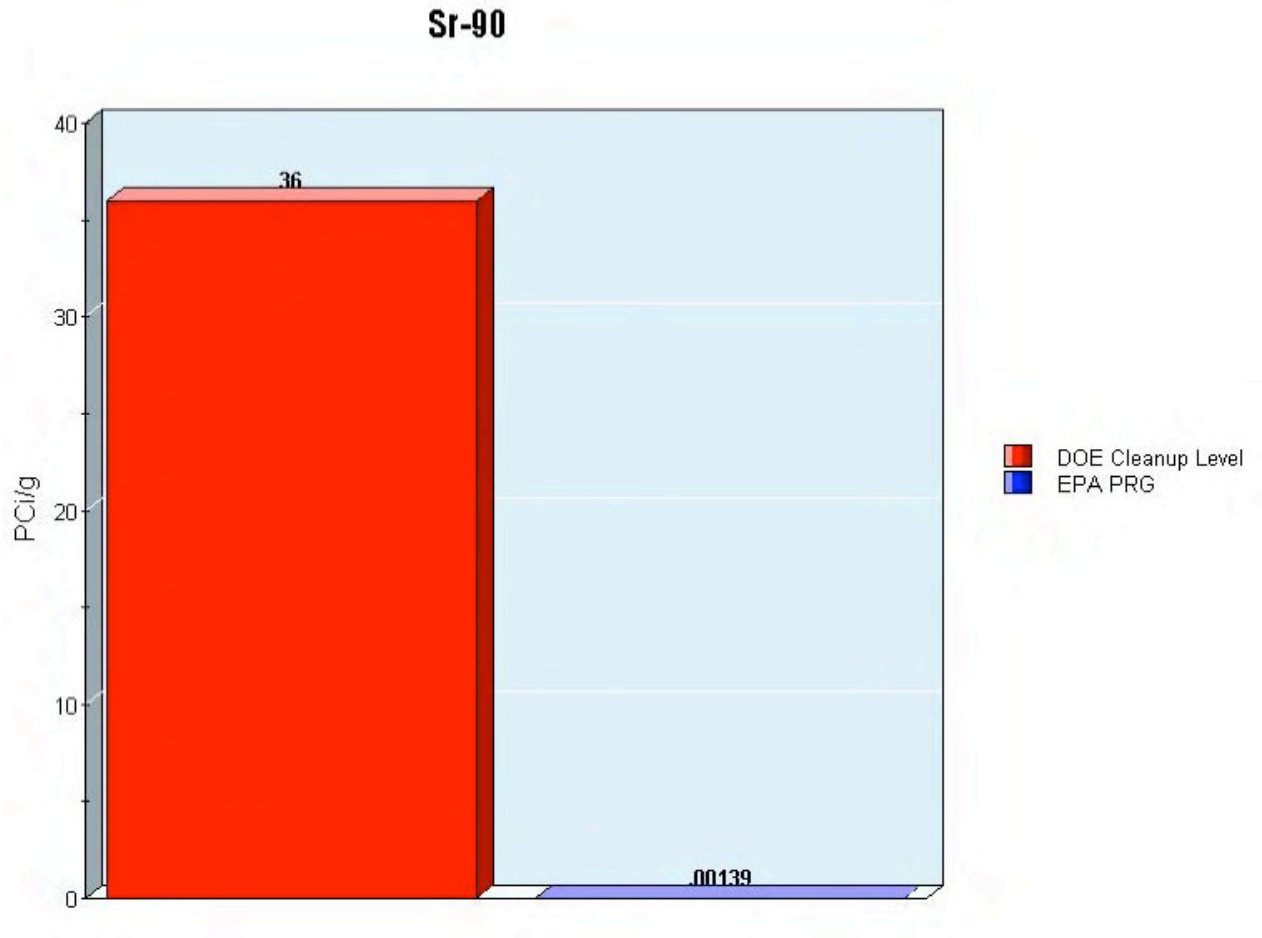
Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



DOE 5 pCi/g Cleanup Standard DOE 15 pCi/g EPA PRG

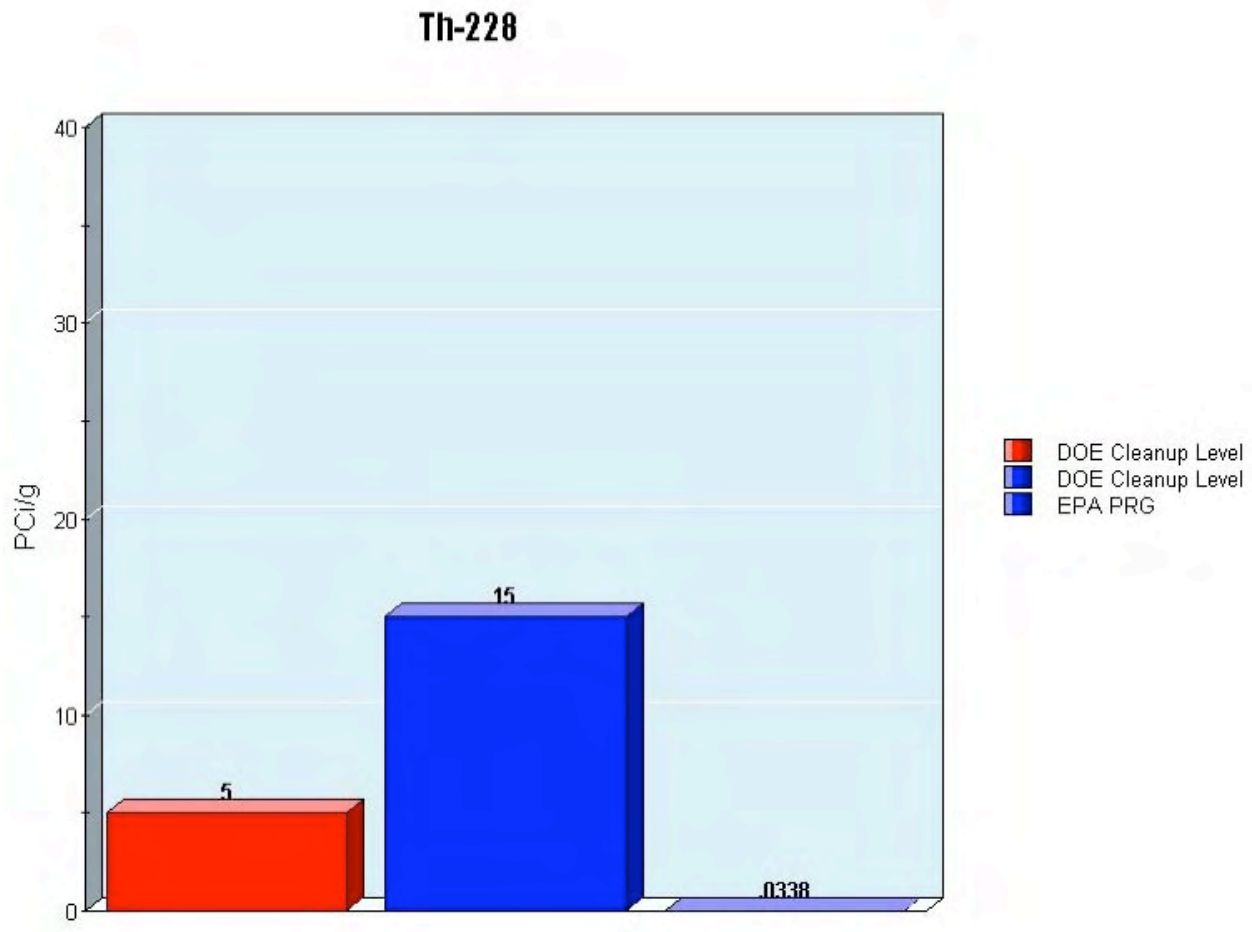
Note: DOE employs two different standards for radium-226, 5 pico-curies per gram (pCi/g) and 15 pCi/g, depending upon depth from the surface. For Ra-226, EPA will generally use the 5 pCi/g soil limit, as an Applicable or Relevant and Appropriate Requirement (ARAR) rather than its PRG.

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



DOE Cleanup Standard EPA PRG

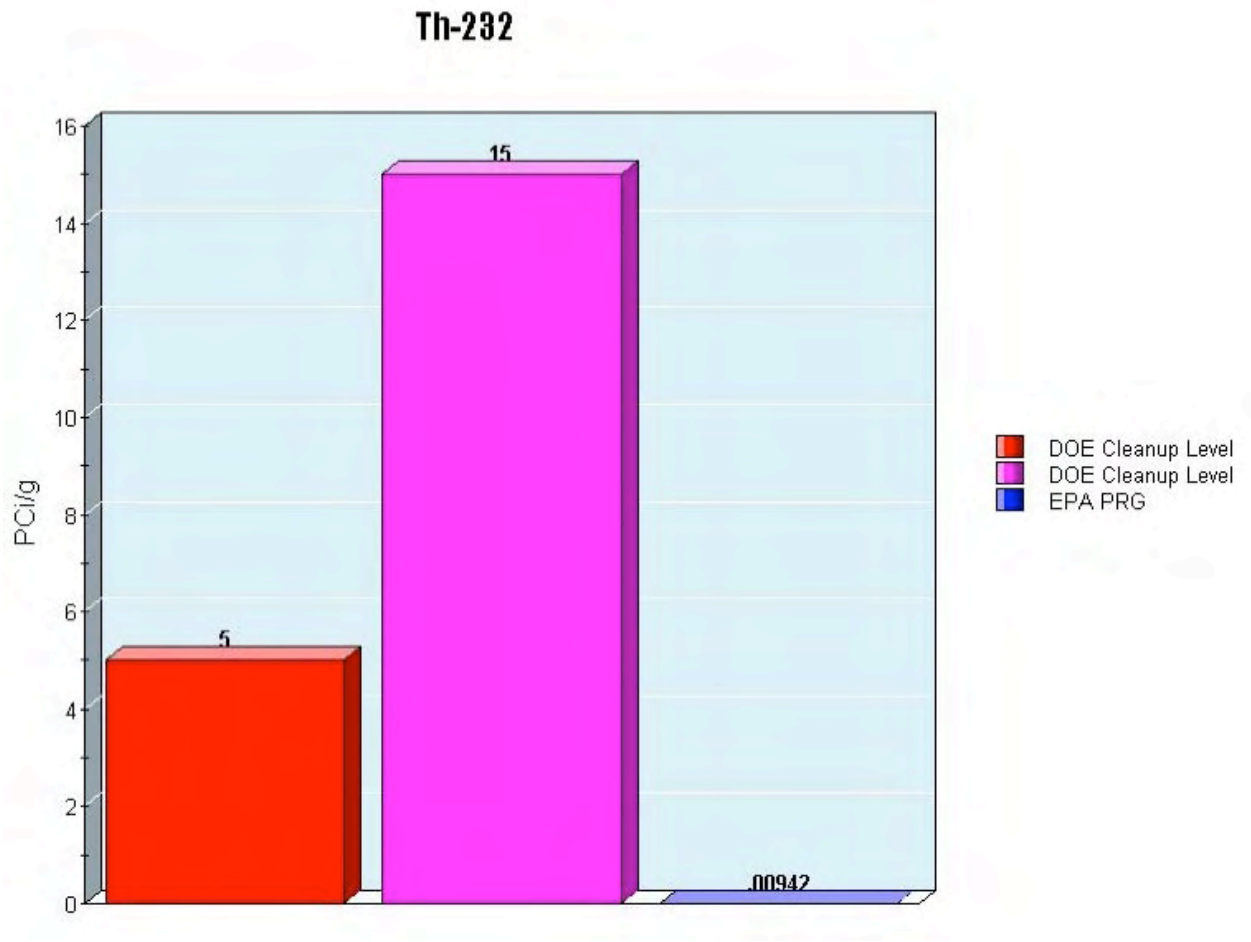
Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



DOE 5 pCi/g Cleanup Standard DOE 15 pCi/g EPA PRG

Note: DOE employs two different standards for thorium-228, 5 pico-curies per gram (pCi/g) and 15 pCi/g, depending upon depth from the surface. For Th-228, EPA will generally use the 5 pCi/g soil limit, as an Applicable or Relevant and Appropriate Requirement (ARAR), rather than its PRG.

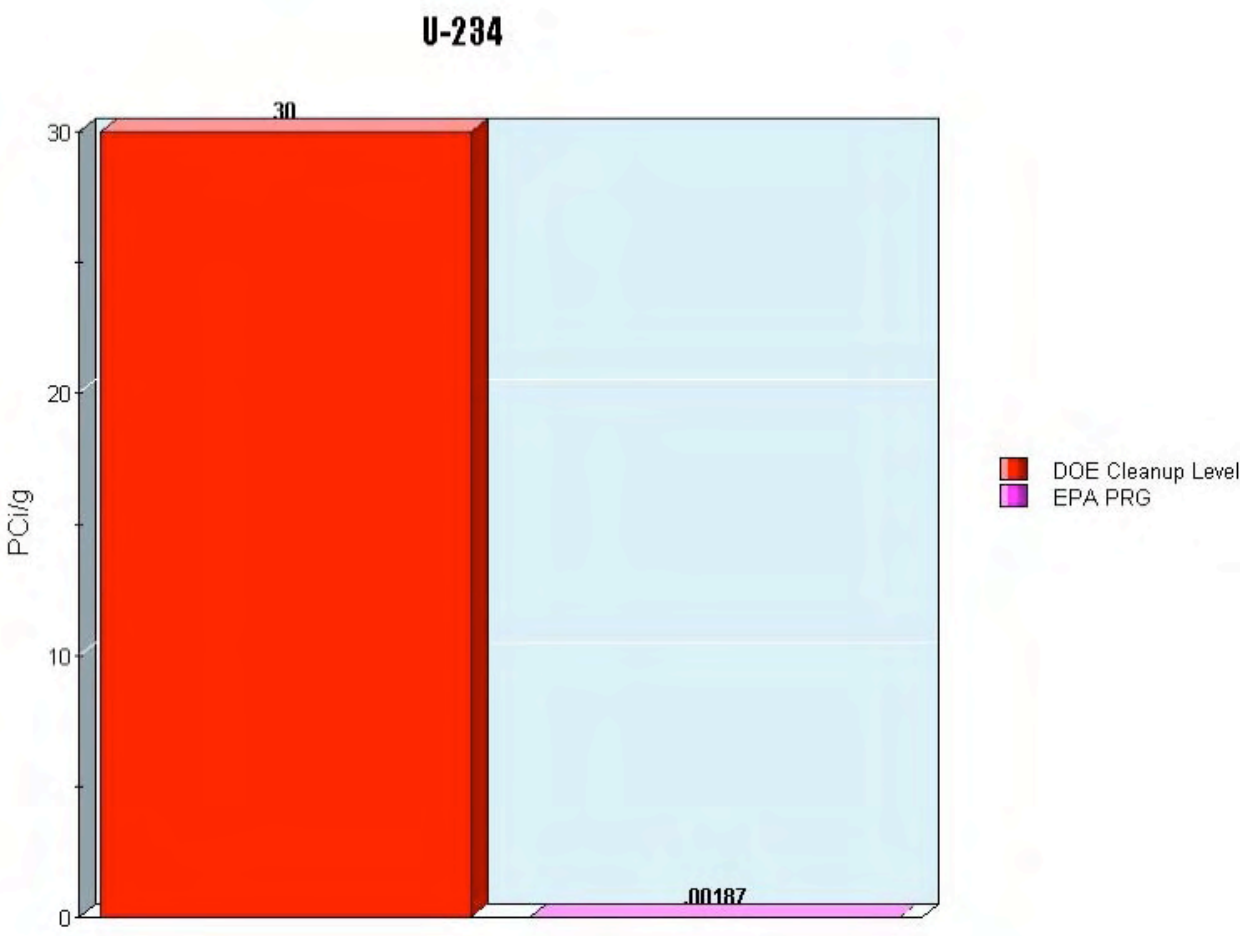
Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



DOE 5 pCi/g Cleanup Standard DOE 15 pCi/g EPA PRG

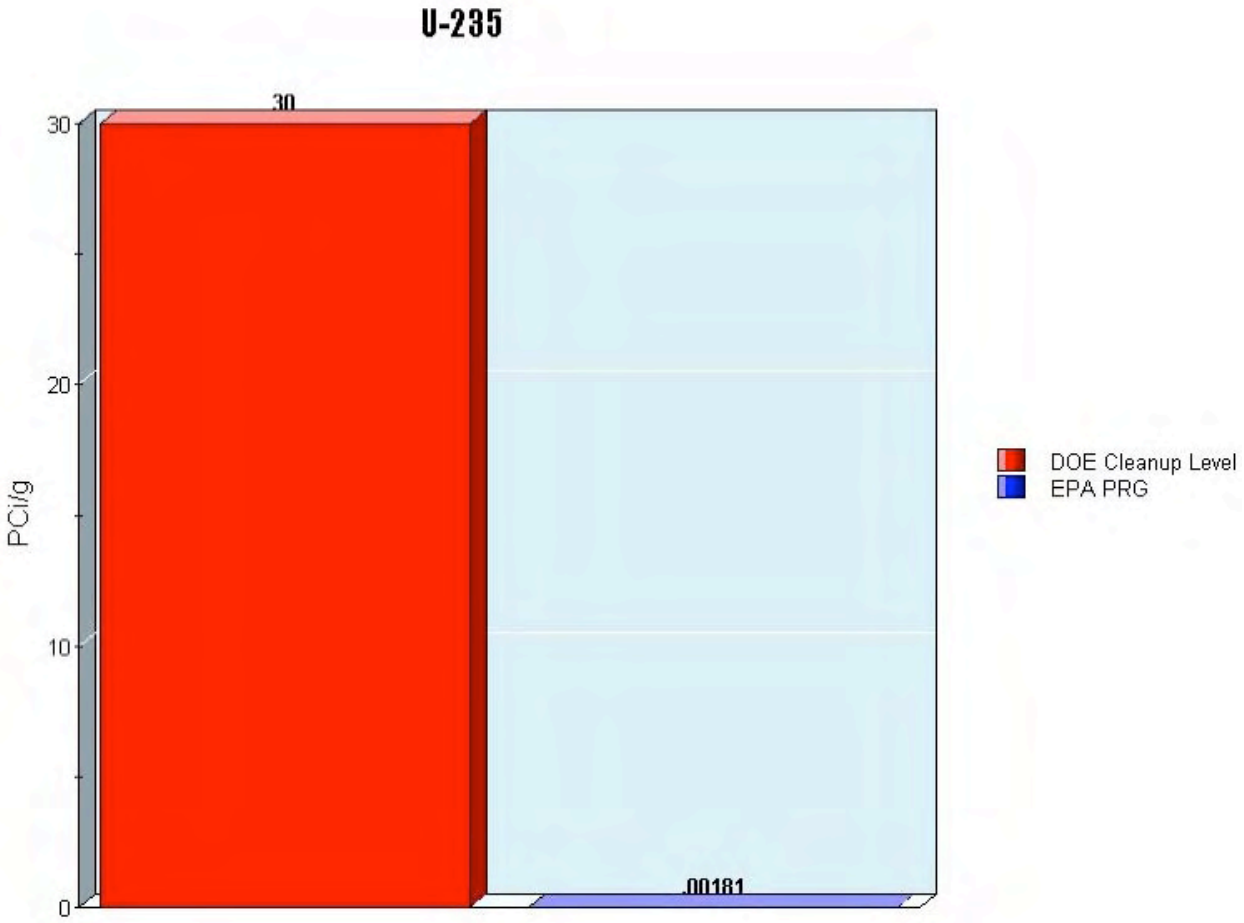
Note: DOE employs two different standards for thorium-232, 5 pico-curies per gram (pCi/g) and 15 pCi/g, depending upon depth from the surface. For Th-232, EPA will generally use the 5 pCi/g soil limit, as an Applicable or Relevant and Appropriate Requirement (ARAR), rather than its PRG.

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



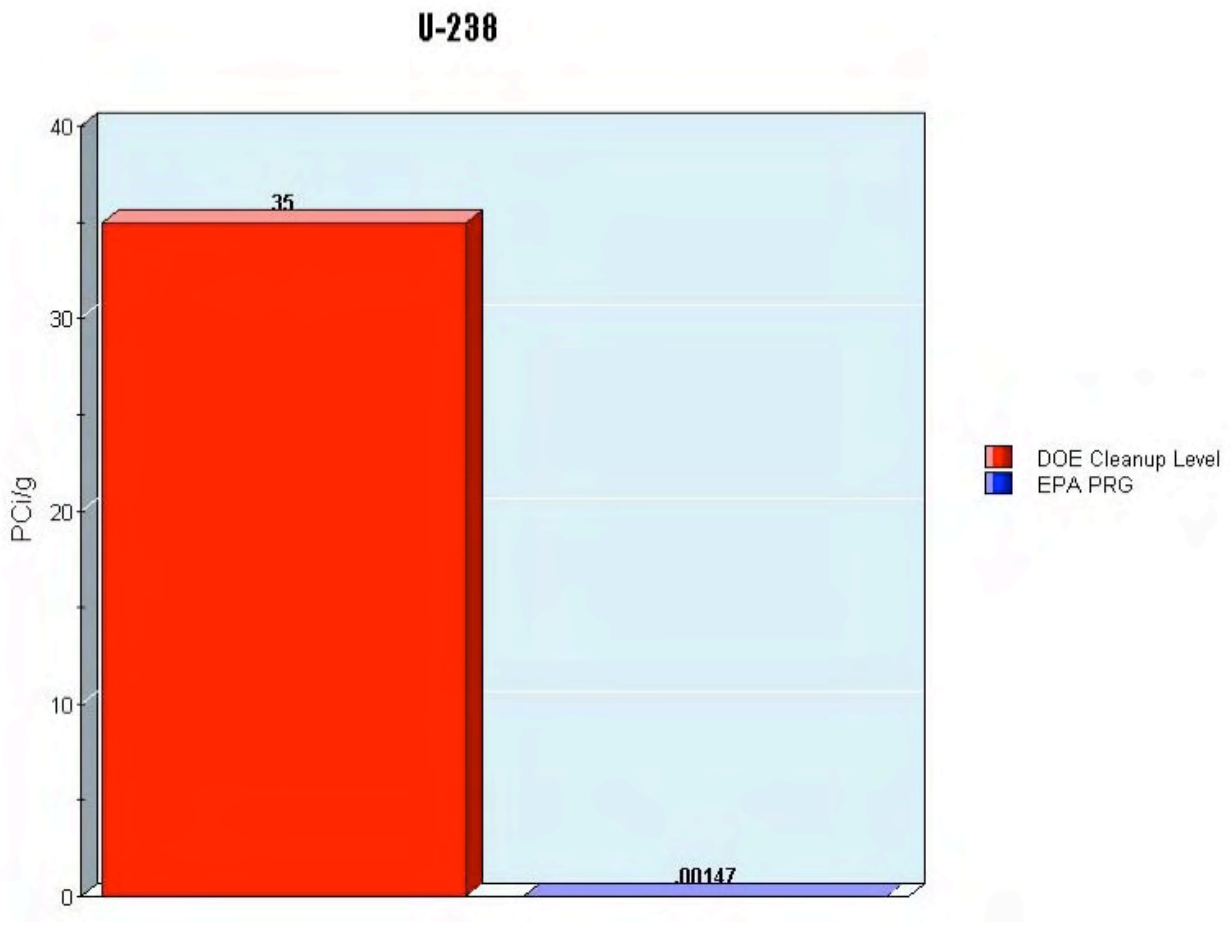
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



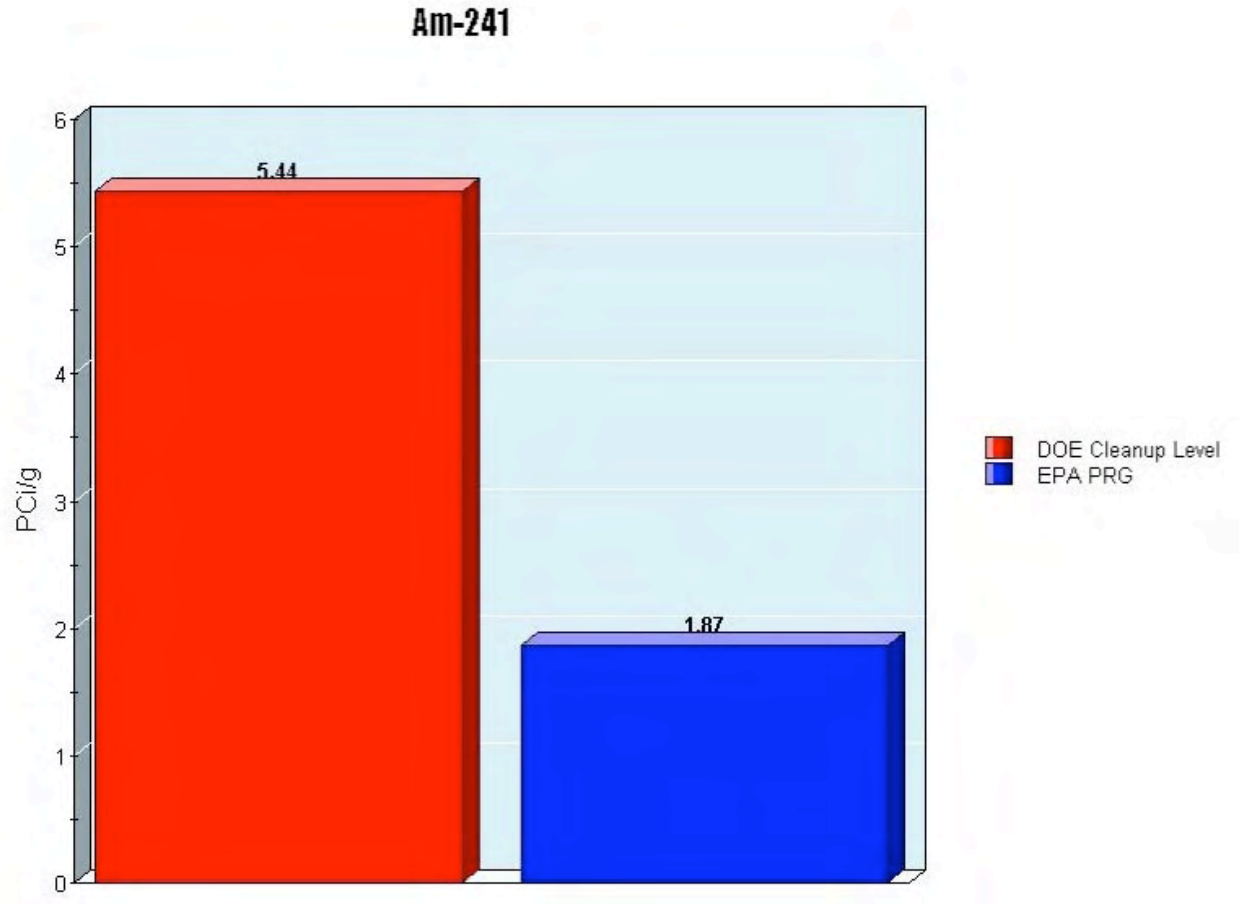
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals

SET B

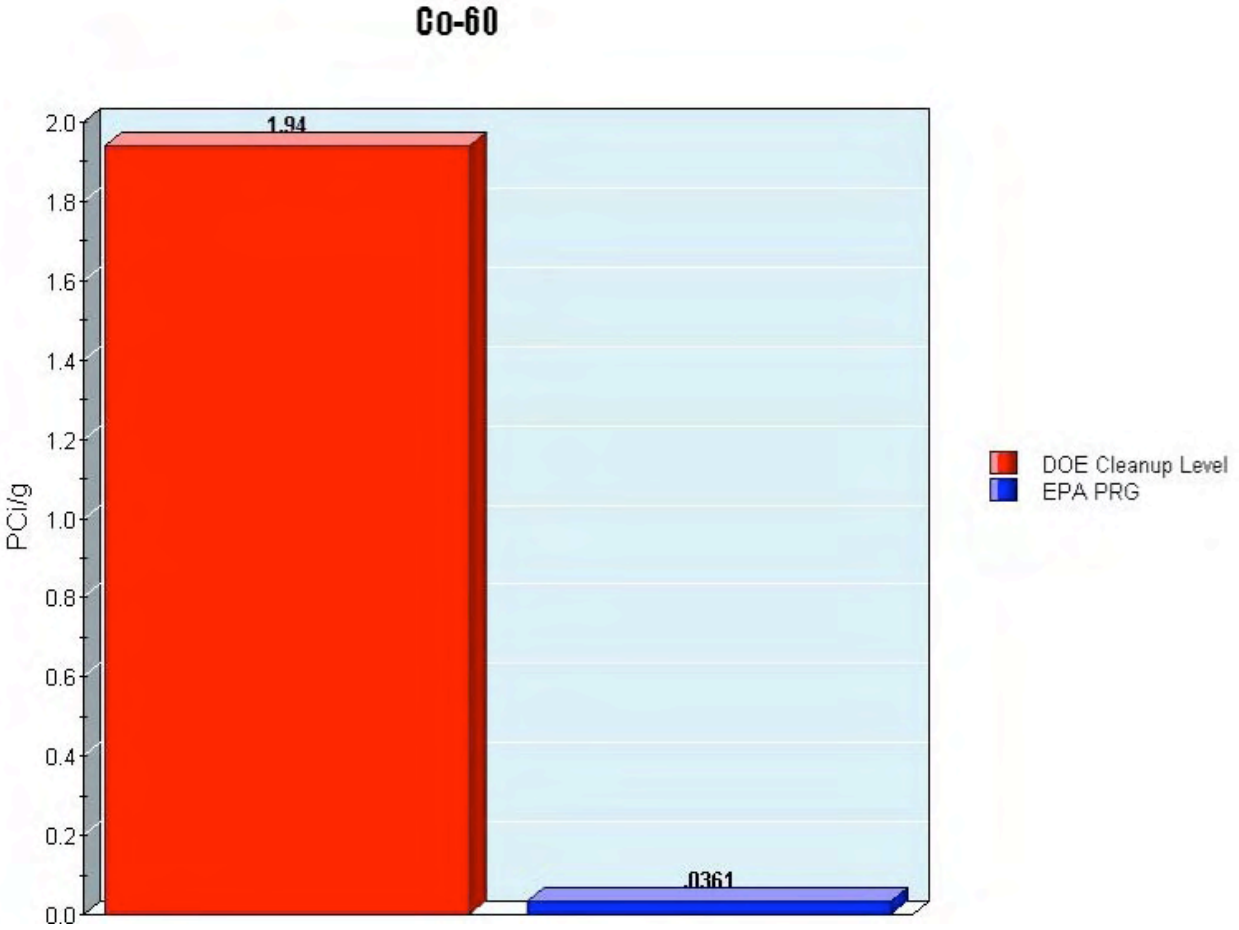
Suburban Residential Exposure Pathway

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



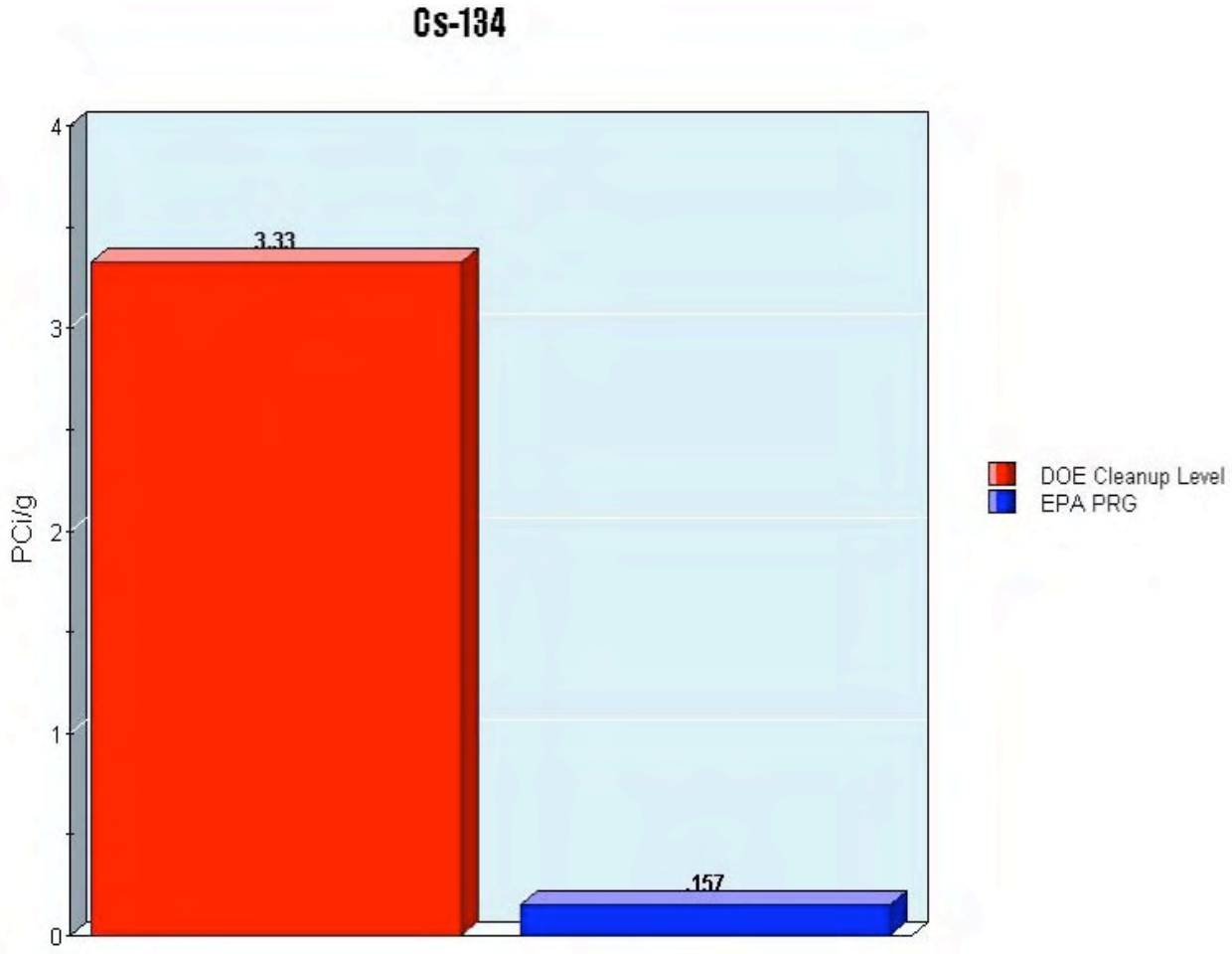
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



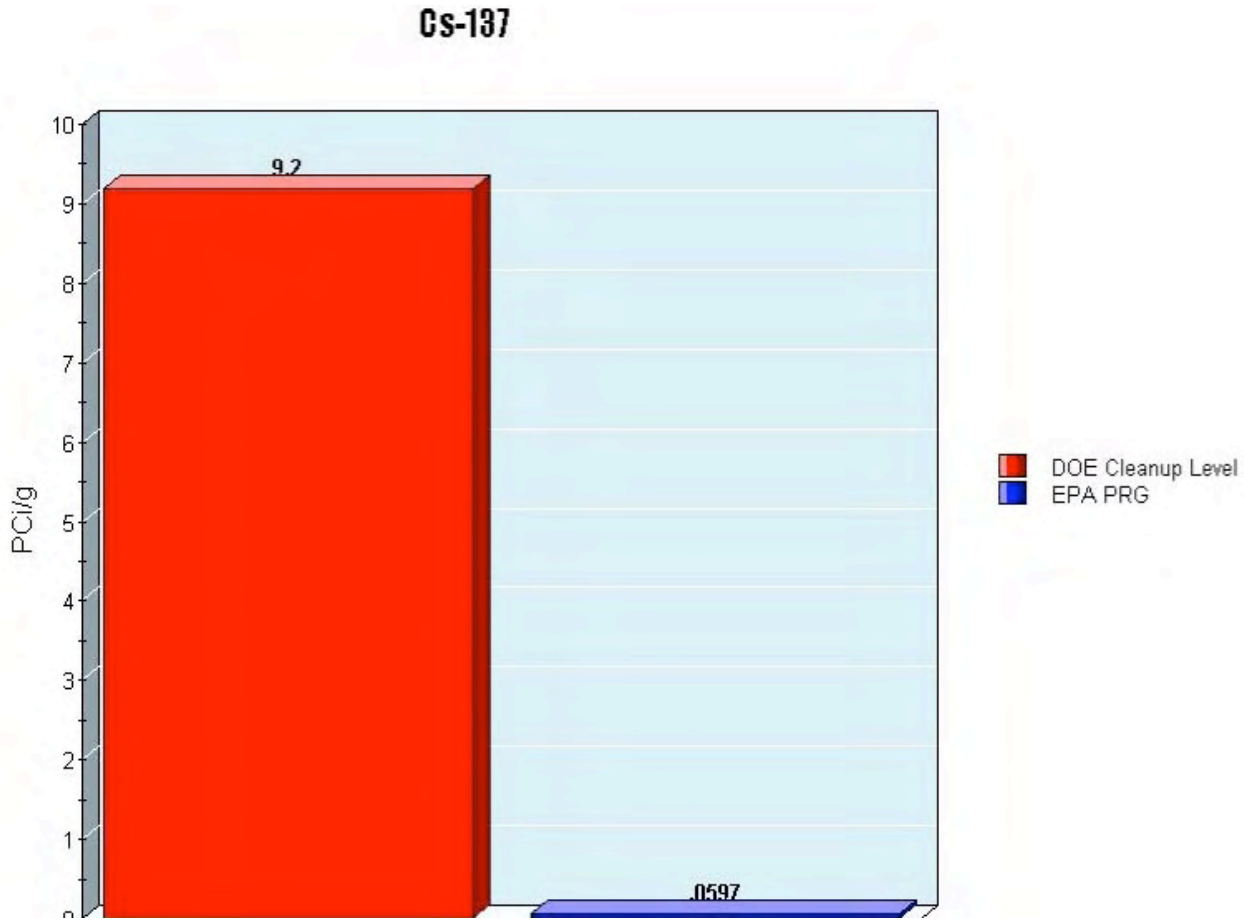
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



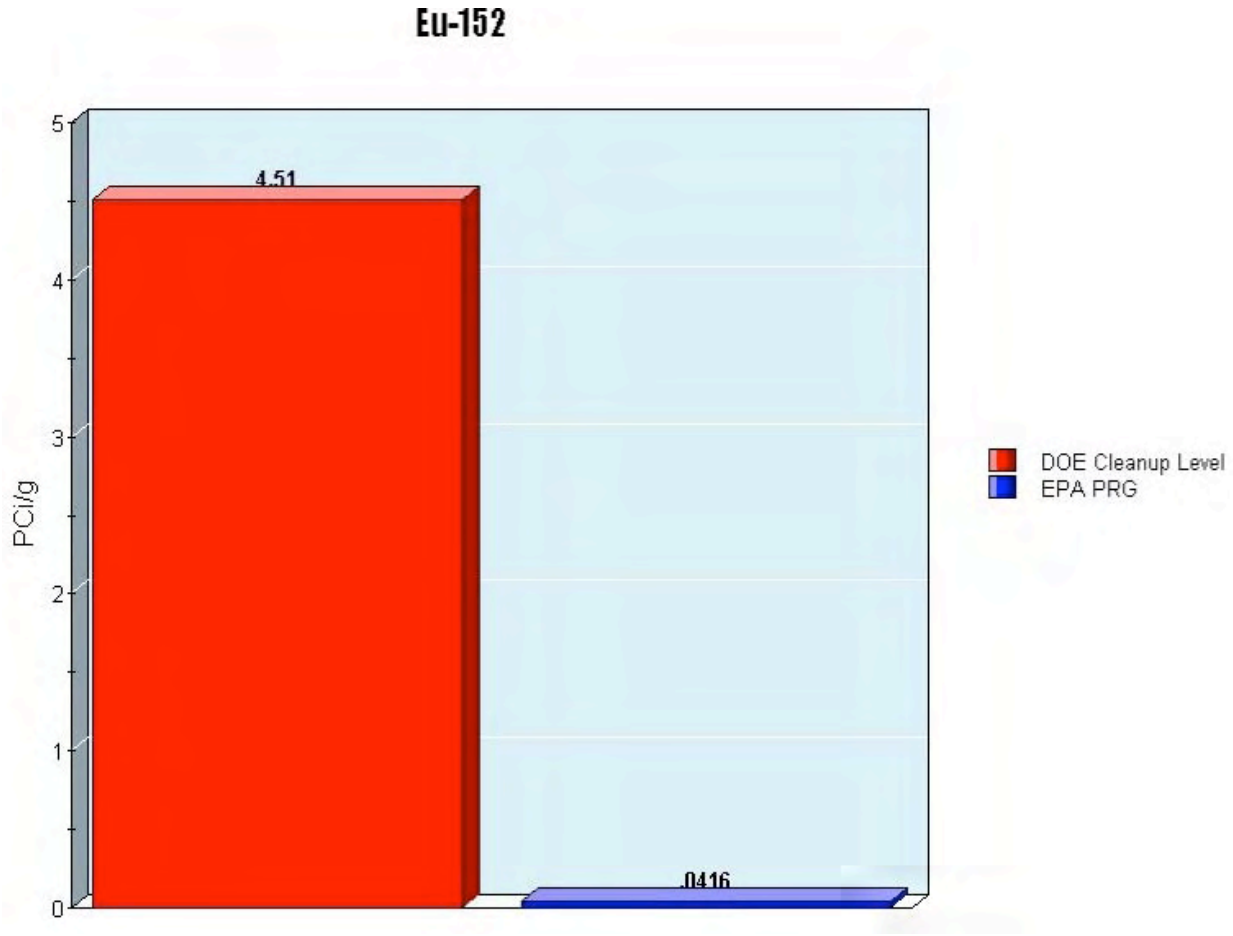
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



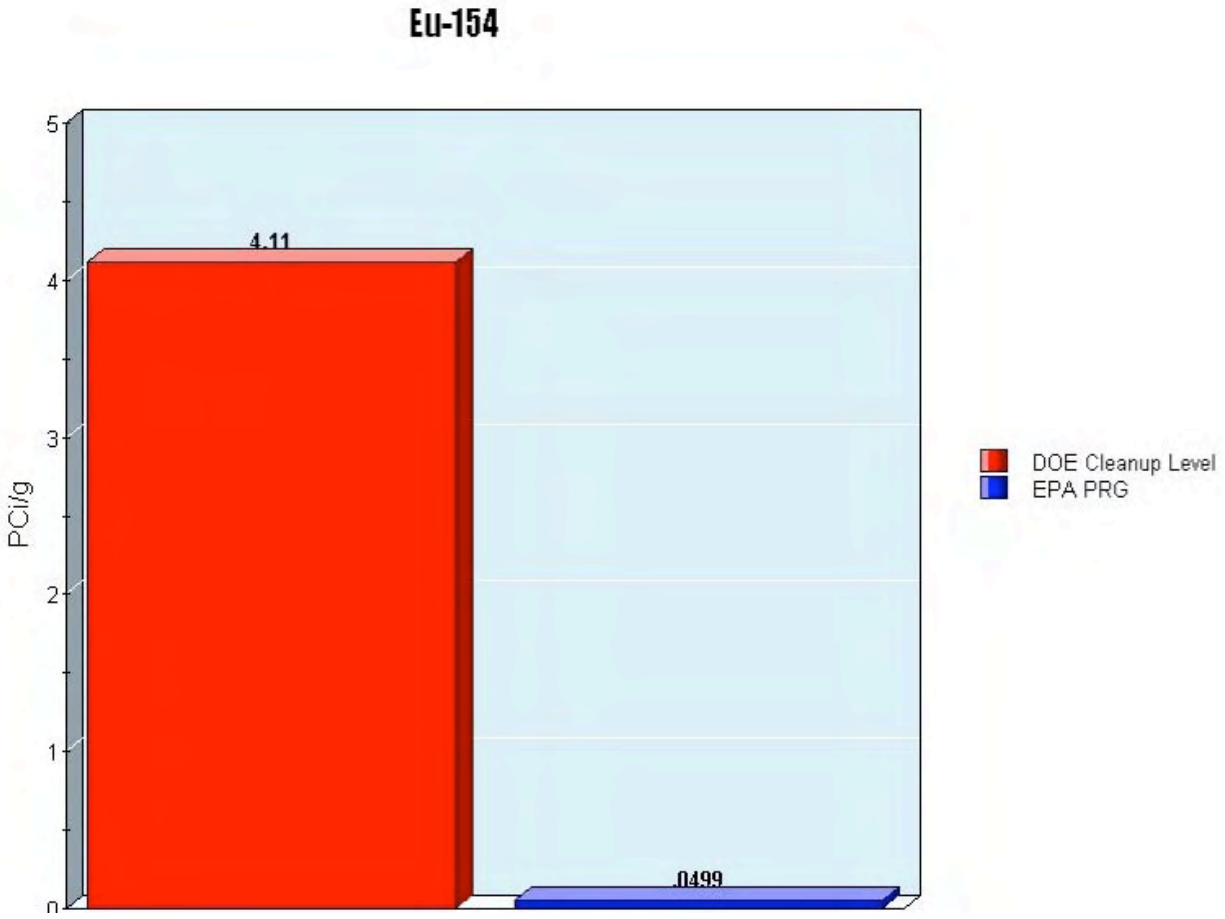
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



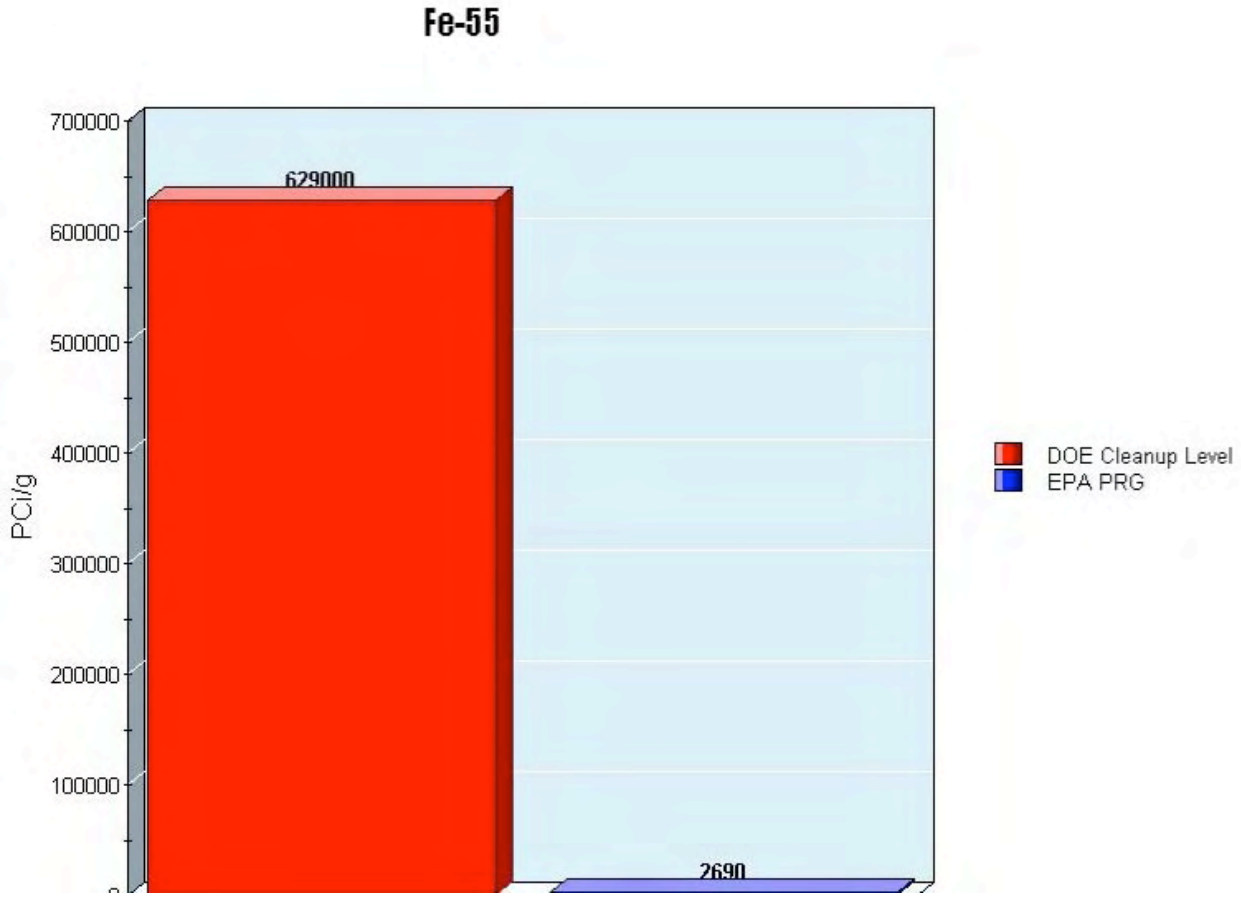
DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



DOE Cleanup Standard EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



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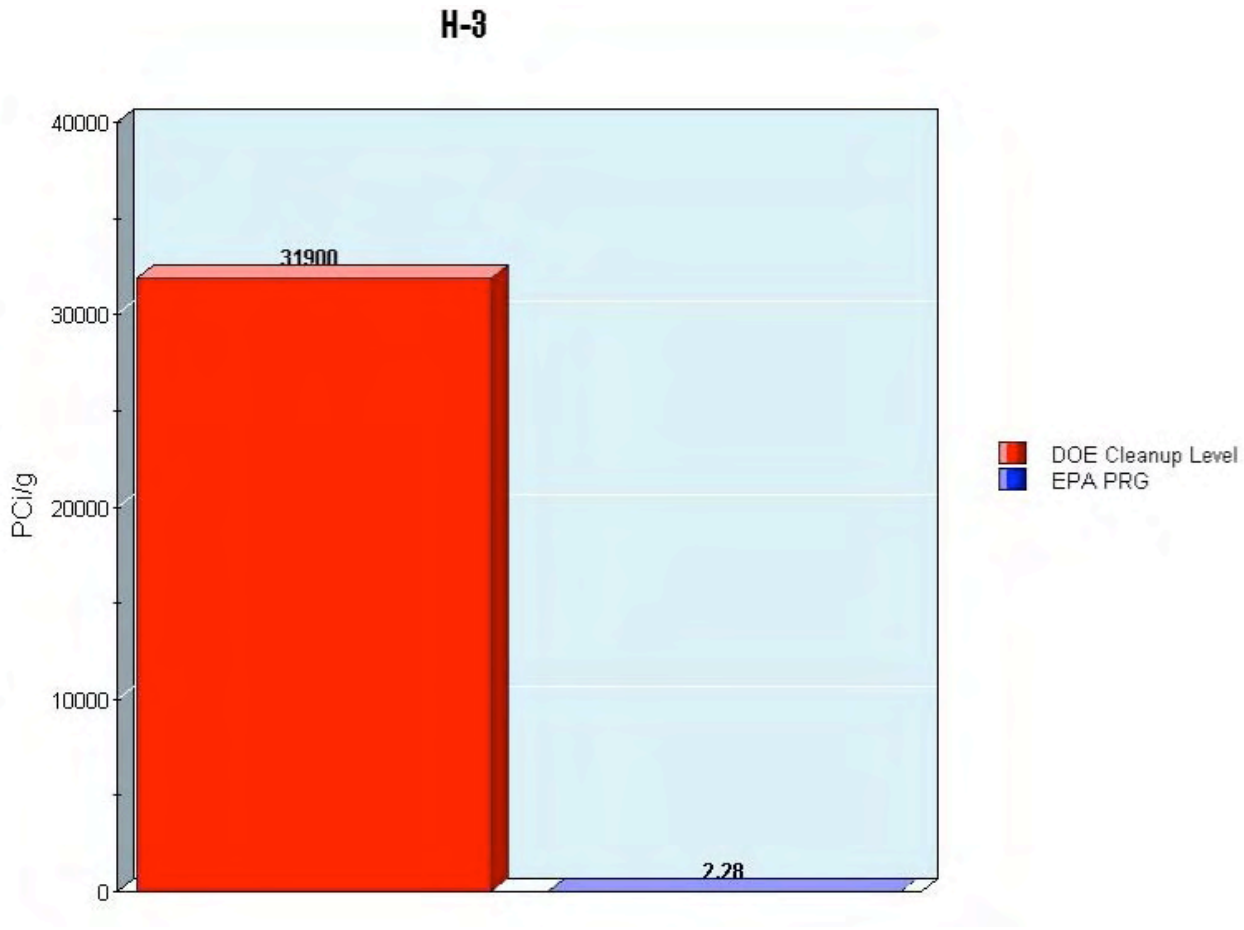

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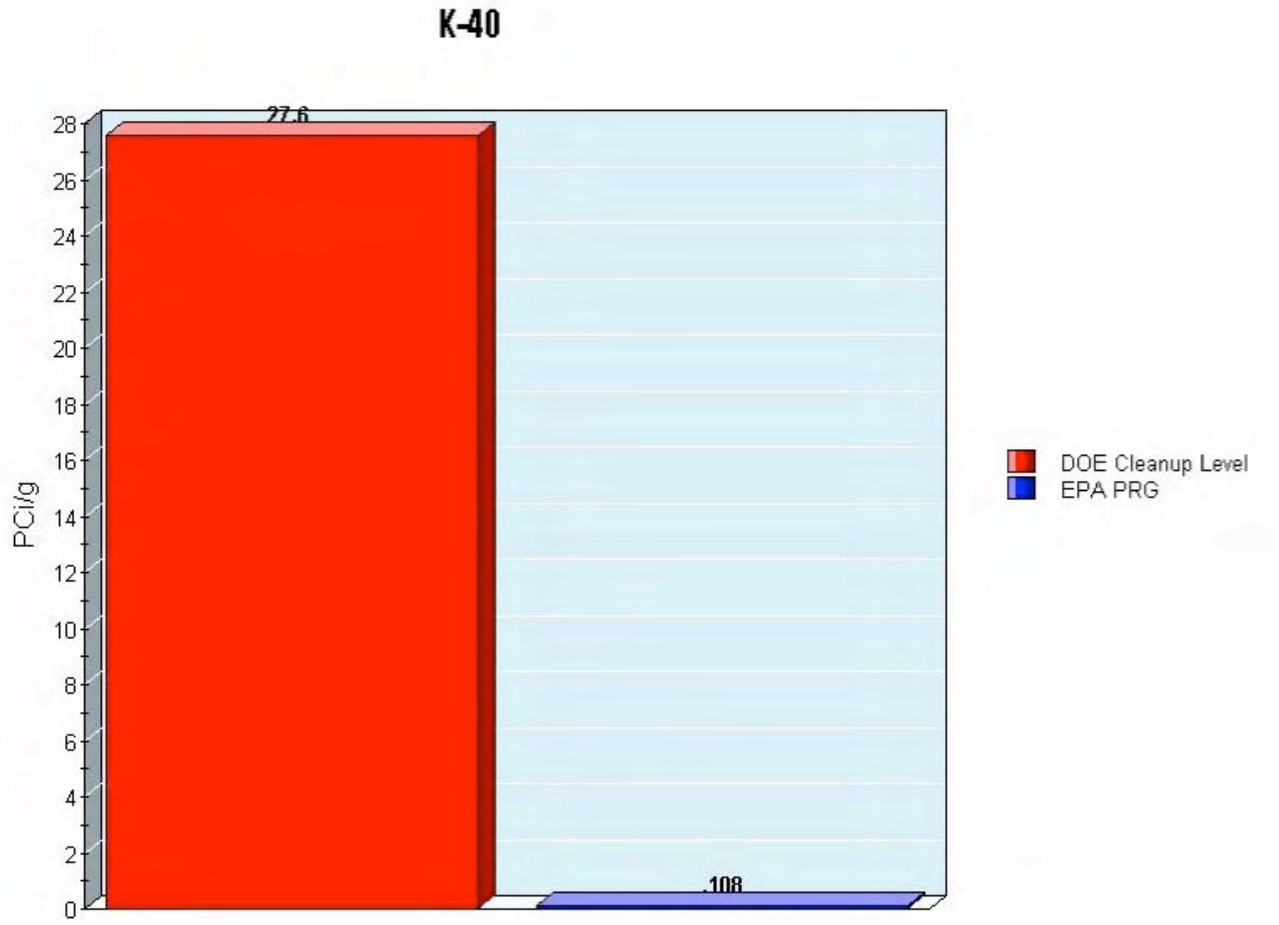

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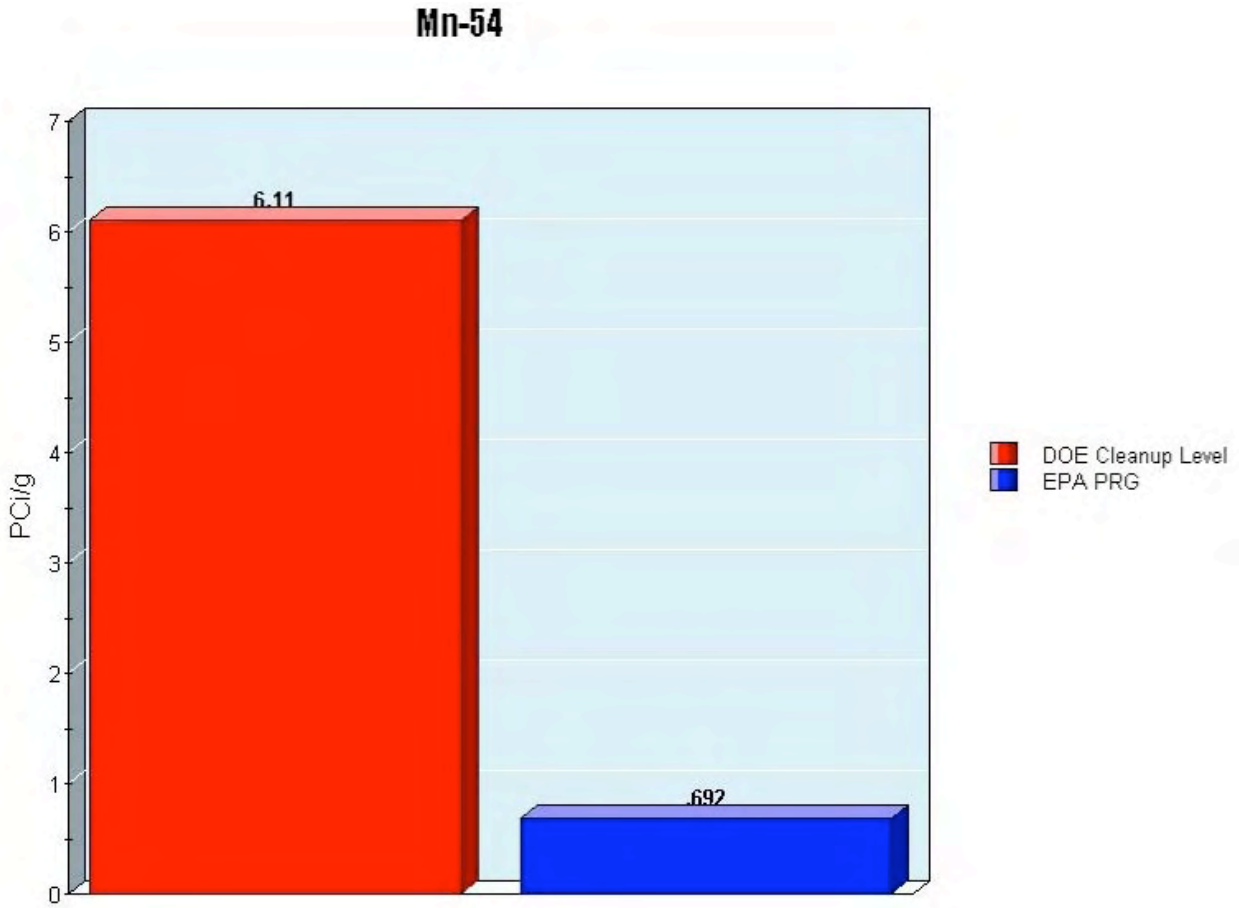

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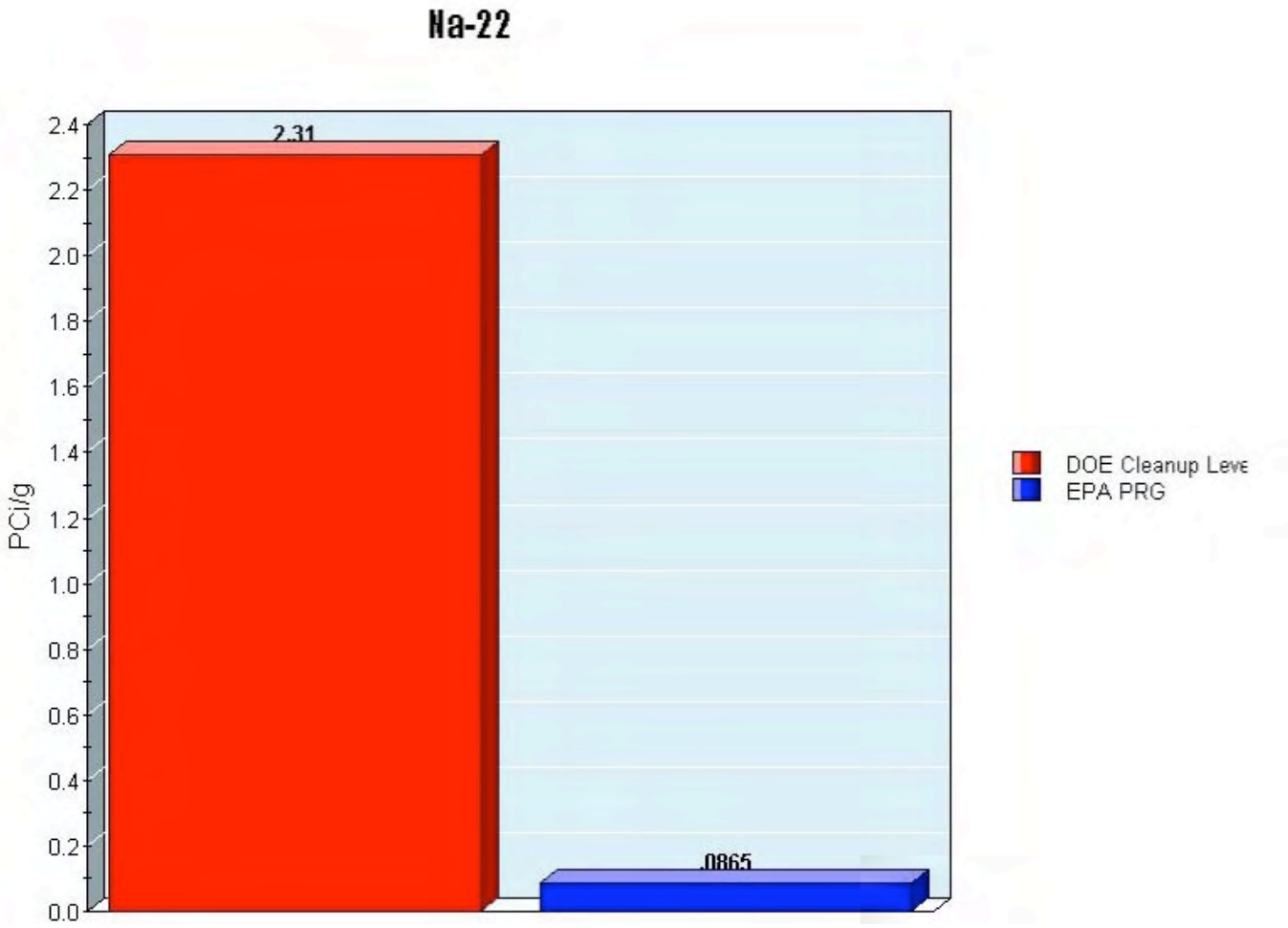

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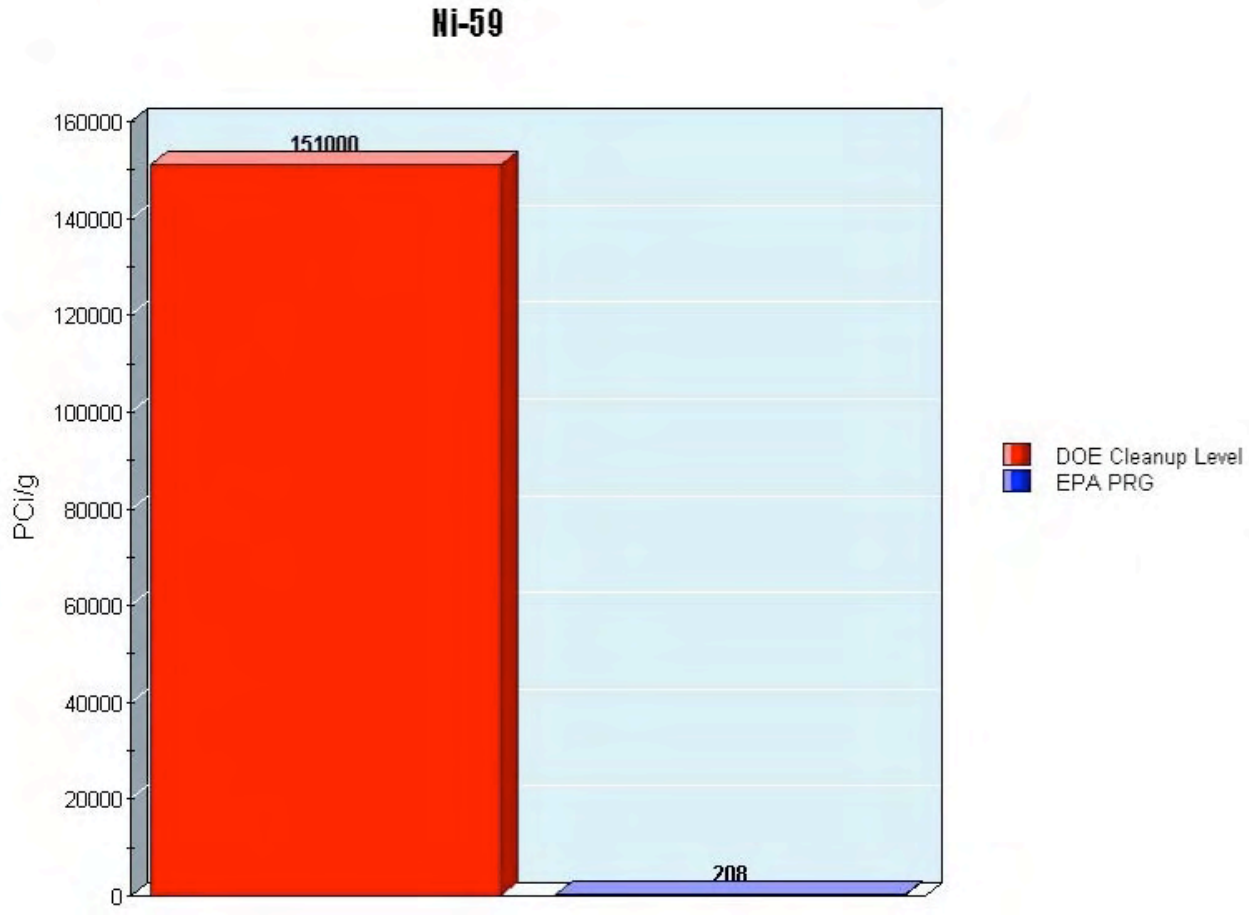

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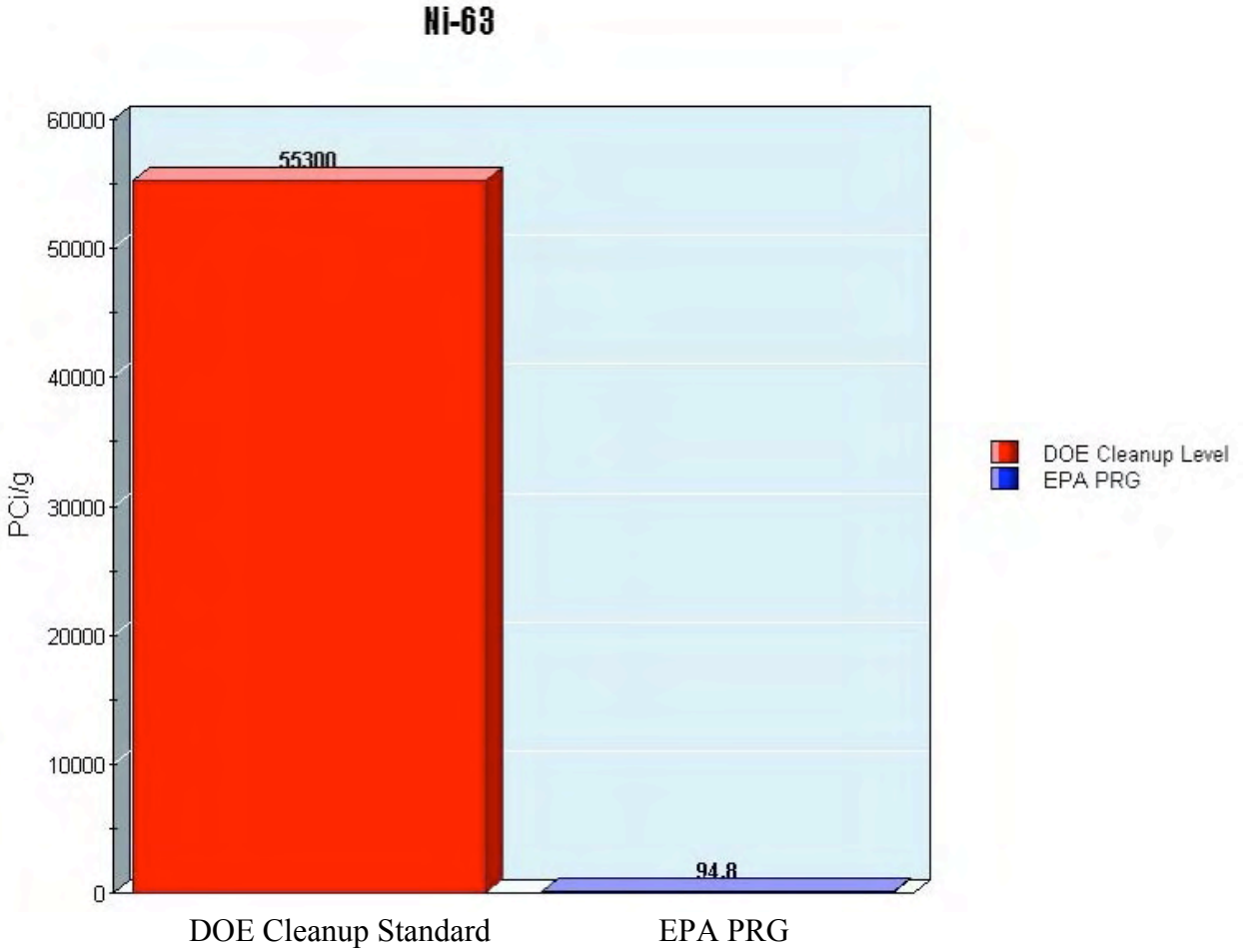

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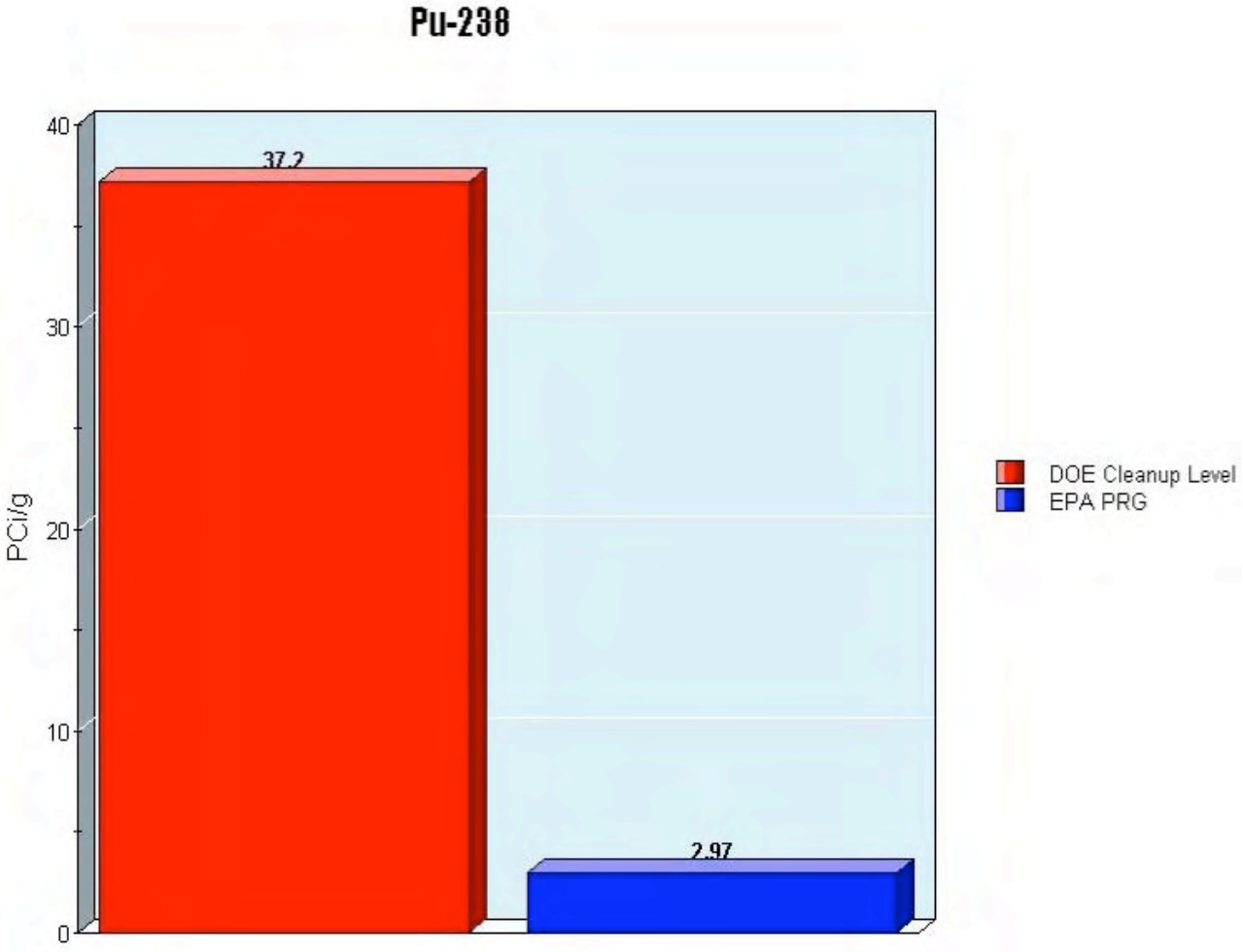

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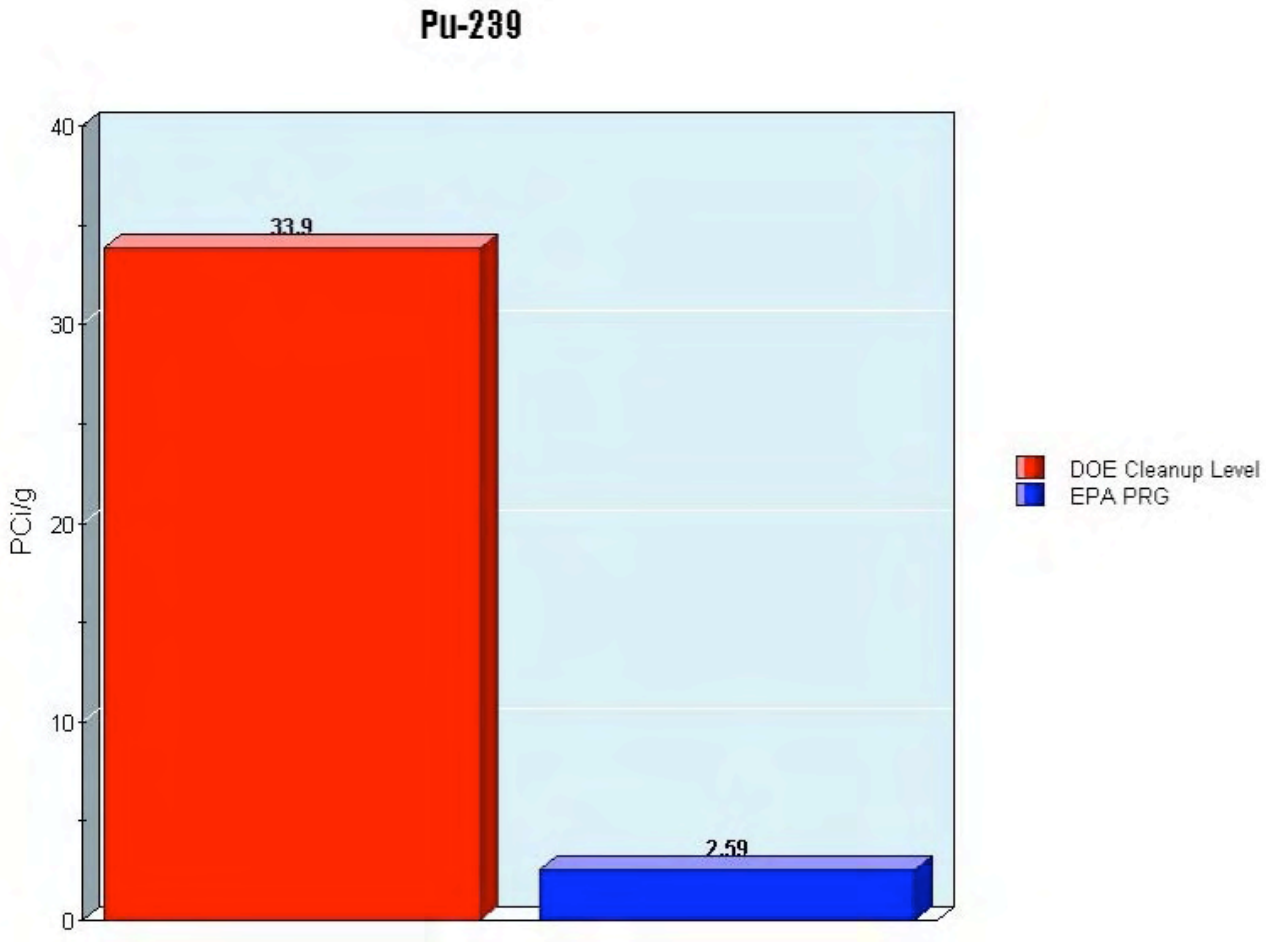

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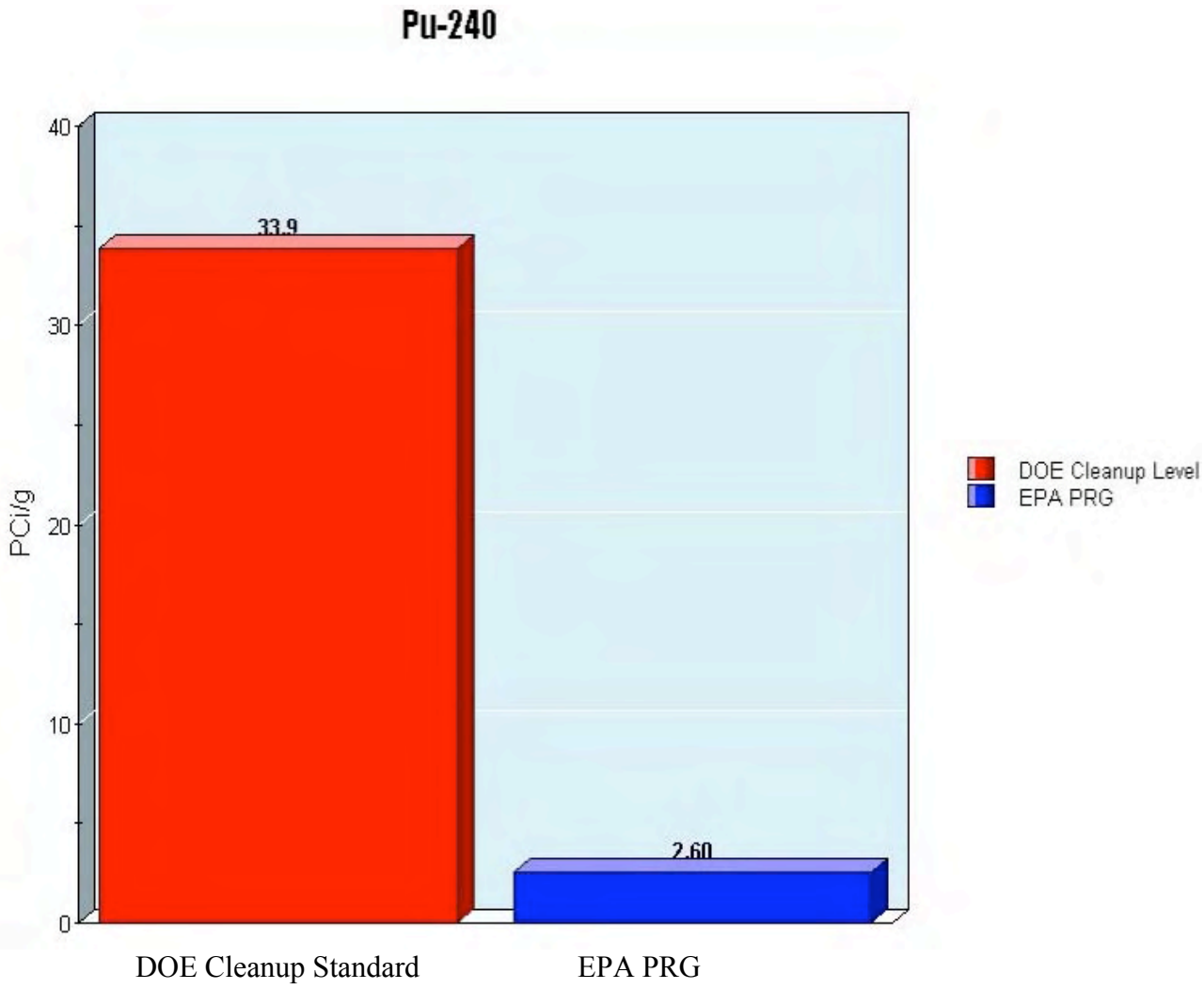

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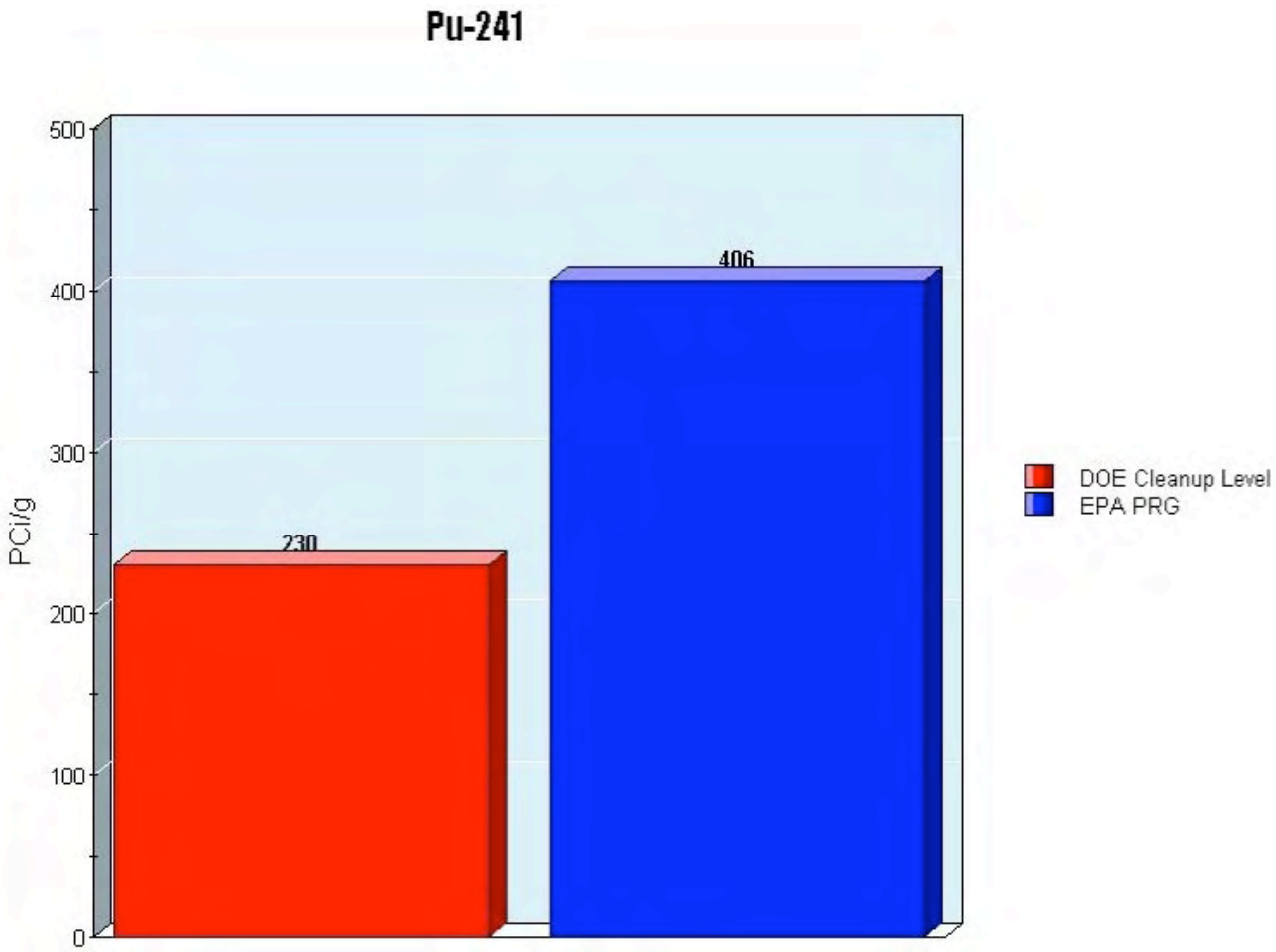

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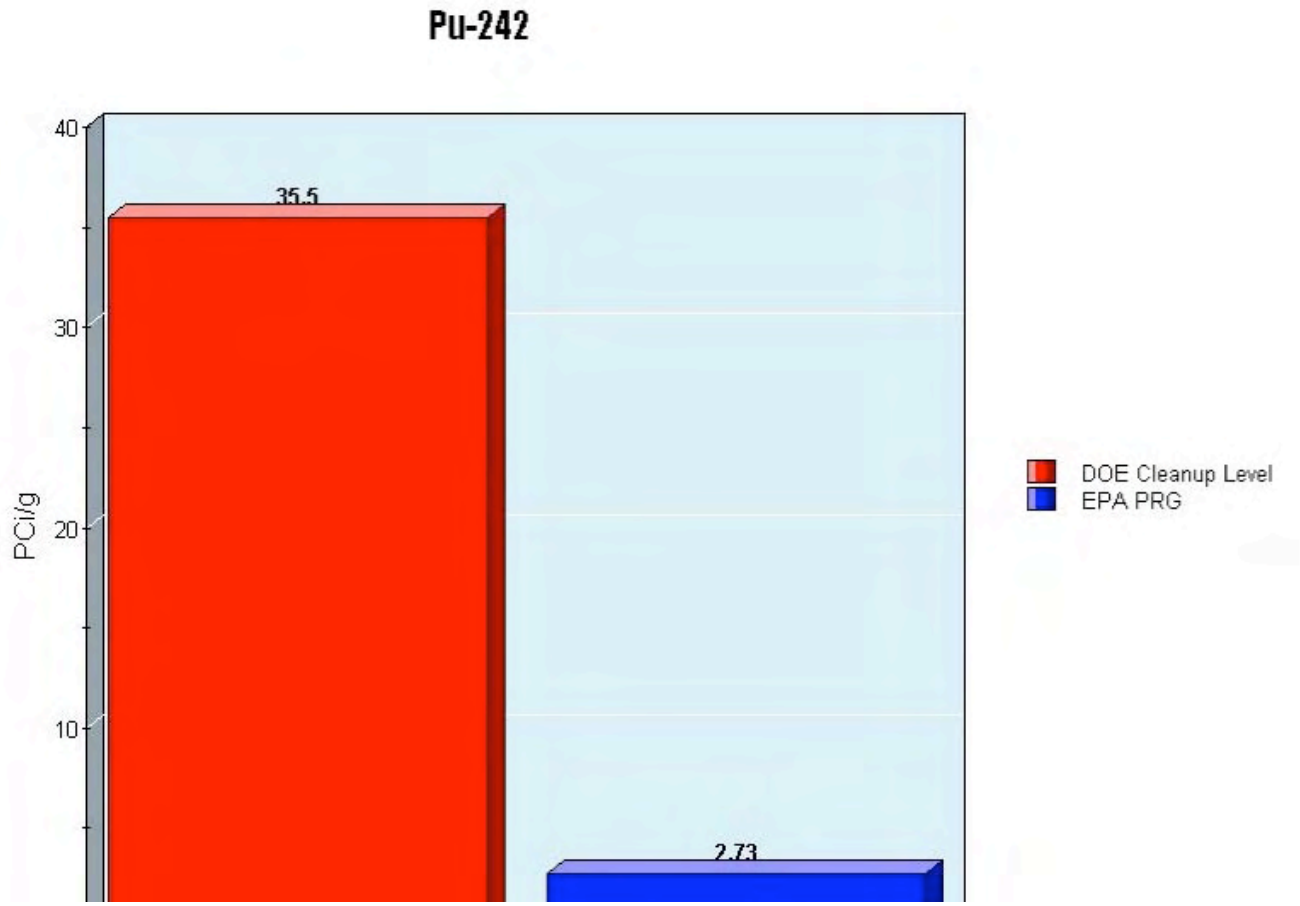

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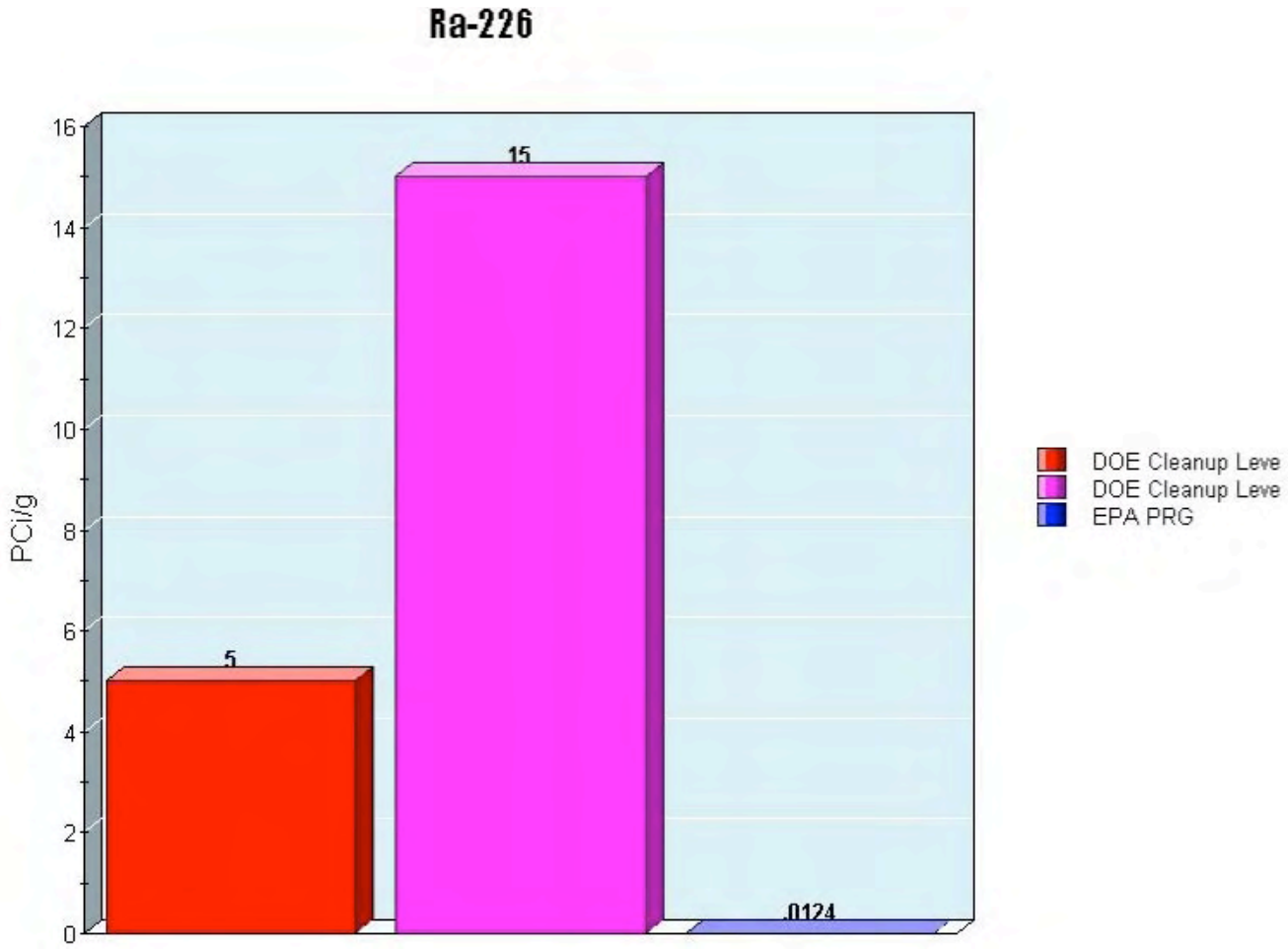
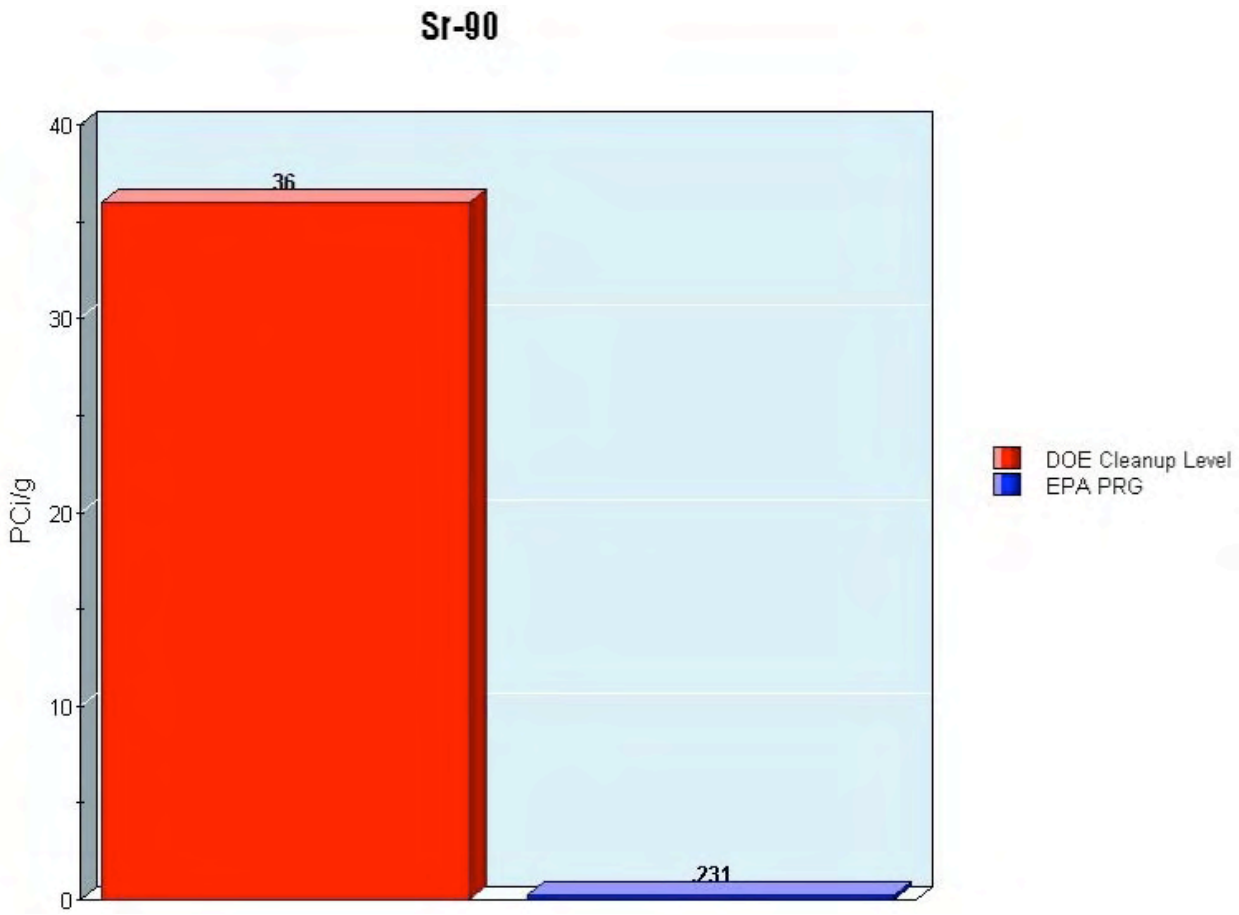


DOE 5 pCi/g Cleanup Standard DOE 15 pCi/g EPA PRG

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



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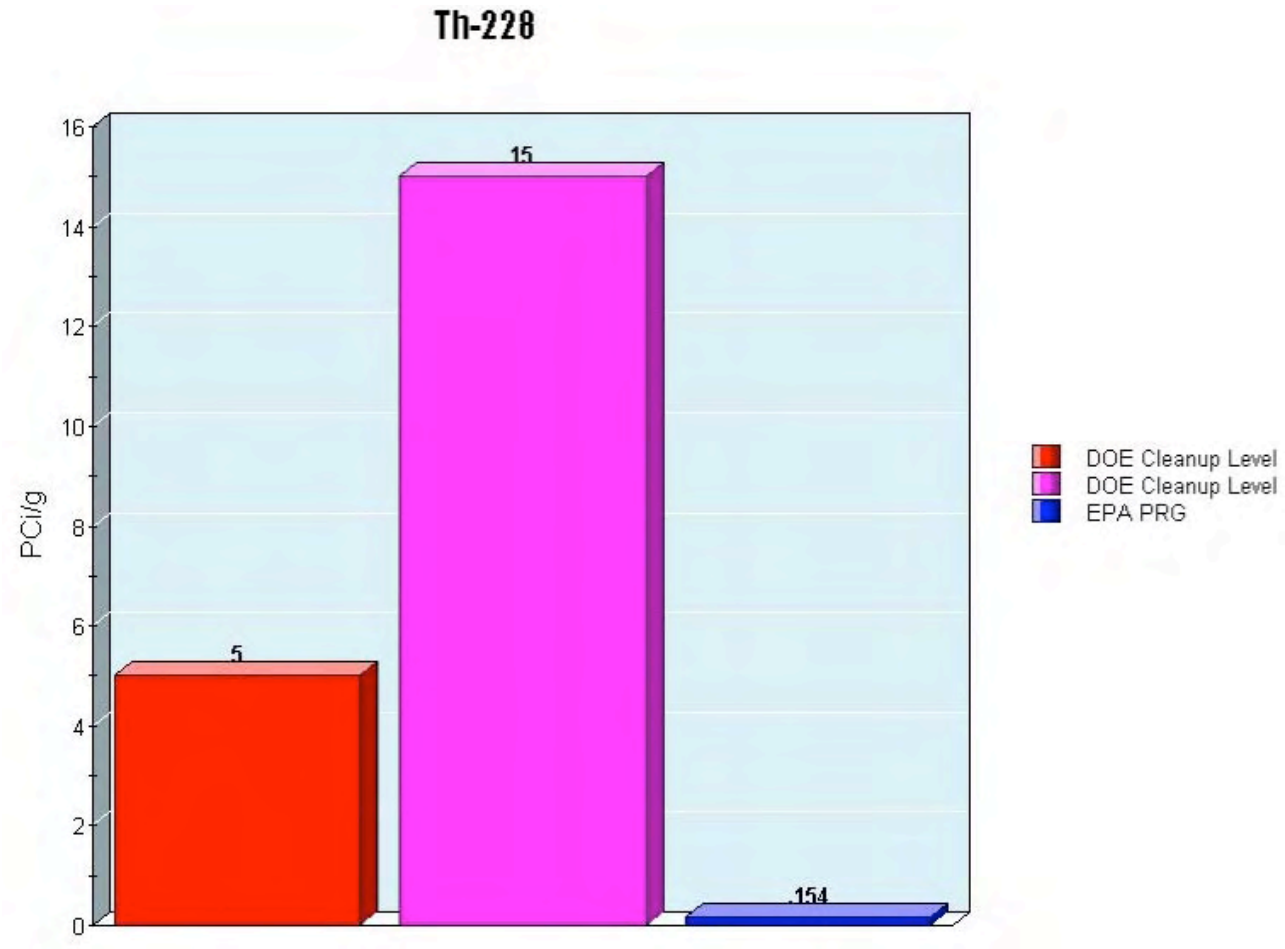
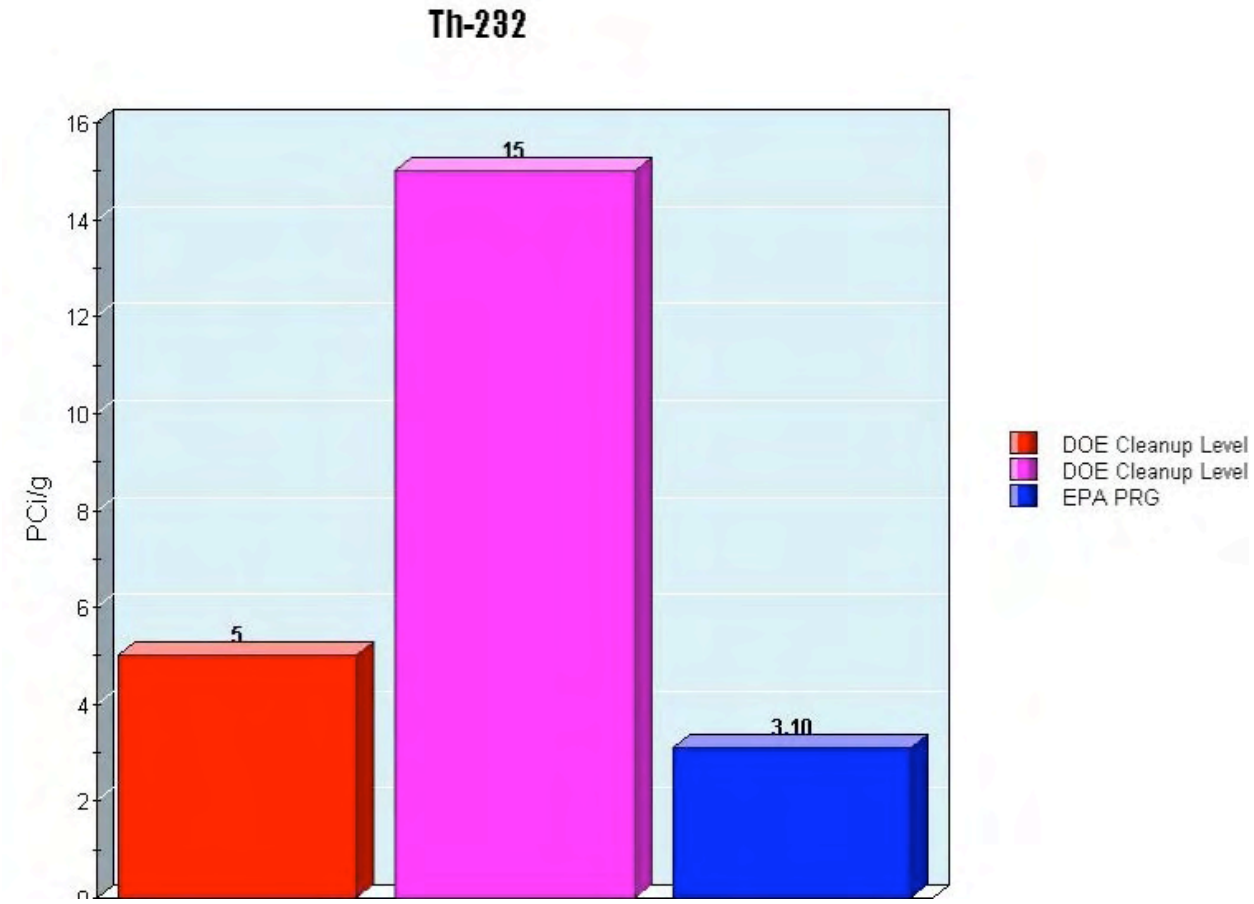


DOE 5 pCi/g Cleanup Standard DOE 15 pCi/g EPA PRG

Note: DOE employs two different standards for thorium-228, 5 pico-curies per gram (pCi/g) and 15 pCi/g, depending upon depth from the surface. For Th-228, EPA will generally use the 5 pCi/g soil limit, as an Applicable or Relevant and Appropriate Requirement (ARAR), rather than its PRG.

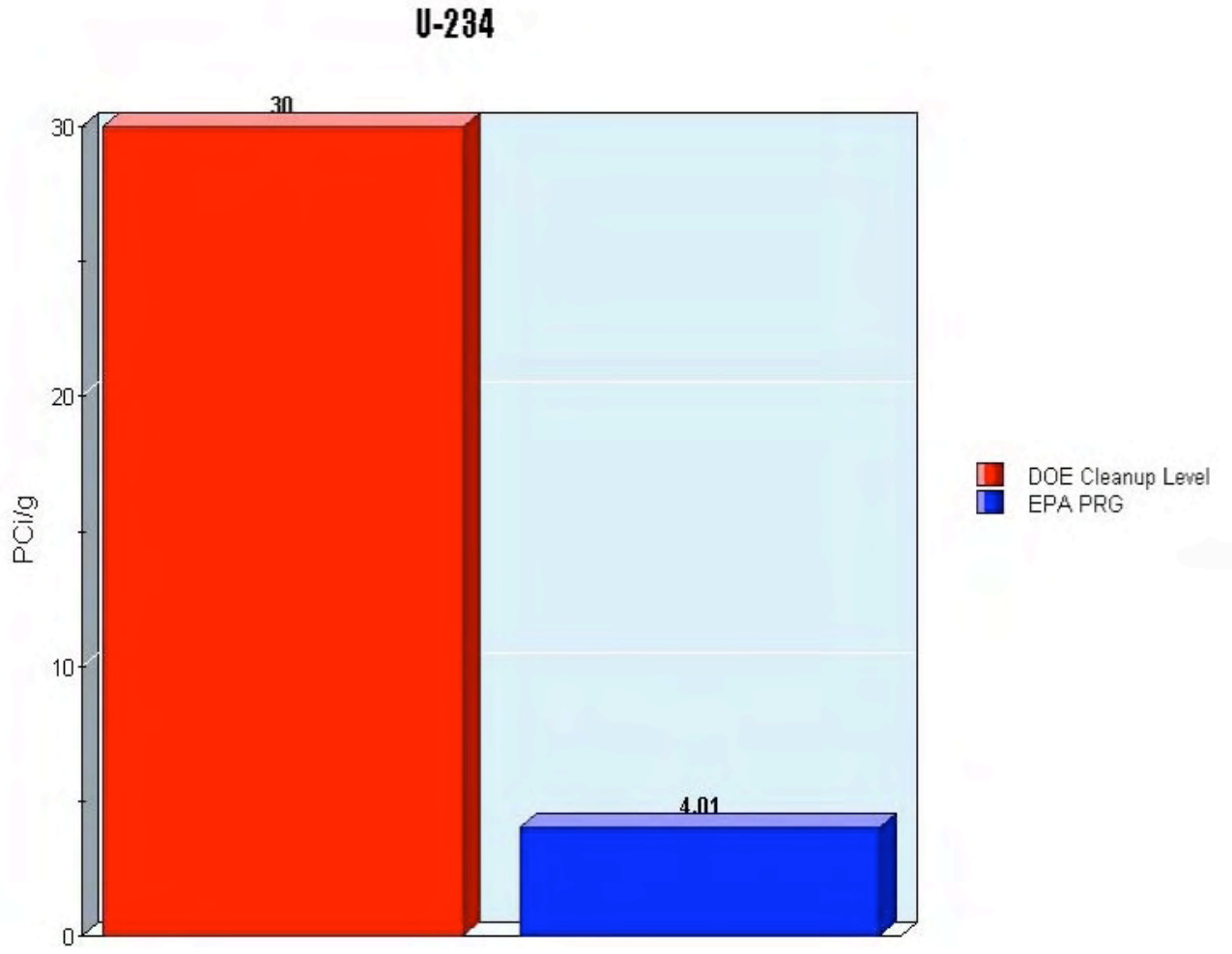
Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



DOE 5 pCi/g Cleanup Standard DOE 15 pCi/g EPA PRG

Note: DOE employs two different standards for thorium-2232, 5 pico-curies per gram (pCi/g) and 15 pCi/g, depending upon depth from the surface. For Th-232, EPA will generally use the 5 pCi/g soil limit, as an Applicable or Relevant and Appropriate Requirement (ARAR), rather than its PRG.

Comparison of DOE Cleanup Standards for SSFL with EPA's Preliminary Remediation Goals



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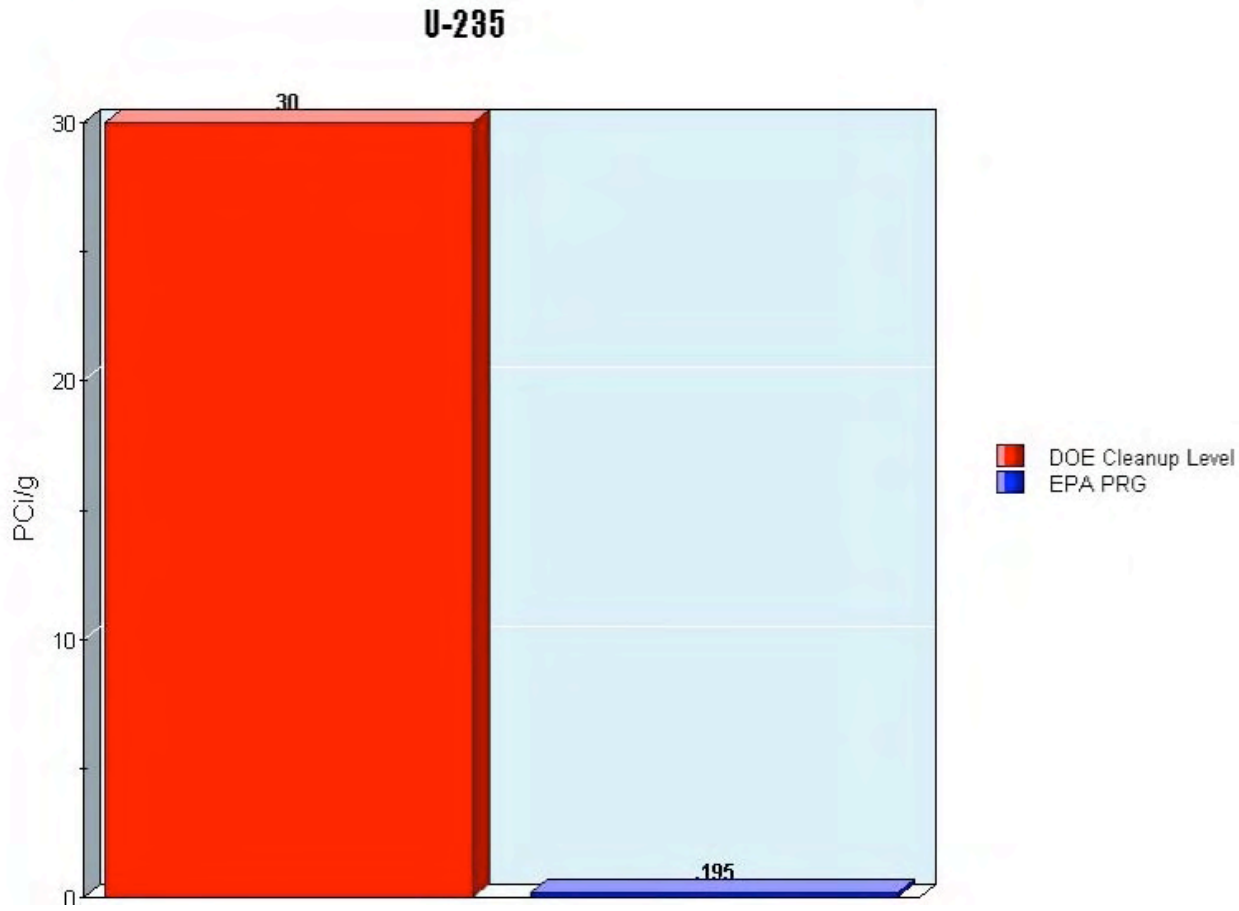

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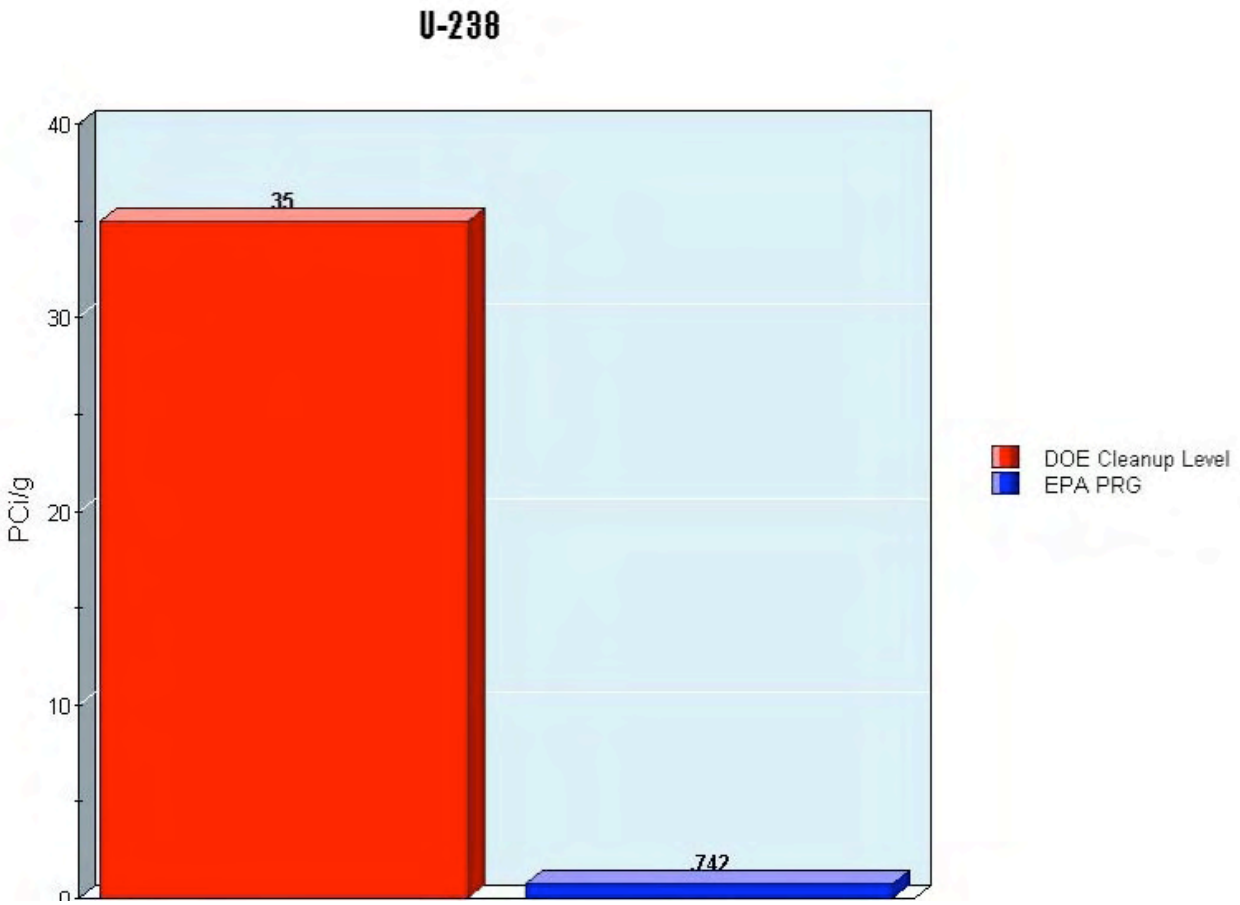

DOE Cleanup Standard EPA PRG

ATTACHMENTS

I. ***DOE-EPA Policy on Decommissioning Department of Energy Facilities Under CERCLA*****, 22 May 1995**

II. EPA's ***Radionuclide Toxicity and Preliminary Remediation Goals for Superfund*****, 4 August 2004**

Department of Energy
And
Environmental Protection Agency

Policy on Decommissioning Department of Energy Facilities under CERCLA

U.S. Department of Energy
U.S. Environmental Protection Agency

MAY 22 1995

MEMORANDUM

SUBJECT: Policy on Decommissioning Department of Energy Facilities Under CERCLA

FROM: Steven A. Herman
Assistant Administrator
Office of Enforcement and Compliance Assurance
United States Environmental Protection Agency

Elliott P. Laws
Assistant Administrator
Office of Solid Waste and Emergency Response
United States Environmental Protection Agency

Thomas P. Gumbly
Assistant Secretary for Environmental Management
United States Department of Energy

TO: See Addressees

The attached policy establishes the approach agreed upon by the Environmental Protection Agency (EPA) and the Department of Energy (DOE) for decommissioning surplus DOE facilities consistent with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This policy is the result of a joint effort by EPA and DOE to develop an approach to decommissioning that ensures protection of worker and public health and the environment, that is consistent with CERCLA, that provides for stakeholder involvement, and that achieves risk reduction without unnecessary delay.

Consistent with the jointly issued "Guidance on Accelerating CERCLA Environmental Restoration at Federal Facilities" (August 22, 1994), this decommissioning policy encourages streamlined decisionmaking. This policy builds on the goal of that guidance to "develop decisions that appropriately address the reduction of risk to human health and the environment as expeditiously as the law allows.

The policy establishes that decommissioning activities will be conducted as non-time critical removal actions, unless the

circumstances at the facility make it inappropriate. Use of non-time critical removals for conducting decommissioning activities effectively integrates EPA oversight responsibility, DOE lead agency responsibility, and state and stakeholder participation.

So that EPA can fulfill its responsibilities to ensure compliance with CERCLA requirements, including remedy selection at NPL facilities, DOE Operations Offices will consult with EPA Regions and share information as determined by the DOE Operations Office and affected EPA Region. Decommissioning projects will retain sufficient flexibility to tailor activities to meet specific site needs and achieve risk reduction and environmental restoration expeditiously.

This policy and any internal procedures adopted for its implementation are intended exclusively for employees of the U.S. Environmental Protection Agency, for employees of the U.S. Department of Energy, and for DOE contractors. This guidance does not constitute rulemaking by EPA and may not be relied upon to create a right or benefit, substantive or procedural, enforceable at law or in equity, by any person. EPA may take action at variance with this guidance or its internal implementing procedures.

Addressees:

United States Environmental Protection Agency
- Waste Management Division Directors, Regions I-X
- Federal Facility Leadership Council Regions I-X
- Regional Counsels, Regions I-X
- Federal Facilities Coordinators, Regions I-X

United States Department of Energy
- Environmental Restoration Office Directors
- Assistant Managers for Environmental Management, DOE Operations Offices

POLICY ON DECOMMISSIONING OF DEPARTMENT OF ENERGY FACILITIES UNDER THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA)

PURPOSE

This Policy establishes the approach agreed upon by the Department of Energy (DOE) and Environmental Protection Agency (EPA) for the conduct of decommissioning projects[1] consistent with CERCLA requirements. This Policy creates a framework for the conduct of decommissioning of DOE facilities and provides guidance to EPA Regions and DOE Operations Offices on the use of CERCLA response authority to decommission such facilities. The principal objectives of this Policy are to ensure that decommissioning activities are protective of worker and public health and the environment, consistent with CERCLA and, where applicable, the Resource Conservation and Recovery Act (RCRA), ensure stakeholder involvement, and achieve risk reduction without unnecessary delay.

This Policy builds on the foundation established in the recent EPA/DOE/DOD "Guidance on Accelerating CERCLA Environmental Restoration at Federal Facilities" (August 22, 1994). Specifically, this Policy represents the next step in realizing the goal of that guidance to "develop decisions that appropriately address the reduction of risk to human health and the environment as expeditiously as the law allows." To achieve that end, this Policy endorses the use of removal action authority to conduct decommissioning, although DOE and EPA recognize that removal action will nor necessarily be the final response action needed at a facility subject to decommissioning.

The DOE Office of Environmental Management (EM), and EPA Federal Facilities Restoration and Reuse Office (FFRRO) and Federal Facilities Enforcement Office (FFEO) have developed this approach for applying CERCLA authority to decommissioning activities to encourage streamlined decisionmaking in decommissioning activities.

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[1] For purposes of this Policy, decommissioning includes those activities that take place after a facility has been deactivated and placed in an ongoing surveillance and maintenance program. Decommissioning can include decontamination and dismantlement. Decontamination encompasses the removal or reduction of radioactive or hazardous contamination from facilities. Dismantlement involves the disassembly or demolition, and removal, of any structure, system, or component and the interim or long-term disposal of waste materials in compliance with applicable requirements.

Deactivation is the process of placing a facility in a safe and stable condition that is protective of workers, the public, and the environment until decommissioning is completed. As the bridge between operations and decommissioning, deactivation can accomplish operations-like activities such as final process runs, and also decontamination activities aimed at placing the facility in a safe aid stable condition.

BACKGROUND

Executive Order 12580 "Superfund Implementation" delegates from the President to the Secretary of Energy certain CERCLA response authorities for facilities under DOE jurisdiction, custody, or control. The EPA/DOE/DOD "Guidance on Accelerating CERCLA Environmental Restoration at Federal Facilities" (August 22, 1994) reaffirms this point, stating that "federal agencies, other than EPA, have jurisdiction for carrying out most response actions at federal facility sites. As EPA is not the lead agency at such sites, its role is different from that at other Superfund sites." Consistent with Executive Order 12580, the National Contingency Plan (NCP) designates DOE as the lead agency for responding to releases on, or where the sole source of the release is from, a facility under DOE's jurisdiction, custody, or control. As lead agency, DOE is authorized to conduct removal action, remedial action, and any other response measures consistent with the NCP. The exercise of such response authority must be in accordance with the requirements of section 120 of CERCLA. For facilities that are listed on the National Priorities List (NPL), section 120 of CERCLA requires DOE and EPA to enter into an Interagency Agreement (IAG), which establishes requirements for remedial action at the facility. Therefore, the roles and authority of DOE and EPA will be defined, in part, by the terms of such agreement. For non-NPL facilities, DOE may take response action subject to CERCLA, the NCP, and other applicable requirements.

DOE will utilize CERCLA response authority whenever a hazardous substance is released, or there is a substantial threat of release, into the environment, and response is necessary to protect public health, welfare, or the environment. DOE Order 5400.4 requires DOE to respond to any release or substantial threat of a release of a hazardous substance into the environment in a manner consistent with CERCLA and the NCP, regardless of whether or not the release or threatened release is from a site listed on the NPL.

The definition of "environment" includes all natural media under U.S. jurisdiction. CERCLA does not generally address releases which are entirely within buildings because the presence of hazardous substances within a building does not constitute a release of such substances into the environment. Hazardous substances within a building, however, may pose a substantial threat of a release that may require a CERCLA response. Determining whether a threat of a release is substantial will depend on the specific circumstances present at a facility.

Under the authority delegated by Executive Order 12580, DOE is responsible for evaluating site conditions to determine if conditions or anticipated activities at facilities subject to decommissioning pose a substantial threat of release. So that EPA can fulfill its

responsibilities to ensure compliance with CERCLA requirements, including remedy selection,[2] at NPL facilities. DOE Operations Offices will consult with EPA Regions and share information as determined by the DOE Operations Office and affected EPA Region. In the event EPA disagrees with DOE's determination as to the presence of a release or substantial threat of release, EPA and DOE should make every effort to resolve the dispute in a manner satisfactory to both parties. If resolution is not possible and EPA determines that a threat of release is substantial, then under section 106 of CERCLA, with the concurrence of the Attorney General, EPA may order DOE to take appropriate action. EPA may also issue a CERCLA section 106 order to any other party, including past or present DOE contractors, that is liable under CERCLA section 107. EPA may further exercise any authority that is provided under an applicable IAG to "stop work" until EPA concerns are satisfactorily addressed. RCRA Authorities may also be available to EPA. Specifically, these authorities may address waste management, corrective action, and closure requirements that may be established or enforced through regulations, permits, orders, or agreements.

SCOPE AND APPLICABILITY

This Policy applies to all decommissioning projects to be conducted by DOE. Decommissioning projects that have selected the removal alternative as of the date this Policy is adopted are not subject to this Policy. Such projects are encouraged, however, to proceed in a manner consistent with this Policy to the maximum extent practicable.

Decommissioning of facilities that are subject to the requirements of an interagency agreement (IAG) in effect on the date this Policy is adopted will be conducted in accordance with such requirements. When existing IAGs are renegotiated or amended, or new agreements are adopted, any requirements applicable to decommissioning activities should be in accordance with this Policy.

CERCLA RESPONSE ACTION TO DECOMMISSION FACILITIES

The NCP recognizes DOE as lead agency for the purpose of determining whether response action is necessary to protect health, welfare, or the environment, and what type of response is most appropriate under the circumstances presented by the site. Response action may be taken when DOE determines that the action will prevent, minimize, stabilize, or eliminate a risk to health or the environment. When DOE determines that CERCLA removal action is necessary, DOE is authorized to evaluate, select, and implement the removal action that DOE determines is most appropriate to address potential risks posed by the release or threat of release. The selection and implementation of such response should comply with the

[2] EPA remedy selection authority is established by section 120(e) of CERCLA. Section 120(e) provides that, absent agreement between EPA and the affected Federal agency, EPA shalt select remedial actions at NPL facilities from alternatives developed through the remedial investigation/feasibility study (RI/FS) process. DOE lead agency authority for removal actions must be coordinated with any anticipated remedial action to ensure an orderly transition from removal to remedial activity is achieved where applicable.

requirements of CERCLA, the NCP, and other applicable authorities. EPA has responsibility to oversee compliance with these requirements.

Although the full range of CERCLA response actions may be applicable to decommissioning activities, non-time critical removal actions should be used for decommissioning, consistent with this Policy. The alternative approaches available to conduct decommissioning projects typically are clear and very limited. This often will eliminate the need for the more thorough analysis of alternatives required for remedial actions. Non-time critical removal action requirements provide greater flexibility to develop decommissioning plans that are appropriate for the circumstances presented. Statutory time and dollar limits on removal action do not apply to removal action conducted by DOE, which increases the scope of projects that may be addressed by DOE removal action. Most importantly, non-time critical removal actions usually will provide benefits to worker safety, public health, and the environment more rapidly and cost-effectively than remedial actions. For these reasons, DOE may exercise removal action authority to conduct decommissioning whenever such action is authorized by CERCLA, the NCP, and Executive Order 12580. To ensure an adequate regulatory role in the removal planning and decision process, EPA Regions are encouraged to communicate with DOE Operations Offices concerning the level of consultation EPA believes is appropriate for specific decommissioning projects. Such an approach will provide greater assurances that the removal action will be consistent with CERCLA requirements and any subsequent remedial action that may be necessary.

DOE Operations Offices will determine that removal action is appropriate for a particular project before proceeding. The scope of activities that qualify removal actions under CERCLA includes site security or control precautions to reduce access or migration, stabilization of structures or buildings, consolidation or removal of substances or structures, and any other actions deemed necessary by the lead agency. Any activity that reduces risks or potential risks in a relatively short time-frame and can be identified as appropriate with a relatively limited amount of analysis of alternatives may be taken under removal action authority. CERCLA requires that removal actions should, to the extent practicable, contribute to the efficient performance of any long term remedial action conducted at the site.

DOE Decommissioning Program

The DOE Decommissioning Program will conduct decommissioning activities in compliance with applicable requirements of CERCLA and the NCP. The decision to conduct decommissioning may be based on any change in the facility's condition that may trigger a need to respond to protect health or the environment, or any other factor that leads DOE to determine that decommissioning of the facility is appropriate. DOE will conduct a removal site evaluation as directed by the NCP to assess site conditions and determine whether a release or substantial threat of release exists at the facility. At any facility for which DOE conducts a removal site evaluation, DOE will consult with EPA and will provide, as requested, EPA with such information necessary for EPA to review such evaluation. At any facility where DOE determines that a release or substantial threat of release has not occurred,

DOE will consult with EPA and provide any information necessary for EPA to evaluate such determination.

Both DOE Operations Offices and EPA Regions must take a good faith approach to assessing potential decommissioning projects. Unless the circumstances at the facility make it inappropriate, decommissioning activities will he conducted as non-rime critical removal actions. Non-time critical removal actions generally will provide the most appropriate level of analysis, oversight, public participation, and flexibility to conduct decommissioning in a cost-effective manner that fully protects health and the environment. Using non-time critical removal action authority will enable DOE to exercise the flexibility provided in the NCP to reduce risks and achieve results without unnecessary expenditure or delay.

Compliance with Applicable Requirements Permits, Agreements, and Orders

Decommissioning activities must comply with all applicable requirements established by any existing IAGs, Federal Facility Agreements (FFAs), Site Treatment Plans required under the Federal Facility Compliance Act, permits and orders issued pursuant to authorized State or Federal programs, and other applicable requirements. Decommissioning activities should comply with relevant and appropriate standards to the extent practicable, as provided by the NCP, and as necessary to contribute to the efficient performance of any long term remedial action.

In particular, States authorized by EPA to implement and enforce State hazardous waste programs in lieu of RCRA may have authority under such programs to enforce requirements applicable to decommissioning activities. These requirements include waste management, corrective action, and closure requirements which may be established or enforced through regulations, permits, orders, or agreements. The degree to which State hazardous waste and other requirements may affect decommissioning projects will depend on a number of site-specific factors including the scope of State authorization, and whether the facility to be decommissioned is included within a RCRA-permitted facility or is otherwise subject to RCRA requirements. EPA and DOE intend to work with authorized States to coordinate RCRA and CERCLA authorities to the maximum extent practicable in order to prevent unnecessary duplication or delay in decommissioning projects subject to both authorities.

EPA Involvement

DOE lead agency responsibilities for determining whether response action is warranted, and what type of response is appropriate, must be coordinated with EPA oversight

and remedy selection authority[3] for facilities included in sites listed on the NPL. Clarifying the integration of DOE and EPA responsibilities at facilities included within a site listed on the NPL and subject to decommissioning is essential to achieving streamlined, effective response action that fully protects human health and the environment. To achieve coordinated integration with respect to decommissioning, this Policy establishes guidelines for defining the appropriate level of EPA consultation and stakeholder participation.

EPA involvement with DOE decommissioning activities on NPL sites will depend on the complexity and potential risk to health and the environment posed by the facility to be decommissioned. EPA involvement should focus on key documents and decision points in the removal action process. The NCP requires EPA approval of sampling and analysis plans developed in accordance with section 300.415(b)(4) of the NCP. EPA involvement may be appropriate with respect to other steps in the removal process.

The extent of EPA involvement will be determined by the EPA Region and DOE Operations Office responsible for the facility, based on the circumstances presented by each facility. Factors to be considered in determining EPA involvement in decommissioning projects include complexity, severity of potential risks, duration, cost, and appropriateness of applying EPA resources to the project. Where no IAG exists for the site, or where an existing IAG does not address decommissioning in general, or specific facilities appropriate for decommissioning in particular, the DOE Operations Office and EPA Region should identify the steps in the removal action process where EPA involvement can be most effective. In particular, EPA involvement should ensure that decommissioning activities comply with applicable requirements, that protection of health and the environment is achieved, and that decommissioning is consistent with ongoing or subsequent remedial actions at the site.

Stakeholder Involvement

Decommissioning activities will be conducted in full compliance with the community relations and public participation requirements established by CERCLA, the NCP, and DOE policies. The nature and scope of these stakeholder involvement requirements will depend on the type of removal action taken. All non-time critical removal actions will comply with the public participation requirements applicable to such actions outlined in the NCP. Where applicable, a formal community relations plan (CRP) will be prepared, specifying the community relations activities to be conducted during the removal. The CRP will be prepared prior to completion of the analysis of removal alternatives. In addition, stakeholders will be provided notice and an opportunity to submit comments on the analysis of removal alternatives. Written responses to public comments will be prepared.

[3] As described in footnote 2, EPA remedy selection authority applies to selection of remedial actions at NPL facilities from alternatives developed through the remedial investigation/feasibility study (RI/FS) process. Removal actions selected by DOE must be consistent with any longer term remedial activity anticipated at the site.

DOE will establish an Administrative Record as provided by CERCLA section 113 and the NCP for non-time critical removals. The Administrative Record will include the results of the removal site evaluation and other factual information and analyses upon which the decision to conduct response action was based. As additional information is developed that forms the basis for selection of the response action, such information will be included in the Administrative Record. The Administrative Record will be accessible to the public, consistent with the requirements of the NCP. Public comments, and DOE's response, will be included in the Administrative Record.

CONCLUSION

Use of non-time critical removals for conducting decommissioning activities effectively integrates DOE lead agency responsibility, EPA oversight responsibility, and stakeholder participation. The DOE Decommissioning Program will utilize DOE expertise in devising and implementing appropriate solutions to decommissioning projects. Effective EPA oversight and stakeholder participation will be provided in compliance with applicable requirements. Decommissioning projects will retain sufficient flexibility to tailor activities to meet specific site needs, and achieve risk reduction and restoration expeditiously.

* * * * *

This policy and any internal procedures adopted for its implementation are intended exclusively for employees of the U.S. Environmental Protection Agency, for employees of the U.S. Department of Energy, and for DOE contractors. This guidance does not constitute rulemaking by the Agency and may not be relied upon to create a right or benefit, substantive or procedural, enforceable at law or in equity, by any person. The Agency may take action at variance with this guidance or its internal implementing procedures.

Environmental Protection Agency

Preliminary Remediation Goals
For
Superfund

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Actinium (89)	Ac-223						1.55E-08	3.58E+07	3.58E+07	5.83E+07	1.31E+08				
Actinium (89)	Ac-224	1.53E-11	2.77E-12	5.59E-12	8.03E-12	4.07E-10	6.06E-07	1.15E+04	1.15E+04	1.89E+04	4.24E+04	8.52E+00	2.20E-01		
Actinium (89)	Ac-225	5.18E-10	9.03E-11	1.89E-10	2.71E-10	2.86E-08	4.50E-08	6.36E+02	4.77E+02	2.44E+03	5.23E+03	2.52E-01	6.51E-03		
Actinium (89)	Ac-226	2.00E-10	2.84E-11	6.92E-11	1.01E-10	4.33E-09	4.46E-07	1.46E+03	1.41E+03	2.54E+03	5.71E+03	6.88E-01	1.75E-02		
Actinium (89)	Ac-227	3.81E-10	2.01E-10	2.01E-10	2.45E-10	1.49E-07	3.48E-10	2.53E+00	1.35E+00	1.14E+01	2.10E+01	2.37E-01	7.20E-03		
Actinium (89)	Ac-227+D	1.16E-09	3.45E-10	4.86E-10	6.53E-10	2.09E-07	1.47E-06	1.04E-01	8.31E-02	2.09E-01	4.67E-01	9.80E-02	2.70E-03		
Actinium (89)	Ac-228	5.55E-12	9.10E-13	1.99E-12	2.89E-12	4.92E-11	4.53E-06	7.32E+02	7.31E+02	1.19E+03	2.69E+03	2.39E+01	6.10E-01		
Aluminum (13)	Al-26	4.70E-11	8.18E-12	1.73E-11	2.49E-11	6.92E-11	1.33E-05	8.38E-03	6.28E-03	1.64E-02	3.70E-02	2.75E+00	7.08E-02		
Aluminum (13)	Al-28						9.32E-06	5.84E+04	5.84E+04	9.53E+04	2.14E+05				
Americium (95)	Am-237	1.24E-13	3.12E-14	5.07E-14	7.18E-14	5.77E-14	1.35E-06	1.24E+04	1.23E+04	2.02E+04	4.54E+04	9.39E+02	2.46E+01	3.54E+12	1.77E+11
Americium (95)	Am-238	2.28E-13	5.96E-14	9.62E-14	1.35E-13	9.51E-14	4.02E-06	3.09E+03	3.09E+03	5.05E+03	1.14E+04	4.95E+02	1.31E+01	1.03E+12	5.17E+10
Americium (95)	Am-239	3.89E-12	5.99E-13	1.38E-12	2.01E-12	8.40E-13	6.91E-07	2.47E+03	2.16E+03	4.03E+03	9.07E+03	3.45E+01	8.77E-01	1.36E+09	6.79E+07
Americium (95)	Am-240	6.81E-12	1.27E-12	2.59E-12	3.70E-12	1.41E-12	4.69E-06	8.53E+01	8.21E+01	1.39E+02	3.13E+02	1.84E+01	4.77E-01	3.97E+07	1.98E+06
Americium (95)	Am-241	2.17E-10	9.10E-11	1.04E-10	1.34E-10	2.81E-08	2.76E-08	1.87E+00	1.32E-02	5.67E+00	1.19E+01	4.58E-01	1.32E-02	2.58E+00	1.29E-01
Americium (95)	Am-242	5.14E-12	7.51E-13	1.79E-12	2.62E-12	5.03E-11	3.48E-08	3.57E+04	7.82E+03	5.94E+04	1.34E+05	2.66E+01	6.73E-01	5.79E+08	2.90E+07
Americium (95)	Am-242m	1.29E-10	7.33E-11	7.07E-11	8.77E-11	1.56E-08	1.05E-09	5.63E+00	2.14E-02	2.24E+01	4.13E+01	6.74E-01	2.01E-02	1.30E-01	6.48E-03
Americium (95)	Am-242m+D	2.21E-10	8.95E-11	1.04E-10	1.36E-10	2.81E-08	4.83E-08	1.45E+00	1.37E-02	3.87E+00	8.32E+00	4.58E-01	1.30E-02	8.81E-02	4.40E-03
Americium (95)	Am-243	2.17E-10	9.03E-11	1.03E-10	1.34E-10	2.70E-08	9.47E-08	8.71E-01	1.27E-02	2.06E+00	4.51E+00	4.62E-01	1.32E-02	2.52E+00	1.26E-01
Americium (95)	Am-243+D	2.32E-10	2.15E-12	1.08E-10	1.42E-10	2.70E-08	6.36E-07	1.66E-01	1.11E-02	3.44E-01	7.73E-01	4.41E-01	1.24E-02	2.52E+00	1.26E-01
Americium (95)	Am-244	7.03E-12	1.12E-12	2.52E-12	3.66E-12	3.09E-12	3.58E-06	5.62E+02	5.35E+02	9.17E+02	2.06E+03	1.89E+01	4.82E-01	1.03E+09	5.16E+07
Americium (95)	Am-244m	1.18E-13	3.81E-14	5.11E-14	7.10E-14	1.02E-13	5.09E-09	9.18E+06	5.49E+06	1.50E+07	3.38E+07	9.32E+02	2.48E+01	2.77E+13	1.38E+12
Americium (95)	Am-245	6.11E-13	1.10E-13	2.22E-13	3.22E-13	1.56E-13	1.04E-07	9.52E+04	8.28E+04	1.56E+05	3.50E+05	2.15E+02	5.48E+00	2.84E+11	1.42E+10
Americium (95)	Am-246	2.93E-13	8.47E-14	1.23E-13	1.73E-13	1.31E-13	2.93E-06	1.07E+04	1.06E+04	1.74E+04	3.92E+04	3.87E+02	1.02E+01	5.11E+12	2.55E+11
Americium (95)	Am-246m	1.48E-13	4.96E-14	6.59E-14	9.10E-14	3.96E-14	4.83E-06	1.01E+04	1.01E+04	1.65E+04	3.71E+04	7.23E+02	1.94E+01	2.32E+13	1.16E+12
Antimony (51)	Sb-115	1.16E-13	3.70E-14	5.14E-14	7.10E-14	2.33E-14	3.92E-06	9.78E+03	9.78E+03	1.60E+04	3.59E+04	9.26E+02	2.48E+01		
Antimony (51)	Sb-116	1.07E-13	3.89E-14	4.96E-14	6.81E-14	1.88E-14	1.05E-05	7.35E+03	7.35E+03	1.20E+04	2.70E+04	9.60E+02	2.59E+01		
Antimony (51)	Sb-116m	4.00E-13	1.18E-13	1.76E-13	2.45E-13	8.81E-14	1.47E-05	1.38E+03	1.38E+03	2.24E+03	5.05E+03	2.71E+02	7.20E+00		
Antimony (51)	Sb-117	1.70E-13	3.50E-14	6.59E-14	9.44E-14	4.07E-14	5.78E-07	1.26E+04	1.26E+04	2.05E+04	4.61E+04	7.23E+02	1.87E+01		
Antimony (51)	Sb-118m	1.67E-12	4.07E-13	6.99E-13	9.81E-13	2.64E-13	1.21E-05	3.36E+02	3.36E+02	5.48E+02	1.23E+03	6.81E+01	1.80E+00		
Antimony (51)	Sb-119	1.35E-12	2.01E-13	4.77E-13	6.96E-13	1.74E-13	2.58E-09	1.82E+05	1.57E+05	3.34E+05	7.50E+05	9.98E+01	2.53E+00		
Antimony (51)	Sb-120a	5.44E-14	1.94E-14	2.48E-14	3.42E-14	1.12E-14	1.94E-06	3.95E+04	3.95E+04	6.45E+04	1.45E+05	1.92E+03	5.16E+01		
Antimony (51)	Sb-120b	1.08E-11	2.45E-12	4.44E-12	6.22E-12	3.30E-12	1.15E-05	1.28E+01	1.28E+01	2.09E+01	4.69E+01	1.07E+01	2.84E-01		
Antimony (51)	Sb-122	3.03E-11	4.44E-12	1.06E-11	1.55E-11	5.48E-12	1.97E-06	1.59E+02	1.58E+02	2.60E+02	5.84E+02	4.49E+00	1.14E-01		
Antimony (51)	Sb-124	3.50E-11	6.03E-12	1.29E-11	1.85E-11	2.43E-11	8.89E-06	1.58E+00	1.58E+00	2.58E+00	5.81E+00	3.69E+00	9.53E-02		
Antimony (51)	Sb-124m						1.56E-06	5.04E+05	5.04E+05	8.23E+05	1.85E+06				
Antimony (51)	Sb-124n	3.81E-14	1.20E-14	1.67E-14	2.32E-14	1.15E-14	7.76E-12	3.30E+09	1.76E+09	1.07E+10	2.31E+10	2.85E+03	7.60E+01		
Antimony (51)	Sb-125	1.12E-11	2.38E-12	4.37E-12	6.14E-12	1.66E-11	1.81E-06	4.62E-01	4.61E-01	7.56E-01	1.70E+00	1.09E+01	2.87E-01		
Antimony (51)	Sb-125+D	1.32E-11		5.13E-12	7.21E-12	1.93E-11	1.81E-06	4.62E-01	4.60E-01	7.56E-01	1.70E+00	9.28E+00	2.45E-01		
Antimony (51)	Sb-126	2.93E-11	5.40E-12	1.11E-11	1.59E-11	1.15E-11	1.28E-05	5.33E+00	5.33E+00	8.70E+00	1.96E+01	4.29E+00	1.11E-01		
Antimony (51)	Sb-126m	1.48E-13	5.11E-14	6.66E-14	9.21E-14	3.16E-14	6.94E-06	9.25E+03	9.25E+03	1.51E+04	3.39E+04	7.15E+02	1.91E+01		
Antimony (51)	Sb-127	2.85E-11	4.29E-12	1.01E-11	1.47E-11	7.51E-12	3.07E-06	7.15E+01	7.12E+01	1.17E+02	2.63E+02	4.71E+00	1.20E-01		
Antimony (51)	Sb-128a	1.19E-13	4.44E-14	5.51E-14	7.55E-14	2.12E-14	9.03E-06	1.30E+04	1.30E+04	2.12E+04	4.77E+04	8.64E+02	2.34E+01		
Antimony (51)	Sb-128b	9.21E-12	1.67E-12	3.45E-12	4.96E-12	1.44E-12	1.40E-05	1.61E+02	1.61E+02	2.63E+02	5.91E+02	1.38E+01	3.56E-01		
Antimony (51)	Sb-129	6.11E-12	9.81E-13	2.19E-12	3.19E-12	9.62E-13	6.85E-06	6.86E+02	6.86E+02	1.12E+03	2.52E+03	2.17E+01	5.53E-01		
Antimony (51)	Sb-130	4.77E-13	1.44E-13	2.07E-13	2.88E-13	9.73E-14	1.51E-05	2.02E+03	2.02E+03	3.29E+03	7.41E+03	2.30E+02	6.12E+00		
Antimony (51)	Sb-131	6.48E-13	1.59E-13	2.56E-13	3.59E-13	9.73E-14	9.08E-06	5.84E+03	5.84E+03	9.53E+03	2.14E+04	1.86E+02	4.91E+00		
Argon (18)	Ar-37						0.00E+00								
Argon (18)	Ar-39						5.94E-10	1.95E+02	1.48E+02	3.80E+02	8.55E+02				
Argon (18)	Ar-41						6.39E-06	1.74E+03	1.74E+03	2.84E+03	6.38E+03				
Arsenic (33)	As-69	2.39E-13	7.70E-14	1.05E-13	1.46E-13	4.29E-14	4.43E-06	1.81E+04	1.81E+04	2.95E+04	6.65E+04	4.54E+02	1.21E+01		
Arsenic (33)	As-70	7.40E-13	2.16E-13	3.20E-13	4.48E-13	1.37E-13	1.96E-05	1.18E+03	1.18E+03	1.93E+03	4.34E+03	1.49E+02	3.94E+00		

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

		Toxicity						Preliminary Remediation Goals (PRG)						Soil to Groundwater	
Element (Atomic Number)	Isotope	Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	DAF=20 (pCi/g)	DAF=1 (pCi/g)
Arsenic (33)	As-71	6.07E-12	1.09E-12	2.28E-12	3.29E-12	1.52E-12	2.37E-06	1.32E+02	1.31E+02	2.16E+02	4.86E+02	2.09E+01	5.36E-01		
Arsenic (33)	As-72	2.79E-11	4.55E-12	1.02E-11	1.48E-11	4.29E-12	8.21E-06	9.48E+01	9.39E+01	1.55E+02	3.49E+02	4.67E+00	1.19E-01		
Arsenic (33)	As-73	4.40E-12	6.85E-13	1.56E-12	2.28E-12	3.88E-12	5.78E-09	1.01E+03	4.53E+02	2.93E+03	6.58E+03	3.05E+01	7.74E-01		
Arsenic (33)	As-74	1.82E-11	3.17E-12	6.70E-12	9.69E-12	8.44E-12	3.35E-06	1.41E+01	1.39E+01	2.32E+01	5.21E+01	7.11E+00	1.82E-01		
Arsenic (33)	As-76	2.70E-11	4.14E-12	9.66E-12	1.42E-11	4.14E-12	2.01E-06	3.79E+02	3.65E+02	6.27E+02	1.41E+03	4.93E+00	1.24E-01		
Arsenic (33)	As-77	7.03E-12	1.06E-12	2.50E-12	3.67E-12	1.76E-12	3.58E-08	1.21E+04	8.19E+03	2.38E+04	5.35E+04	1.90E+01	4.81E-01		
Arsenic (33)	As-78	1.61E-12	3.59E-13	6.33E-13	9.03E-13	2.69E-13	6.11E-06	2.20E+03	2.20E+03	3.59E+03	8.08E+03	7.52E+01	1.95E+00		
Astatine (85)	At-207	1.66E-12	4.77E-13	6.96E-13	9.51E-13	7.77E-12	6.11E-06	1.85E+03	1.85E+03	3.01E+03	6.78E+03	6.84E+01	1.85E+00		
Astatine (85)	At-211	8.21E-11	2.23E-11	3.37E-11	4.63E-11	3.58E-10	7.94E-08	3.10E+04	3.12E+04	5.60E+04	1.25E+05	1.41E+00	3.81E-02		
Astatine (85)	At-215						8.09E-10	9.04E+14	9.04E+14	1.48E+15	3.32E+15				
Astatine (85)	At-216						3.08E-09	7.92E+13	7.92E+13	1.29E+14	2.91E+14				
Astatine (85)	At-217						1.32E-09	1.72E+12	1.72E+12	2.80E+12	6.30E+12				
Astatine (85)	At-218						3.57E-09	1.02E+10	1.02E+10	1.67E+10	3.76E+10				
Barium (56)	Ba-126	2.24E-12	4.66E-13	8.51E-13	1.22E-12	3.49E-13	5.83E-07	2.17E+04	2.16E+04	3.54E+04	7.96E+04	5.60E+01	1.45E+00		
Barium (56)	Ba-128	4.33E-11	6.92E-12	1.52E-11	2.23E-11	7.22E-12	2.10E-07	1.59E+03	1.41E+03	2.70E+03	6.06E+03	3.13E+00	7.91E-02		
Barium (56)	Ba-131	5.25E-12	1.02E-12	2.00E-12	2.87E-12	2.91E-12	1.77E-06	4.05E+01	4.04E+01	6.61E+01	1.49E+02	2.38E+01	6.15E-01		
Barium (56)	Ba-131m	2.11E-14	6.88E-15	9.25E-15	1.29E-14	1.69E-14	1.67E-07	5.00E+05	5.00E+05	8.16E+05	1.84E+06	5.15E+03	1.37E+02		
Barium (56)	Ba-133	1.39E-11	4.37E-12	6.81E-12	9.44E-12	1.16E-11	1.44E-06	1.75E-01	1.61E-01	3.06E-01	6.89E-01	6.99E+00	1.87E-01		
Barium (56)	Ba-133m	9.07E-12	1.42E-12	3.19E-12	4.66E-12	2.04E-12	1.96E-07	2.64E+03	2.56E+03	4.35E+03	9.77E+03	1.49E+01	3.78E-01		
Barium (56)	Ba-135m	7.29E-12	1.14E-12	2.56E-12	3.74E-12	1.61E-12	1.70E-07	4.13E+03	4.02E+03	6.79E+03	1.53E+04	1.86E+01	4.72E-01		
Barium (56)	Ba-137m						2.69E-06	1.78E+05	1.78E+05	2.90E+05	6.53E+05				
Barium (56)	Ba-139	9.73E-13	2.06E-13	3.70E-13	5.33E-13	1.79E-13	1.65E-07	8.92E+04	8.89E+04	1.46E+05	3.28E+05	1.29E+02	3.31E+00		
Barium (56)	Ba-140	4.18E-11	6.77E-12	1.49E-11	2.17E-11	2.03E-11	7.61E-07	8.67E+01	8.37E+01	1.43E+02	3.21E+02	3.20E+00	8.13E-02		
Barium (56)	Ba-141	5.59E-13	1.22E-13	2.14E-13	3.07E-13	9.69E-14	3.79E-06	1.76E+04	1.76E+04	2.87E+04	6.45E+04	2.23E+02	5.74E+00		
Barium (56)	Ba-142	2.27E-13	5.88E-14	9.29E-14	1.31E-13	4.55E-14	4.85E-06	2.37E+04	2.37E+04	3.87E+04	8.71E+04	5.13E+02	1.35E+01		
Berkelium (97)	Bk-245	9.73E-12	1.45E-12	3.43E-12	5.00E-12	7.22E-12	7.09E-07	2.41E+02	2.41E+02	3.94E+02	8.87E+02	1.39E+01	3.53E-01		
Berkelium (97)	Bk-246	5.25E-12	9.99E-13	2.01E-12	2.88E-12	9.25E-13	4.25E-06	1.09E+02	1.09E+02	1.78E+02	4.00E+02	2.37E+01	6.12E-01		
Berkelium (97)	Bk-247	2.49E-10	1.12E-10	1.24E-10	1.60E-10	3.26E-08	3.09E-07	3.27E-01	2.47E-01	6.80E-01	1.51E+00	3.84E-01	1.10E-02		
Berkelium (97)	Bk-249	2.95E-12	5.99E-13	1.11E-12	1.57E-12	5.14E-11	2.63E-12	6.34E+03	6.61E+03	5.60E+04	1.02E+05	4.29E+01	1.12E+00		
Berkelium (97)	Bk-250	1.54E-12	2.77E-13	5.66E-13	8.18E-13	1.03E-12	4.23E-06	1.49E+03	1.49E+03	2.43E+03	5.48E+03	8.41E+01	2.16E+00		
Beryllium (4)	Be-10	2.02E-11	2.96E-12	7.03E-12	1.02E-11	9.40E-11	7.43E-10	2.48E+01	1.16E+01	1.97E+02	4.10E+02	6.77E+00	1.73E-01		
Beryllium (4)	Be-7	2.02E-13	5.03E-14	8.66E-14	1.20E-13	2.13E-13	2.13E-07	7.46E+01	7.45E+01	1.22E+02	2.74E+02	5.50E+02	1.47E+01		
Bismuth (83)	Bi-200	3.65E-13	9.36E-14	1.52E-13	2.13E-13	7.55E-14	1.06E-05	3.16E+03	3.16E+03	5.16E+03	1.16E+04	3.13E+02	8.28E+00		
Bismuth (83)	Bi-201	1.09E-12	2.26E-13	4.22E-13	6.03E-13	1.90E-13	6.05E-06	1.87E+03	1.86E+03	3.04E+03	6.85E+03	1.13E+02	2.92E+00		
Bismuth (83)	Bi-202	6.18E-13	1.66E-13	2.65E-13	3.69E-13	1.12E-13	1.24E-05	9.81E+02	9.81E+02	1.60E+03	3.60E+03	1.80E+02	4.78E+00		
Bismuth (83)	Bi-203	4.85E-12	1.01E-12	1.92E-12	2.73E-12	8.21E-13	1.16E-05	1.48E+02	1.48E+02	2.42E+02	5.45E+02	2.48E+01	6.46E-01		
Bismuth (83)	Bi-205	8.18E-12	1.79E-12	3.32E-12	4.66E-12	3.24E-12	8.19E-06	6.75E+00	6.72E+00	1.10E+01	2.48E+01	1.43E+01	3.78E-01		
Bismuth (83)	Bi-206	1.98E-11	4.00E-12	7.73E-12	1.10E-11	5.85E-12	1.52E-05	8.91E+00	8.87E+00	1.46E+01	3.28E+01	6.16E+00	1.60E-01		
Bismuth (83)	Bi-207	1.49E-11	2.77E-12	5.66E-12	8.14E-12	2.10E-11	7.08E-06	2.04E-02	1.65E-02	3.84E-02	8.65E-02	8.41E+00	2.17E-01		
Bismuth (83)	Bi-210	2.55E-11	3.74E-12	8.92E-12	1.30E-11	3.17E-10	2.76E-09	4.80E+03	1.34E+03	8.55E+04	1.86E+05	5.34E+00	1.36E-01		
Bismuth (83)	Bi-210m	1.45E-10	2.92E-11	5.51E-11	7.77E-11	1.17E-08	1.01E-06	9.27E-02	4.79E-02	2.16E-01	4.84E-01	8.64E-01	2.27E-02		
Bismuth (83)	Bi-211						1.88E-07	3.03E+06	3.03E+06	4.95E+06	1.11E+07				
Bismuth (83)	Bi-212	1.78E-12	4.40E-13	7.10E-13	9.99E-13	7.77E-11	8.87E-07	2.26E+04	2.24E+04	3.70E+04	8.33E+04	6.71E+01	1.77E+00		
Bismuth (83)	Bi-213	1.28E-12	3.17E-13	5.11E-13	7.18E-13	6.85E-11	5.65E-07	4.71E+04	4.67E+04	7.70E+04	1.73E+05	9.32E+01	2.46E+00		
Bismuth (83)	Bi-214	4.33E-13	1.47E-13	1.92E-13	2.65E-13	2.90E-11	7.48E-06	8.19E+03	8.19E+03	1.34E+04	3.01E+04	2.48E+02	6.66E+00		
Bromine (35)	Br-74	3.19E-13	1.22E-13	1.50E-13	2.05E-13	6.44E-14	2.32E-05	2.08E+03	2.08E+03	3.39E+03	7.63E+03	3.17E+02	8.60E+00		
Bromine (35)	Br-74m	5.29E-13	1.98E-13	2.46E-13	3.36E-13	1.15E-13	2.00E-05	1.47E+03	1.47E+03	2.40E+03	5.39E+03	1.94E+02	5.25E+00		
Bromine (35)	Br-75	3.42E-13	1.22E-13	1.57E-13	2.13E-13	1.13E-13	5.21E-06	2.39E+03	2.38E+03	3.90E+03	8.77E+03	3.03E+02	8.28E+00		
Bromine (35)	Br-76	3.34E-12	9.99E-13	1.45E-12	1.97E-12	1.10E-12	1.30E-05	9.62E+01	9.55E+01	1.57E+02	3.54E+02	3.28E+01	8.95E-01		
Bromine (35)	Br-77	6.51E-13	2.20E-13	3.01E-13	4.03E-13	2.06E-13	1.34E-06	2.69E+02	2.65E+02	4.42E+02	9.94E+02	1.58E+02	4.38E+00		
Bromine (35)	Br-80	1.03E-13	3.85E-14	4.70E-14	6.48E-14	1.80E-14	3.55E-07	1.97E+05	1.95E+05	3.22E+05	7.25E+05	1.01E+03	2.72E+01		

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Bromine (35)	Br-80m	6.70E-13	1.97E-13	2.82E-13	3.89E-13	2.43E-13	5.95E-09	3.64E+05	1.38E+05	1.26E+06	2.82E+06	1.69E+02	4.53E+00		
Bromine (35)	Br-82	3.70E-12	1.24E-12	1.71E-12	2.30E-12	1.66E-12	1.24E-05	4.63E+01	4.58E+01	7.58E+01	1.70E+02	2.78E+01	7.67E-01		
Bromine (35)	Br-83	1.94E-13	6.33E-14	8.44E-14	1.16E-13	1.21E-13	3.46E-08	2.32E+05	1.99E+05	4.01E+05	9.02E+05	5.64E+02	1.52E+01		
Bromine (35)	Br-84	3.21E-13	1.19E-13	1.48E-13	2.02E-13	7.18E-14	9.35E-06	4.10E+03	4.09E+03	6.69E+03	1.51E+04	3.22E+02	8.73E+00		
Cadmium (48)	Cd-104	4.14E-13	1.02E-13	1.72E-13	2.41E-13	7.66E-14	9.70E-07	2.17E+04	1.74E+04	3.55E+04	8.00E+04	2.77E+02	7.32E+00	5.76E+11	2.88E+10
Cadmium (48)	Cd-107	9.99E-13	1.49E-13	3.50E-13	5.11E-13	3.10E-13	3.48E-08	8.16E+04	5.61E+03	1.47E+05	3.30E+05	1.36E+02	3.45E+00	6.21E+09	3.11E+08
Cadmium (48)	Cd-109	1.14E-11	3.36E-12	5.00E-12	6.70E-12	2.19E-11	8.73E-09	3.32E+01	2.66E-01	3.26E+02	7.25E+02	9.52E+00	2.63E-01	5.69E+02	2.85E+01
Cadmium (48)	Cd-113	3.85E-11	2.18E-11	2.28E-11	2.90E-11	1.12E-10	7.36E-11	5.65E-01	2.80E-03	7.83E+01	1.42E+02	2.09E+00	6.08E-02	1.23E-01	6.14E-03
Cadmium (48)	Cd-113m	5.11E-11	2.63E-11	2.87E-11	3.64E-11	1.30E-10	4.45E-10	8.70E-01	5.26E-03	1.05E+02	1.94E+02	1.66E+00	4.85E-02	3.67E-01	1.83E-02
Cadmium (48)	Cd-115	2.47E-11	3.60E-12	8.66E-12	1.27E-11	5.14E-12	1.01E-06	3.46E+02	2.71E+01	6.13E+02	1.38E+03	5.50E+00	1.39E-01	3.70E+06	1.85E+05
Cadmium (48)	Cd-115m	4.74E-11	7.70E-12	1.70E-11	2.46E-11	2.92E-11	1.13E-07	6.69E+01	7.50E-01	2.72E+02	6.10E+02	2.80E+00	7.17E-02	4.70E+03	2.35E+02
Cadmium (48)	Cd-117	3.81E-12	6.22E-13	1.37E-12	1.99E-12	6.51E-13	5.23E-06	1.56E+03	1.12E+03	2.55E+03	5.73E+03	3.48E+01	8.86E-01	1.08E+10	5.39E+08
Cadmium (48)	Cd-117m	3.26E-12	6.03E-13	1.22E-12	1.76E-12	6.55E-13	1.03E-05	5.86E+02	5.00E+02	9.58E+02	2.16E+03	3.90E+01	1.00E+00	6.65E+09	3.33E+08
Calcium (20)	Ca-41	5.74E-13	3.24E-13	3.53E-13	4.37E-13	2.09E-13	0.00E+00	2.26E+01	3.90E+00	5.49E+03	9.88E+03	1.35E+02	4.04E+00		
Calcium (20)	Ca-45	6.07E-12	1.52E-12	2.47E-12	3.37E-12	9.40E-12	3.96E-11	1.35E+02	3.14E+01	3.74E+04	6.98E+04	1.93E+01	5.23E-01		
Calcium (20)	Ca-47	2.02E-11	3.85E-12	7.55E-12	1.08E-11	7.88E-12	5.24E-06	3.48E+01	3.24E+01	5.82E+01	1.31E+02	6.31E+00	1.63E-01		
Calcium (20)	Ca-49						1.75E-05	7.99E+03	7.99E+03	1.30E+04	2.93E+04				
Californium (98)	Cf-244	2.93E-13	9.03E-14	1.25E-13	1.74E-13	2.96E-11	6.83E-11	5.54E+08	5.07E+08	1.28E+09	2.79E+09	3.81E+02	1.01E+01		
Californium (98)	Cf-246	6.11E-11	8.58E-12	2.11E-11	3.09E-11	1.47E-09	9.25E-11	6.07E+04	5.09E+04	7.92E+05	1.45E+06	2.26E+00	5.71E-02		
Californium (98)	Cf-248	1.18E-10	2.42E-11	4.44E-11	6.22E-11	1.81E-08	4.73E-11	1.40E+02	1.16E+02	1.24E+03	2.28E+03	1.07E+00	2.84E-02		
Californium (98)	Cf-249	2.54E-10	1.14E-10	1.27E-10	1.63E-10	3.40E-08	1.37E-06	8.15E-02	6.13E-02	1.62E-01	3.63E-01	3.75E-01	1.08E-02		
Californium (98)	Cf-250	1.85E-10	7.10E-11	8.62E-11	1.12E-10	2.66E-08	4.48E-11	7.76E+00	5.67E+00	4.26E+01	7.76E+01	5.52E-01	1.57E-02		
Californium (98)	Cf-251	2.67E-10	1.17E-10	1.32E-10	1.70E-10	3.40E-08	3.76E-07	2.70E-01	1.99E-01	5.64E-01	1.26E+00	3.61E-01	1.04E-02		
Californium (98)	Cf-252			6.85E-08	9.30E+08	2.59E-05	8.66E-11	4.25E-17	1.02E-17	3.10E+00	6.97E+00	6.95E-04	1.90E-21		
Californium (98)	Cf-253	1.20E-11	1.96E-12	4.26E-12	6.11E-12	4.22E-09	4.86E-11	2.51E+04	2.11E+04	2.13E+05	4.11E+05	1.12E+01	2.89E-01		
Californium (98)	Cf-254						1.46E-13	9.58E+07	9.58E+07	1.56E+08	3.52E+08				
Carbon (6)	C-11	8.70E-14	3.32E-14	4.07E-14	5.59E-14	2.78E-14	4.45E-06	1.34E+04	1.30E+03	2.19E+04	4.93E+04	1.17E+03	3.16E+01	6.71E+12	3.36E+11
Carbon (6)	C-14	2.79E-12	1.38E-12	1.55E-12	2.00E-12	7.07E-12	7.83E-12	4.56E-01	5.63E-05	1.23E+03	2.24E+03	1.29E+00	8.82E-01	4.01E+01	2.00E+00
Cerium (58)	Ce-134	4.59E-11	6.62E-12	1.59E-11	2.33E-11	6.96E-12	8.24E-09	1.79E+04	9.86E+02	5.09E+04	1.12E+05	2.99E+00	7.57E-02	1.35E+07	6.74E+05
Cerium (58)	Ce-135	1.02E-11	1.78E-12	3.81E-12	5.48E-12	1.75E-12	7.74E-06	1.49E+02	1.48E+02	2.43E+02	5.48E+02	1.25E+01	3.22E-01	9.42E+08	4.71E+07
Cerium (58)	Ce-137	3.64E-13	5.85E-14	1.31E-13	1.91E-13	4.11E-14	4.46E-08	5.06E+04	4.82E+04	8.26E+04	1.86E+05	3.64E+02	9.23E+00	1.05E+11	5.24E+09
Cerium (58)	Ce-137m	9.99E-12	1.42E-12	3.47E-12	5.07E-12	1.94E-12	1.38E-07	4.23E+03	2.98E+03	6.98E+03	1.57E+04	1.37E+01	3.48E-01	2.71E+08	1.35E+07
Cerium (58)	Ce-139	3.70E-12	6.07E-13	1.35E-12	1.95E-12	5.66E-12	4.54E-07	1.35E+01	1.29E+01	2.20E+01	4.96E+01	3.53E+01	9.04E-01	7.51E+04	3.75E+03
Cerium (58)	Ce-143	2.04E-11	2.93E-12	7.10E-12	1.04E-11	3.74E-12	1.09E-06	5.63E+02	5.07E+02	9.22E+02	2.07E+03	6.71E+00	1.70E-01	1.44E+08	7.19E+06
Cerium (58)	Ce-141	1.34E-11	1.89E-12	4.63E-12	6.77E-12	1.14E-11	2.27E-07	1.14E+02	8.46E+01	1.87E+02	4.21E+02	1.03E+01	2.61E-01	3.95E+05	1.97E+04
Cerium (58)	Ce-144	1.02E-10	1.42E-11	3.52E-11	5.18E-11	1.10E-10	5.02E-08	4.46E+01	4.46E+00	9.36E+01	2.09E+02	1.35E+00	3.40E-02	5.64E+02	2.82E+01
Cerium (58)	Ce-144+D	1.02E-10		3.53E-11	5.19E-11	1.10E-10	2.44E-07	1.14E+01	3.45E+00	1.99E+01	4.49E+01	1.35E+00	3.40E-02	5.64E+02	2.82E+01
Cesium (55)	Cs-125	1.29E-13	4.77E-14	5.96E-14	8.18E-14	1.64E-14	2.92E-06	9.28E+03	8.60E+03	1.51E+04	3.41E+04	7.99E+02	2.16E+01	9.61E+12	4.81E+11
Cesium (55)	Cs-126						4.74E-06	1.57E+05	1.57E+05	2.56E+05	5.76E+05				
Cesium (55)	Cs-127	1.38E-13	5.00E-14	6.51E-14	8.73E-14	2.47E-14	1.68E-06	1.93E+03	1.69E+03	3.16E+03	7.11E+03	7.31E+02	2.02E+01	1.27E+11	6.34E+09
Cesium (55)	Cs-128						3.92E-06	7.97E+04	7.97E+04	1.30E+05	2.93E+05				
Cesium (55)	Cs-129	4.00E-13	1.38E-13	1.85E-13	2.48E-13	7.44E-14	1.05E-06	6.03E+02	3.63E+02	9.84E+02	2.21E+03	2.57E+02	7.11E+00	1.69E+09	8.45E+07
Cesium (55)	Cs-130	1.02E-13	3.85E-14	4.74E-14	6.48E-14	1.24E-14	2.22E-06	1.84E+04	1.70E+04	3.00E+04	6.74E+04	1.00E+03	2.72E+01	2.74E+13	1.37E+12
Cesium (55)	Cs-131	4.11E-13	1.37E-13	1.86E-13	2.49E-13	7.51E-14	4.90E-09	1.69E+04	1.25E+02	2.90E+04	6.52E+04	2.56E+02	7.08E+00	3.20E+07	1.60E+06
Cesium (55)	Cs-132	2.89E-12	1.18E-12	1.46E-12	1.91E-12	5.92E-13	3.11E-06	4.20E+01	1.55E+01	6.86E+01	1.54E+02	3.26E+01	9.23E-01	9.12E+06	4.56E+05
Cesium (55)	Cs-134	5.81E-11	4.48E-11	4.22E-11	5.14E-11	1.65E-11	7.10E-06	1.57E-01	7.47E-03	2.59E-01	5.82E-01	1.13E+00	3.43E-02	1.65E+02	8.24E+00
Cesium (55)	Cs-134m	8.84E-14	3.28E-14	4.14E-14	5.55E-14	1.99E-14	5.02E-08	1.39E+05	3.41E+04	2.28E+05	5.12E+05	1.15E+03	3.18E+01	9.25E+11	4.63E+10
Cesium (55)	Cs-135	7.18E-12	4.70E-12	4.74E-12	5.88E-12	1.86E-12	2.36E-11	1.78E+01	5.09E-03	3.63E+02	6.59E+02	1.00E+01	3.00E-01	1.84E+02	9.18E+00
Cesium (55)	Cs-135m	9.10E-14	3.66E-14	4.51E-14	6.07E-14	1.32E-14	7.37E-06	3.12E+03	3.05E+03	5.09E+03	1.15E+04	1.06E+03	2.91E+01	9.16E+12	4.58E+11
Cesium (55)	Cs-136	1.65E-11	7.22E-12	8.66E-12	1.12E-11	3.49E-12	1.00E-05	6.45E+00	1.56E+00	1.05E+01	2.37E+01	5.50E+00	1.57E-01	3.76E+05	1.88E+04
Cesium (55)	Cs-137	4.33E-11	3.17E-11	3.04E-11	3.74E-11	1.19E-11	5.32E-10	3.88E+00	1.23E-03	6.50E+01	1.20E+02	1.57E+00	4.72E-02	5.66E+01	2.83E+00

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Toxicity: Soil Ingestion Slope Factor-Adult (risk/pCi)	Toxicity: Water Ingestion Slope Factor (risk/pCi)	Toxicity: Food Ingestion Slope Factor (risk/pCi)	Toxicity: Inhalation Slope Factor (risk/pCi)	Toxicity: External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	PRG: Agricultural Soil (pCi/g)	PRG: Outdoor Worker Soil (pCi/g)	PRG: Indoor Worker Soil (pCi/g)	PRG: Tap Water (pCi/L)	PRG: Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	Soil to Groundwater: DAF=1 (pCi/g)
Cesium (55)	Cs-137+D	4.33E-11	3.17E-11	3.04E-11	3.74E-11	1.19E-11	2.55E-06	5.97E-02	1.20E-03	1.13E-01	2.53E-01	1.57E+00	4.72E-02	5.66E+01	2.83E+00
Cesium (55)	Cs-138	3.40E-13	1.27E-13	1.58E-13	2.16E-13	4.00E-14	1.19E-05	3.18E+03	3.03E+03	5.19E+03	1.17E+04	3.01E+02	8.17E+00	7.08E+12	3.54E+11
Chlorine (17)	Cl-36	7.66E-12	2.29E-12	3.30E-12	4.44E-12	2.50E-11	1.74E-09	5.65E-02	1.02E-02	1.08E+02	2.35E+02	1.44E+01	3.97E-01		
Chlorine (17)	Cl-38	4.22E-13	1.55E-13	1.93E-13	2.64E-13	9.40E-14	7.93E-06	4.07E+03	3.89E+03	6.74E+03	1.52E+04	2.47E+02	6.68E+00		
Chlorine (17)	Cl-39	3.31E-13	1.21E-13	1.52E-13	2.08E-13	9.36E-14	7.09E-06	3.05E+03	2.93E+03	5.05E+03	1.14E+04	3.13E+02	8.48E+00		
Chromium (24)	Cr-48	1.84E-12	4.07E-13	7.44E-13	1.05E-12	7.51E-13	1.62E-06	5.45E+02	5.45E+02	8.90E+02	2.00E+03	6.40E+01	1.68E+00		
Chromium (24)	Cr-49	3.20E-13	9.10E-14	1.35E-13	1.89E-13	7.36E-14	4.43E-06	6.54E+03	6.54E+03	1.07E+04	2.40E+04	3.53E+02	9.33E+00		
Chromium (24)	Cr-51	4.96E-13	8.88E-14	1.85E-13	2.66E-13	1.67E-13	1.27E-07	2.41E+02	2.41E+02	3.93E+02	8.84E+02	2.57E+02	6.63E+00		
Cobalt (27)	Co-55	1.23E-11	2.38E-12	4.63E-12	6.70E-12	2.07E-12	9.21E-06	1.26E+02	7.59E+00	2.06E+02	4.63E+02	1.03E+01	2.63E-01	6.68E+06	3.34E+05
Cobalt (27)	Co-56	2.56E-11	5.29E-12	1.01E-11	1.43E-11	1.85E-11	1.80E-05	5.96E-01	3.31E-02	9.74E-01	2.19E+00	4.71E+00	1.23E-01	2.62E+02	1.31E+01
Cobalt (27)	Co-57	2.78E-12	4.85E-13	1.04E-12	1.49E-12	2.09E-12	3.55E-07	8.73E+00	9.66E-02	1.44E+01	3.23E+01	4.58E+01	1.18E+00	1.68E+02	8.40E+00
Cobalt (27)	Co-58	7.44E-12	1.57E-12	2.95E-12	4.18E-12	5.99E-12	4.48E-06	2.66E+00	1.27E-01	4.36E+00	9.80E+00	1.61E+01	4.22E-01	1.11E+03	5.56E+01
Cobalt (27)	Co-58m	3.47E-13	5.99E-14	1.26E-13	1.83E-13	6.88E-14	1.00E-12	5.92E+06	5.65E+02	4.33E+08	7.99E+08	3.78E+02	9.64E+00	8.98E+08	4.49E+07
Cobalt (27)	Co-60	4.03E-11	7.33E-12	1.57E-11	2.23E-11	3.58E-11	1.24E-05	3.61E-02	9.01E-04	6.02E-02	1.35E-01	3.03E+00	7.91E-02	2.41E+00	1.21E-01
Cobalt (27)	Co-60m	5.88E-15	2.12E-15	2.66E-15	3.66E-15	3.96E-15	1.86E-08	6.24E+06	1.20E+06	1.02E+07	2.29E+07	1.79E+04	4.82E+02	1.16E+14	5.82E+12
Cobalt (27)	Co-61	6.40E-13	1.32E-13	2.43E-13	3.49E-13	1.43E-13	2.48E-07	4.95E+04	1.59E+03	8.10E+04	1.82E+05	1.96E+02	5.05E+00	1.43E+10	7.16E+08
Cobalt (27)	Co-62m	1.79E-13	6.55E-14	8.25E-14	1.13E-13	3.17E-14	1.35E-05	6.50E+03	5.51E+03	1.06E+04	2.39E+04	5.77E+02	1.56E+01	2.14E+12	1.07E+11
Copper (29)	Cu-60	3.00E-13	1.04E-13	1.37E-13	1.89E-13	5.77E-14	1.93E-05	2.72E+03	2.72E+03	4.44E+03	1.00E+04	3.48E+02	9.33E+00		
Copper (29)	Cu-61	1.20E-12	2.39E-13	4.63E-13	6.70E-13	2.41E-13	3.63E-06	1.64E+03	1.64E+03	2.68E+03	6.03E+03	1.03E+02	2.63E+00		
Copper (29)	Cu-62						4.43E-06	2.83E+04	2.83E+04	4.61E+04	1.04E+05				
Copper (29)	Cu-64	1.72E-12	2.93E-13	6.40E-13	9.32E-13	4.33E-13	8.30E-07	1.92E+03	1.89E+03	3.15E+03	7.08E+03	7.44E+01	1.89E+00		
Copper (29)	Cu-66						4.32E-07	5.53E+05	5.53E+05	9.03E+05	2.03E+06				
Copper (29)	Cu-67	5.29E-12	8.88E-13	1.94E-12	2.83E-12	2.35E-12	3.83E-07	8.38E+02	7.67E+02	1.40E+03	3.15E+03	2.45E+01	6.23E-01		
Curium (96)	Cm-238	8.70E-13	1.65E-13	3.28E-13	4.70E-13	1.35E-11	1.90E-07	4.45E+04	4.40E+04	7.27E+04	1.64E+05	1.45E+02	3.75E+00	1.44E+12	7.21E+10
Curium (96)	Cm-240	9.88E-11	1.53E-11	3.49E-11	5.07E-11	9.51E-09	6.19E-11	2.07E+03	1.23E+02	2.42E+04	4.46E+04	1.36E+00	3.48E-02	1.86E+05	9.29E+03
Curium (96)	Cm-241	1.35E-11	2.15E-12	4.85E-12	7.03E-12	1.01E-10	1.94E-06	1.33E+01	1.31E+01	2.17E+01	4.88E+01	9.82E+00	2.51E-01	9.06E+05	4.53E+04
Curium (96)	Cm-242	1.05E-10	1.87E-11	3.85E-11	5.48E-11	1.51E-08	7.73E-11	3.22E+02	1.89E+01	3.20E+03	5.92E+03	1.24E+00	3.22E-02	4.62E+03	2.31E+02
Curium (96)	Cm-243	2.05E-10	7.84E-11	9.47E-11	1.23E-10	2.69E-08	4.19E-07	3.49E-01	1.27E-01	6.79E-01	1.52E+00	5.03E-01	1.43E-02	3.64E+01	1.82E+00
Curium (96)	Cm-244	1.81E-10	6.88E-11	8.36E-11	1.08E-10	2.53E-08	4.85E-11	6.69E+00	3.04E-01	3.79E+01	6.90E+01	5.70E-01	1.63E-02	4.35E+01	2.17E+00
Curium (96)	Cm-245	2.18E-10	9.14E-11	1.04E-10	1.35E-10	2.77E-08	2.38E-07	4.11E-01	9.22E-02	8.76E-01	1.95E+00	4.58E-01	1.31E-02	7.91E-01	3.96E-02
Curium (96)	Cm-246	2.12E-10	9.03E-11	1.02E-10	1.31E-10	2.77E-08	4.57E-11	3.40E+00	1.29E-01	1.88E+01	3.42E+01	4.67E-01	1.35E-02	8.08E-01	4.04E-02
Curium (96)	Cm-247	2.11E-10	8.58E-11	9.95E-11	1.30E-10	2.50E-08	1.31E-06	8.31E-02	4.28E-02	1.65E-01	3.71E-01	4.79E-01	1.36E-02	8.25E-01	4.13E-02
Curium (96)	Cm-248			9.52E-09	1.23E-08	2.54E-06	3.42E-11	3.89E-01	1.43E-03	4.80E+00	1.08E+01	5.00E-03	1.43E-04	2.59E+01	1.29E+00
Curium (96)	Cm-249	2.18E-13	4.92E-14	8.40E-14	1.20E-13	7.25E-14	8.51E-08	2.23E+05	2.22E+05	3.64E+05	8.19E+05	5.67E+02	1.47E+01	2.83E+13	1.42E+12
Dysprosium (66)	Dy-155	1.35E-12	2.68E-13	5.25E-13	7.47E-13	2.45E-13	2.44E-06	8.33E+02	8.33E+02	1.36E+03	3.06E+03	9.07E+01	2.36E+00		
Dysprosium (66)	Dy-157	5.62E-13	1.21E-13	2.26E-13	3.20E-13	8.33E-14	1.32E-06	1.90E+03	1.90E+03	3.10E+03	6.98E+03	2.11E+02	5.51E+00		
Dysprosium (66)	Dy-159	1.47E-12	2.37E-13	5.29E-13	7.70E-13	1.28E-12	3.19E-08	1.83E+02	1.83E+02	3.00E+02	6.76E+02	9.00E+01	2.29E+00		
Dysprosium (66)	Dy-165	1.15E-12	1.95E-13	4.14E-13	6.03E-13	2.10E-13	9.49E-08	9.17E+04	9.17E+04	1.50E+05	3.37E+05	1.15E+02	2.92E+00		
Dysprosium (66)	Dy-166	3.22E-11	4.48E-12	1.11E-11	1.63E-11	8.36E-12	6.02E-08	3.85E+03	3.86E+03	6.69E+03	1.50E+04	4.29E+00	1.08E-01		
Einsteinium (99)	Es-250	1.44E-13	3.55E-14	5.96E-14	8.36E-14	5.07E-13	1.69E-06	5.73E+03	5.73E+03	9.34E+03	2.10E+04	7.99E+02	2.11E+01		
Einsteinium (99)	Es-251	2.89E-12	4.33E-13	1.02E-12	1.49E-12	6.40E-12	2.55E-07	2.41E+03	2.41E+03	3.94E+03	8.86E+03	4.67E+01	1.18E+00		
Einsteinium (99)	Es-253	1.01E-10	1.44E-11	3.49E-11	5.11E-11	8.84E-09	1.25E-09	2.67E+03	2.77E+03	2.12E+04	4.19E+04	1.36E+00	3.45E-02		
Einsteinium (99)	Es-254	1.50E-10	2.82E-11	5.51E-11	7.81E-11	1.85E-08	8.55E-09	1.03E+02	1.06E+02	4.05E+02	8.52E+02	8.64E-01	2.26E-02		
Einsteinium (99)	Es-254m	7.88E-11	1.11E-11	2.73E-11	4.00E-11	1.53E-09	2.10E-06	2.45E+02	2.45E+02	4.02E+02	9.03E+02	1.74E+00	4.41E-02		
Erbium (68)	Er-161	8.10E-13	1.65E-13	3.15E-13	4.51E-13	1.34E-13	4.09E-06	1.53E+03	1.53E+03	2.50E+03	5.63E+03	1.51E+02	3.91E+00		
Erbium (68)	Er-165	2.42E-13	4.18E-14	8.95E-14	1.30E-13	3.13E-14	3.05E-08	6.40E+04	6.40E+04	1.05E+05	2.35E+05	5.32E+02	1.36E+01		
Erbium (68)	Er-169	7.36E-12	1.02E-12	2.53E-12	3.70E-12	3.85E-12	9.10E-11	8.09E+04	8.41E+04	6.86E+05	1.35E+06	1.88E+01	4.77E-01		
Erbium (68)	Er-171	5.74E-12	8.70E-13	2.02E-12	2.96E-12	9.40E-13	1.42E-06	1.90E+03	1.90E+03	3.10E+03	6.99E+03	2.36E+01	5.96E-01		
Erbium (68)	Er-172	1.70E-11	2.55E-12	5.99E-12	8.77E-12	4.74E-12	2.20E-06	1.87E+02	1.87E+02	3.06E+02	6.88E+02	7.95E+00	2.01E-01		
Europium (63)	Eu-145	6.77E-12	1.46E-12	2.73E-12	3.85E-12	1.81E-12	6.95E-06	2.05E+01	2.05E+01	3.35E+01	7.53E+01	1.74E+01	4.58E-01		
Europium (63)	Eu-146	1.12E-11	2.45E-12	4.55E-12	6.40E-12	2.59E-12	1.16E-05	1.58E+01	1.58E+01	2.58E+01	5.81E+01	1.05E+01	2.76E-01		

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Europium (63)	Eu-147	5.37E-12	9.69E-13	2.02E-12	2.90E-12	3.85E-12	2.04E-06	1.73E+01	1.73E+01	2.82E+01	6.35E+01	2.36E+01	6.08E-01		
Europium (63)	Eu-148	1.04E-11	2.38E-12	4.29E-12	6.03E-12	9.92E-12	9.84E-06	1.58E+00	1.58E+00	2.58E+00	5.80E+00	1.11E+01	2.92E-01		
Europium (63)	Eu-149	1.40E-12	2.34E-13	5.14E-13	7.40E-13	1.07E-12	1.42E-07	6.39E+01	6.39E+01	1.04E+02	2.35E+02	9.26E+01	2.38E+00		
Europium (63)	Eu-150a	6.88E-12	9.81E-13	2.38E-12	3.50E-12	1.03E-12	1.95E-07	8.22E+03	8.20E+03	1.35E+04	3.03E+04	2.00E+01	5.04E-01		
Europium (63)	Eu-150b	1.08E-11	2.43E-12	4.33E-12	6.07E-12	1.12E-10	6.49E-06	2.29E-02	1.88E-02	4.29E-02	9.65E-02	1.10E+01	2.91E-01		
Europium (63)	Eu-152	1.62E-11	2.96E-12	6.07E-12	8.70E-12	9.10E-11	5.30E-06	4.16E-02	3.76E-02	7.37E-02	1.66E-01	7.84E+00	2.03E-01		
Europium (63)	Eu-152m	8.51E-12	1.25E-12	2.98E-12	4.37E-12	1.12E-12	1.33E-06	1.64E+03	1.64E+03	2.67E+03	6.02E+03	1.60E+01	4.04E-01		
Europium (63)	Eu-154	2.85E-11	4.74E-12	1.03E-11	1.49E-11	1.15E-10	5.83E-06	4.99E-02	4.72E-02	8.57E-02	1.93E-01	4.62E+00	1.18E-01		
Europium (63)	Eu-155	5.40E-12	8.07E-13	1.90E-12	2.77E-12	1.48E-11	1.24E-07	3.80E+00	3.74E+00	6.34E+00	1.43E+01	2.51E+01	6.37E-01		
Europium (63)	Eu-156	3.56E-11	5.44E-12	1.27E-11	1.84E-11	1.37E-11	6.62E-06	8.41E+00	8.40E+00	1.37E+01	3.09E+01	3.75E+00	9.59E-02		
Europium (63)	Eu-157	1.06E-11	1.54E-12	3.70E-12	5.40E-12	1.57E-12	9.60E-07	1.39E+03	1.39E+03	2.27E+03	5.11E+03	1.29E+01	3.27E-01		
Europium (63)	Eu-158	5.22E-13	1.39E-13	2.14E-13	3.01E-13	1.10E-13	5.06E-06	5.25E+03	5.25E+03	8.57E+03	1.93E+04	2.23E+02	5.86E+00		
Fermium (100)	Fm-252	4.92E-11	6.92E-12	1.69E-11	2.48E-11	1.03E-09	5.09E-11	1.28E+05	1.34E+05	1.59E+06	2.90E+06	2.82E+00	7.11E-02		
Fermium (100)	Fm-253	1.48E-11	2.13E-12	5.14E-12	7.51E-12	1.28E-09	2.24E-07	1.25E+03	1.25E+03	2.05E+03	4.62E+03	9.26E+00	2.35E-01		
Fermium (100)	Fm-254	6.07E-12	9.58E-13	2.15E-12	3.13E-12	1.98E-10	1.23E-10	6.42E+06	6.66E+06	4.19E+07	8.41E+07	2.21E+01	5.63E-01		
Fermium (100)	Fm-255	4.77E-11	6.73E-12	1.65E-11	2.42E-11	8.84E-10	3.85E-09	9.57E+04	9.83E+04	3.52E+05	7.58E+05	2.89E+00	7.29E-02		
Fermium (100)	Fm-257	1.23E-10	2.05E-11	4.40E-11	6.29E-11	2.04E-08	3.06E-07	2.59E+01	2.60E+01	4.43E+01	9.94E+01	1.08E+00	2.80E-02		
Fluorine (9)	F-18	2.00E-13	7.88E-14	9.73E-14	1.30E-13	1.21E-13	4.45E-06	2.49E+03	2.49E+03	4.06E+03	9.14E+03	4.89E+02	1.36E+01		
Francium (87)	Fr-219						1.44E-08	2.42E+11	2.42E+11	3.95E+11	8.88E+11				
Francium (87)	Fr-220						3.25E-08	8.21E+07	8.21E+07	1.34E+08	3.02E+08				
Francium (87)	Fr-221						1.11E-07	2.29E+06	2.29E+06	3.73E+06	8.40E+06				
Francium (87)	Fr-222	3.43E-12	1.07E-12	1.48E-12	2.02E-12	2.42E-11	1.14E-08	7.12E+06	7.14E+06	1.20E+07	2.69E+07	3.22E+01	8.73E-01		
Francium (87)	Fr-223	1.78E-11	4.85E-12	7.29E-12	1.00E-11	3.06E-12	1.40E-07	3.92E+05	3.93E+05	6.49E+05	1.46E+06	6.53E+00	1.76E-01		
Gadolinium (64)	Gd-145	1.99E-13	6.59E-14	8.92E-14	1.23E-13	3.63E-14	1.13E-05	4.71E+03	4.71E+03	7.69E+03	1.73E+04	5.34E+02	1.43E+01		
Gadolinium (64)	Gd-146	1.39E-11	2.26E-12	5.03E-12	7.29E-12	2.27E-11	5.56E-07	3.14E+01	3.13E+01	5.14E+01	1.16E+02	9.47E+00	2.42E-01		
Gadolinium (64)	Gd-147	6.33E-12	1.25E-12	2.46E-12	3.50E-12	1.34E-12	5.87E-06	9.08E+01	9.08E+01	1.48E+02	3.34E+02	1.94E+01	5.04E-01		
Gadolinium (64)	Gd-148	9.07E-11	3.37E-11	4.22E-11	5.51E-11	1.26E-08	0.00E+00	7.84E+00	3.87E+00	5.48E+01	9.97E+01	1.13E+00	3.20E-02		
Gadolinium (64)	Gd-149	6.03E-12	1.02E-12	2.23E-12	3.22E-12	2.76E-12	1.59E-06	5.66E+01	5.66E+01	9.24E+01	2.08E+02	2.14E+01	5.48E-01		
Gadolinium (64)	Gd-151	3.20E-12	4.85E-13	1.14E-12	1.65E-12	2.92E-12	1.20E-07	5.85E+01	5.84E+01	9.59E+01	2.16E+02	4.18E+01	1.07E+00		
Gadolinium (64)	Gd-152	6.29E-11	2.40E-11	2.97E-11	3.85E-11	9.10E-09	0.00E+00	1.01E+01	4.80E+00	7.02E+01	1.28E+02	1.60E+00	4.58E-02		
Gadolinium (64)	Gd-153	4.26E-12	6.66E-13	1.52E-12	2.22E-12	6.55E-12	1.62E-07	2.15E+01	2.15E+01	3.52E+01	7.92E+01	3.13E+01	7.94E-01		
Gadolinium (64)	Gd-159	9.21E-12	1.31E-12	3.19E-12	4.66E-12	1.46E-12	1.74E-07	6.22E+03	6.20E+03	1.02E+04	2.30E+04	1.49E+01	3.78E-01		
Gallium (31)	Ga-65	1.39E-13	4.96E-14	6.33E-14	8.73E-14	2.84E-14	5.04E-06	1.59E+04	1.59E+04	2.60E+04	5.84E+04	7.52E+02	2.02E+01		
Gallium (31)	Ga-66	1.80E-11	2.81E-12	6.40E-12	9.32E-12	2.18E-12	1.26E-05	1.72E+02	1.72E+02	2.80E+02	6.30E+02	7.44E+00	1.89E-01		
Gallium (31)	Ga-67	2.89E-12	4.59E-13	1.04E-12	1.51E-12	9.55E-13	5.36E-07	4.84E+02	4.84E+02	7.90E+02	1.78E+03	4.58E+01	1.17E+00		
Gallium (31)	Ga-68	7.18E-13	1.66E-13	2.83E-13	4.03E-13	1.28E-13	4.17E-06	4.30E+03	4.30E+03	7.02E+03	1.58E+04	1.68E+02	4.38E+00		
Gallium (31)	Ga-70	1.19E-13	3.96E-14	5.22E-14	7.22E-14	2.92E-14	4.39E-08	1.31E+06	1.31E+06	2.14E+06	4.81E+06	9.12E+02	2.44E+01		
Gallium (31)	Ga-72	1.53E-11	2.54E-12	5.59E-12	8.07E-12	2.17E-12	1.37E-05	1.05E+02	1.05E+02	1.72E+02	3.86E+02	8.52E+00	2.19E-01		
Gallium (31)	Ga-73	3.92E-12	6.07E-13	1.39E-12	2.03E-12	6.14E-13	1.25E-06	3.31E+03	3.31E+03	5.40E+03	1.22E+04	3.43E+01	8.69E-01		
Germanium (32)	Ge-66	7.99E-13	2.58E-13	3.70E-13	4.88E-13	2.50E-13	2.86E-06	3.12E+03	3.11E+03	5.11E+03	1.15E+04	1.29E+02	3.61E+00		
Germanium (32)	Ge-67	2.28E-13	8.62E-14	1.06E-13	1.45E-13	4.59E-14	6.24E-06	1.04E+04	1.04E+04	1.70E+04	3.84E+04	4.49E+02	1.22E+01		
Germanium (32)	Ge-68	1.85E-11	3.48E-12	6.96E-12	9.88E-12	4.88E-11	4.69E-13	3.25E+01	7.98E+00	1.12E+04	2.01E+04	6.84E+00	1.79E-01		
Germanium (32)	Ge-69	2.35E-12	5.99E-13	9.84E-13	1.35E-12	8.81E-13	4.02E-06	1.29E+02	1.28E+02	2.11E+02	4.75E+02	4.84E+01	1.31E+00		
Germanium (32)	Ge-71	1.73E-13	3.19E-14	6.48E-14	9.18E-14	5.18E-14	4.74E-13	8.53E+04	2.10E+04	2.66E+07	4.90E+07	7.35E+02	1.92E+01		
Germanium (32)	Ge-75	1.85E-13	6.92E-14	8.66E-14	1.17E-13	8.44E-14	1.38E-07	1.06E+05	1.03E+05	1.74E+05	3.92E+05	5.50E+02	1.51E+01		
Germanium (32)	Ge-77	2.81E-12	7.92E-13	1.22E-12	1.65E-12	1.15E-12	4.82E-06	3.72E+02	3.68E+02	6.09E+02	1.37E+03	3.90E+01	1.07E+00		
Germanium (32)	Ge-78	6.22E-13	2.43E-13	3.09E-13	4.03E-13	2.48E-13	1.10E-06	1.27E+04	1.26E+04	2.08E+04	4.68E+04	1.54E+02	4.38E+00		
Gold (79)	Au-193	2.05E-12	3.26E-13	7.36E-13	1.07E-12	4.55E-13	4.30E-07	2.65E+03	2.61E+03	4.36E+03	9.80E+03	6.47E+01	1.65E+00		
Gold (79)	Au-194	4.22E-12	8.70E-13	1.66E-12	2.36E-12	7.92E-13	4.93E-06	1.04E+02	1.04E+02	1.70E+02	3.83E+02	2.87E+01	7.47E-01		
Gold (79)	Au-195	4.22E-12	6.48E-13	1.50E-12	2.19E-12	6.48E-12	1.38E-07	3.22E+01	2.91E+01	5.47E+01	1.23E+02	3.17E+01	8.05E-01		
Gold (79)	Au-195m						7.37E-07	3.25E+06	3.25E+06	5.31E+06	1.19E+07				

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Gold (79)	Au-198	1.78E-11	2.66E-12	6.29E-12	9.18E-12	4.00E-12	1.70E-06	1.82E+02	1.75E+02	3.01E+02	6.77E+02	7.57E+00	1.92E-01		
Gold (79)	Au-198m	2.09E-11	3.20E-12	7.44E-12	1.08E-11	7.77E-12	1.89E-06	1.92E+02	1.85E+02	3.18E+02	7.15E+02	6.40E+00	1.63E-01		
Gold (79)	Au-199	7.92E-12	1.16E-12	2.78E-12	4.07E-12	3.12E-12	2.79E-07	9.32E+02	8.49E+02	1.58E+03	3.55E+03	1.71E+01	4.33E-01		
Gold (79)	Au-200	3.85E-13	9.92E-14	1.55E-13	2.20E-13	8.55E-14	1.30E-06	1.94E+04	1.93E+04	3.16E+04	7.11E+04	3.07E+02	8.02E+00		
Gold (79)	Au-200m	1.48E-11	2.50E-12	5.44E-12	7.88E-12	2.81E-12	9.04E-06	1.20E+02	1.19E+02	1.96E+02	4.41E+02	8.75E+00	2.24E-01		
Gold (79)	Au-201	1.01E-13	3.19E-14	4.33E-14	6.03E-14	3.30E-14	2.29E-07	2.02E+05	2.01E+05	3.29E+05	7.40E+05	1.10E+03	2.92E+01		
Hafnium (72)	Hf-170	5.81E-12	1.05E-12	2.19E-12	3.14E-12	1.20E-12	2.04E-06	6.22E+02	6.22E+02	1.02E+03	2.29E+03	2.17E+01	5.62E-01		
Hafnium (72)	Hf-172	1.37E-11	2.35E-12	4.96E-12	7.14E-12	6.92E-11	1.62E-07	7.57E+00	7.57E+00	1.25E+01	2.81E+01	9.60E+00	2.47E-01		
Hafnium (72)	Hf-173	2.85E-12	5.00E-13	1.06E-12	1.52E-12	5.92E-13	1.34E-06	6.32E+02	6.32E+02	1.03E+03	2.32E+03	4.49E+01	1.16E+00		
Hafnium (72)	Hf-175	5.29E-12	9.21E-13	1.96E-12	2.83E-12	4.29E-12	1.35E-06	8.95E+00	8.95E+00	1.46E+01	3.29E+01	2.43E+01	6.23E-01		
Hafnium (72)	Hf-177m	4.74E-13	1.33E-13	2.01E-13	2.81E-13	1.81E-13	8.58E-06	2.76E+03	2.76E+03	4.51E+03	1.02E+04	2.37E+02	6.28E+00		
Hafnium (72)	Hf-178m	3.89E-11	8.40E-12	1.51E-11	2.13E-11	3.70E-10	9.57E-06	1.60E-02	1.32E-02	2.98E-02	6.70E-02	3.15E+00	8.28E-02		
Hafnium (72)	Hf-179m	1.81E-11	2.94E-12	6.55E-12	9.51E-12	1.38E-11	3.42E-06	9.86E+00	9.86E+00	1.61E+01	3.62E+01	7.27E+00	1.85E-01		
Hafnium (72)	Hf-180m	1.89E-12	3.56E-13	7.18E-13	1.03E-12	4.14E-13	3.93E-06	9.40E+02	9.40E+02	1.53E+03	3.45E+03	6.63E+01	1.71E+00		
Hafnium (72)	Hf-181	1.79E-11	2.75E-12	6.36E-12	9.25E-12	1.76E-11	2.24E-06	8.90E+00	8.90E+00	1.45E+01	3.27E+01	7.49E+00	1.91E-01		
Hafnium (72)	Hf-182	1.27E-11	3.74E-12	5.37E-12	7.25E-12	3.41E-10	9.10E-07	1.22E-01	9.18E-02	2.40E-01	5.40E-01	8.87E+00	2.43E-01		
Hafnium (72)	Hf-182m	2.70E-13	6.99E-14	1.11E-13	1.57E-13	1.04E-13	3.83E-06	5.18E+03	5.18E+03	8.45E+03	1.90E+04	4.29E+02	1.12E+01		
Hafnium (72)	Hf-183	6.25E-13	1.31E-13	2.39E-13	3.42E-13	1.65E-13	3.30E-06	5.77E+03	5.77E+03	9.42E+03	2.12E+04	1.99E+02	5.16E+00		
Hafnium (72)	Hf-184	8.18E-12	1.26E-12	2.91E-12	4.26E-12	1.38E-12	8.64E-07	5.70E+03	5.70E+03	9.31E+03	2.10E+04	1.64E+01	4.14E-01		
Holmium (67)	Ho-155	2.63E-13	6.25E-14	1.05E-13	1.49E-13	5.29E-14	1.52E-06	1.67E+04	1.67E+04	2.73E+04	6.14E+04	4.54E+02	1.18E+01		
Holmium (67)	Ho-157	3.49E-14	1.07E-14	1.54E-14	2.13E-14	7.36E-15	1.84E-06	5.26E+04	5.26E+04	8.58E+04	1.93E+05	3.09E+03	8.28E+01		
Holmium (67)	Ho-159	3.96E-14	1.28E-14	1.78E-14	2.46E-14	1.22E-14	1.16E-06	3.18E+04	3.18E+04	5.20E+04	1.17E+05	2.68E+03	7.17E+01		
Holmium (67)	Ho-161	1.33E-13	2.48E-14	4.96E-14	7.14E-14	1.98E-14	5.52E-08	1.47E+05	1.47E+05	2.40E+05	5.41E+05	9.60E+02	2.47E+01		
Holmium (67)	Ho-162	1.29E-14	4.66E-15	5.96E-15	8.18E-15	5.40E-15	6.02E-07	1.35E+05	1.35E+05	2.20E+05	4.96E+05	7.99E+03	2.16E+02		
Holmium (67)	Ho-162m	1.81E-13	4.55E-14	7.47E-14	1.05E-13	5.18E-14	2.46E-06	7.29E+03	7.29E+03	1.19E+04	2.68E+04	6.37E+02	1.68E+01		
Holmium (67)	Ho-164	4.11E-14	1.26E-14	1.75E-14	2.45E-14	1.65E-14	2.78E-08	1.51E+06	1.51E+06	2.47E+06	5.55E+06	2.72E+03	7.20E+01		
Holmium (67)	Ho-164m	1.05E-13	2.50E-14	4.14E-14	5.88E-14	3.48E-14	3.63E-08	8.95E+05	8.95E+05	1.46E+06	3.29E+06	1.15E+03	3.00E+01		
Holmium (67)	Ho-166	2.67E-11	3.74E-12	9.21E-12	1.35E-11	3.85E-12	1.18E-07	6.19E+03	6.07E+03	1.04E+04	2.35E+04	5.17E+00	1.31E-01		
Holmium (67)	Ho-166m	2.10E-11	4.29E-12	8.03E-12	1.14E-11	3.09E-10	7.69E-06	1.46E-02	1.10E-02	2.86E-02	6.44E-02	5.93E+00	1.55E-01		
Holmium (67)	Ho-167	9.95E-13	1.73E-13	3.64E-13	5.25E-13	2.25E-13	1.45E-06	4.52E+03	4.52E+03	7.38E+03	1.66E+04	1.31E+02	3.36E+00		
Hydrogen (1)	H-3 (vapor)	9.25E-14		5.07E-14	6.51E-14	5.62E-14	0.00E+00					1.44E+02		1.65E+02	8.25E+00
Hydrogen (1)	H-3 (organic)	2.20E-13		1.12E-13	1.44E-13	1.99E-13		2.28E+00	1.60E-01	1.42E+00	3.20E+00		1.22E+01		
Indium (49)	In-109	6.25E-13	1.32E-13	2.46E-13	3.50E-13	1.11E-13	2.90E-06	1.67E+03	1.67E+03	2.72E+03	6.13E+03	1.94E+02	5.04E+00		
Indium (49)	In-110a	7.03E-13	1.68E-13	2.81E-13	4.00E-13	1.17E-13	7.13E-06	2.47E+03	2.47E+03	4.04E+03	9.09E+03	1.69E+02	4.41E+00		
Indium (49)	In-110b	1.77E-12	4.51E-13	7.59E-13	1.05E-12	2.65E-13	1.41E-05	2.94E+02	2.94E+02	4.80E+02	1.08E+03	6.27E+01	1.68E+00		
Indium (49)	In-111	3.40E-12	6.25E-13	1.29E-12	1.85E-12	8.03E-13	1.42E-06	2.11E+02	2.11E+02	3.44E+02	7.73E+02	3.69E+01	9.53E-01		
Indium (49)	In-112	3.70E-14	1.33E-14	1.68E-14	2.32E-14	1.10E-14	1.15E-06	7.36E+04	7.36E+04	1.20E+05	2.70E+05	2.83E+03	7.60E+01		
Indium (49)	In-113m	2.47E-13	5.11E-14	9.47E-14	1.35E-13	5.18E-14	1.05E-06	1.17E+04	1.17E+04	1.90E+04	4.28E+04	5.03E+02	1.31E+01		
Indium (49)	In-114						1.35E-08	7.54E+07	7.54E+07	1.23E+08	2.77E+08				
Indium (49)	In-114m	7.03E-11	1.07E-11	2.48E-11	3.60E-11	3.00E-11	3.57E-07	4.63E+01	4.54E+01	7.79E+01	1.75E+02	1.92E+00	4.90E-02		
Indium (49)	In-115	5.85E-11	3.19E-11	3.38E-11	4.33E-11	4.03E-10	2.70E-10	9.73E+00	4.14E+00	5.14E+01	9.37E+01	1.41E+00	4.07E-02		
Indium (49)	In-115m	1.24E-12	1.96E-13	4.40E-13	6.40E-13	2.15E-13	6.27E-07	7.21E+03	7.21E+03	1.18E+04	2.65E+04	1.08E+02	2.76E+00		
Indium (49)	In-116m	3.77E-13	1.07E-13	1.62E-13	2.26E-13	8.77E-14	1.23E-05	1.83E+03	1.83E+03	2.98E+03	6.71E+03	2.94E+02	7.80E+00		
Indium (49)	In-117	1.67E-13	4.74E-14	7.03E-14	9.84E-14	5.59E-14	2.90E-06	9.60E+03	9.60E+03	1.57E+04	3.52E+04	6.77E+02	1.79E+01		
Indium (49)	In-117m	1.22E-12	2.17E-13	4.44E-13	6.44E-13	2.33E-13	3.35E-07	3.11E+04	3.11E+04	5.08E+04	1.14E+05	1.07E+02	2.74E+00		
Indium (49)	In-119						3.54E-06	1.43E+05	1.43E+05	2.34E+05	5.27E+05				
Indium (49)	In-119m	1.70E-13	5.85E-14	7.55E-14	1.04E-13	3.34E-14	5.63E-08	1.20E+06	1.20E+06	1.96E+06	4.42E+06	6.31E+02	1.70E+01		
Iodine (53)	I-120	2.33E-12	5.66E-13	9.03E-13	2.46E-12	3.89E-13	1.33E-05	1.13E+03	4.13E+02	1.85E+03	4.16E+03	5.27E+01	7.17E-01	4.41E+09	2.21E+08
Iodine (53)	I-120m	1.20E-12	3.53E-13	5.03E-13	1.30E-12	1.98E-13	2.55E-05	9.02E+02	6.09E+02	1.47E+03	3.31E+03	9.47E+01	1.36E+00	1.85E+10	9.26E+08
Iodine (53)	I-121	5.59E-13	1.44E-13	2.27E-13	6.03E-13	9.81E-14	1.63E-06	5.88E+03	1.31E+03	9.60E+03	2.16E+04	2.10E+02	2.92E+00	7.12E+09	3.56E+08
Iodine (53)	I-122						4.17E-06	8.08E+04	8.08E+04	1.32E+05	2.97E+05				

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Toxicity: Soil Ingestion Slope Factor-Adult (risk/pCi)	Toxicity: Water Ingestion Slope Factor (risk/pCi)	Toxicity: Food Ingestion Slope Factor (risk/pCi)	Toxicity: Inhalation Slope Factor (risk/pCi)	Toxicity: External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	PRG: Agricultural Soil (pCi/g)	PRG: Outdoor Worker Soil (pCi/g)	PRG: Indoor Worker Soil (pCi/g)	PRG: Tap Water (pCi/L)	PRG: Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	Soil to Groundwater: DAF=1 (pCi/g)
Iodine (53)	I-123	1.96E-12	3.77E-13	6.96E-13	2.05E-12	3.03E-13	5.10E-07	3.01E+03	7.77E+01	4.93E+03	1.11E+04	6.84E+01	8.60E-01	5.99E+07	3.00E+06
Iodine (53)	I-124	1.16E-10	2.18E-11	4.14E-11	1.22E-10	1.76E-11	5.10E-06	3.92E+01	1.75E-01	6.48E+01	1.46E+02	1.15E+00	1.45E-02	1.74E+04	8.72E+02
Iodine (53)	I-125	5.55E-11	1.70E-11	2.54E-11	6.29E-11	1.06E-11	7.24E-09	3.28E+02	2.38E-02	2.46E+03	5.25E+03	1.87E+00	2.80E-02	1.37E+02	6.87E+00
Iodine (53)	I-126	2.31E-10	3.24E-11	8.73E-11	2.48E-10	3.70E-11	1.96E-06	3.10E+01	2.79E-02	5.41E+01	1.22E+02	5.45E-01	7.11E-03	8.55E+02	4.27E+01
Iodine (53)	I-128	1.89E-13	6.14E-14	8.14E-14	2.06E-13	3.04E-14	3.74E-07	1.30E+05	2.11E+04	2.13E+05	4.79E+05	5.85E+02	8.56E+00	5.14E+11	2.57E+10
Iodine (53)	I-129	2.71E-10	1.14E-10	1.48E-10	3.22E-10	6.07E-11	6.10E-09	5.96E-01	2.76E-05	1.09E+01	2.08E+01	3.22E-01	5.48E-03	4.60E-03	2.30E-04
Iodine (53)	I-130	1.80E-11	3.41E-12	6.36E-12	1.88E-11	2.76E-12	9.67E-06	1.69E+02	8.77E+00	2.77E+02	6.22E+02	7.49E+00	9.38E-02	7.43E+06	3.71E+05
Iodine (53)	I-131	1.26E-10	2.43E-11	4.55E-11	1.34E-10	1.95E-11	1.59E-06	6.32E+01	8.33E-02	1.08E+02	2.43E+02	1.05E+00	1.32E-02	4.29E+03	2.14E+02
Iodine (53)	I-132	2.22E-12	5.07E-13	8.44E-13	2.34E-12	3.74E-13	1.06E-05	8.33E+02	2.71E+02	1.36E+03	3.06E+03	5.64E+01	7.54E-01	1.63E+09	8.14E+07
Iodine (53)	I-132m	1.70E-12	3.40E-13	6.11E-13	1.78E-12	2.70E-13	1.40E-06	1.04E+04	8.03E+02	1.70E+04	3.82E+04	7.79E+01	9.91E-01	6.12E+09	3.06E+08
Iodine (53)	I-133	4.26E-11	7.25E-12	1.44E-11	4.40E-11	6.25E-12	2.72E-06	3.56E+02	2.34E+00	5.86E+02	1.32E+03	3.31E+00	4.01E-02	1.17E+06	5.83E+04
Iodine (53)	I-134	5.96E-13	1.76E-13	2.50E-13	6.44E-13	1.02E-13	1.24E-05	1.87E+03	1.26E+03	3.05E+03	6.86E+03	1.90E+02	2.74E+00	3.78E+10	1.89E+09
Iodine (53)	I-135	8.62E-12	1.64E-12	3.05E-12	8.99E-12	1.34E-12	7.83E-06	3.92E+02	3.32E+01	6.41E+02	1.44E+03	1.56E+01	1.96E-01	5.45E+07	2.73E+06
Iridium (77)	Ir-182	2.33E-13	6.92E-14	9.95E-14	1.39E-13	5.03E-14	5.85E-06	1.39E+04	1.39E+04	2.27E+04	5.10E+04	4.79E+02	1.27E+01		
Iridium (77)	Ir-184	1.67E-12	3.38E-13	6.44E-13	9.21E-13	3.30E-13	8.66E-06	7.77E+02	7.77E+02	1.27E+03	2.85E+03	7.39E+01	1.91E+00		
Iridium (77)	Ir-185	3.61E-12	6.03E-13	1.32E-12	1.91E-12	7.25E-13	2.69E-06	5.39E+02	5.38E+02	8.80E+02	1.98E+03	3.61E+01	9.23E-01		
Iridium (77)	Ir-186a	5.44E-12	1.04E-12	2.08E-12	2.98E-12	1.06E-12	7.40E-06	1.74E+02	1.74E+02	2.84E+02	6.38E+02	2.29E+01	5.92E-01		
Iridium (77)	Ir-186b	5.07E-13	1.12E-13	2.00E-13	2.84E-13	1.11E-13	4.22E-06	2.75E+03	2.75E+03	4.49E+03	1.01E+04	2.38E+02	6.21E+00		
Iridium (77)	Ir-187	1.57E-12	2.71E-13	5.77E-13	8.33E-13	2.87E-13	1.42E-06	1.36E+03	1.36E+03	2.22E+03	5.00E+03	8.25E+01	2.12E+00		
Iridium (77)	Ir-188	6.40E-12	1.30E-12	2.52E-12	3.58E-12	1.38E-12	7.68E-06	6.37E+01	6.37E+01	1.04E+02	2.34E+02	1.89E+01	4.93E-01		
Iridium (77)	Ir-189	4.29E-12	6.44E-13	1.51E-12	2.21E-12	2.33E-12	1.69E-07	3.72E+02	3.62E+02	6.14E+02	1.38E+03	3.15E+01	7.98E-01		
Iridium (77)	Ir-190	1.50E-11	2.72E-12	5.66E-12	8.10E-12	8.81E-12	5.99E-06	1.17E+01	1.16E+01	1.91E+01	4.29E+01	8.41E+00	2.18E-01		
Iridium (77)	Ir-190m	8.44E-14	1.59E-14	3.17E-14	4.55E-14	3.89E-14	8.69E-13	3.93E+08	1.22E+08	9.79E+09	1.88E+10	1.50E+03	3.88E+01		
Iridium (77)	Ir-190n	1.07E-12	2.33E-13	4.26E-13	6.03E-13	2.14E-13	6.48E-06	1.01E+03	1.01E+03	1.65E+03	3.71E+03	1.12E+02	2.92E+00		
Iridium (77)	Ir-191m						1.58E-07	9.37E+07	9.37E+07	1.53E+08	3.44E+08				
Iridium (77)	Ir-192	2.04E-11	3.30E-12	7.36E-12	1.07E-11	2.41E-11	3.40E-06	3.36E+00	3.33E+00	5.49E+00	1.24E+01	6.47E+00	1.65E-01		
Iridium (77)	Ir-192m	2.16E-12	6.77E-13	9.81E-13	1.32E-12	1.02E-10	5.39E-07	2.16E-01	1.63E-01	4.20E-01	9.45E-01	4.85E+01	1.34E+00		
Iridium (77)	Ir-194	2.49E-11	3.52E-12	8.62E-12	1.26E-11	3.40E-12	4.09E-07	2.51E+03	2.37E+03	4.22E+03	9.49E+03	5.52E+00	1.40E-01		
Iridium (77)	Ir-194m	2.29E-11	4.55E-12	8.88E-12	1.26E-11	4.59E-11	1.01E-05	4.90E-01	4.88E-01	8.00E-01	1.80E+00	5.36E+00	1.40E-01		
Iridium (77)	Ir-195	1.10E-12	1.85E-13	3.96E-13	5.77E-13	2.39E-13	1.12E-07	7.22E+04	7.14E+04	1.18E+05	2.66E+05	1.20E+02	3.06E+00		
Iridium (77)	Ir-195m	2.89E-12	4.63E-13	1.03E-12	1.50E-12	5.96E-13	1.58E-06	3.38E+03	3.37E+03	5.52E+03	1.24E+04	4.62E+01	1.18E+00		
Iron (26)	Fe-52	1.94E-11	3.29E-12	7.07E-12	1.03E-11	2.73E-12	3.07E-06	7.99E+02	1.99E+02	1.30E+03	2.93E+03	6.74E+00	1.71E-01	2.15E+08	1.08E+07
Iron (26)	Fe-55	2.09E-12	5.18E-13	8.62E-13	1.16E-12	7.99E-13	0.00E+00	2.69E+03	8.21E-01	2.21E+04	3.97E+04	5.52E+01	1.52E+00	1.02E+03	5.08E+01
Iron (26)	Fe-59	2.07E-11	4.07E-12	7.88E-12	1.11E-11	1.33E-11	5.83E-06	3.26E+00	1.20E+00	5.32E+00	1.20E+01	6.04E+00	1.59E-01	1.16E+04	5.80E+02
Iron (26)	Fe-60	3.53E-10	1.28E-10	1.80E-10	2.39E-10	1.84E-10	6.38E-12	2.03E+00	3.88E-04	1.39E+01	2.50E+01	2.65E-01	7.38E-03	1.75E-02	8.73E-04
Krypton (36)	Kr-74						4.90E-06	2.16E+04	2.16E+04	3.53E+04	7.94E+04				
Krypton (36)	Kr-76						1.73E-06	7.94E+02	7.94E+02	1.30E+03	2.91E+03				
Krypton (36)	Kr-77						4.22E-06	3.87E+03	3.87E+03	6.31E+03	1.42E+04				
Krypton (36)	Kr-79						1.08E-06	5.38E+02	5.38E+02	8.77E+02	1.97E+03				
Krypton (36)	Kr-81						2.18E-08	5.12E+00	3.84E+00	1.00E+01	2.26E+01				
Krypton (36)	Kr-81m						4.60E-07	1.22E+07	1.22E+07	2.00E+07	4.49E+07				
Krypton (36)	Kr-83m						1.34E-11	8.29E+08	8.29E+08	1.35E+09	3.04E+09				
Krypton (36)	Kr-85						1.05E-08	2.41E+01	2.23E+01	4.20E+01	9.45E+01				
Krypton (36)	Kr-85m						5.46E-07	8.31E+03	8.31E+03	1.36E+04	3.05E+04				
Krypton (36)	Kr-87						4.00E-06	3.99E+03	3.99E+03	6.52E+03	1.47E+04				
Krypton (36)	Kr-88						1.02E-05	7.01E+02	7.01E+02	1.14E+03	2.58E+03				
Lanthanum (57)	La-131	2.28E-13	5.74E-14	9.32E-14	1.31E-13	5.48E-14	2.76E-06	7.49E+03	7.49E+03	1.22E+04	2.75E+04	5.11E+02	1.35E+01		
Lanthanum (57)	La-132	4.85E-12	8.44E-13	1.78E-12	2.58E-12	6.25E-13	9.52E-06	4.45E+02	4.45E+02	7.26E+02	1.63E+03	2.68E+01	6.84E-01		
Lanthanum (57)	La-134						3.05E-06	5.99E+04	5.99E+04	9.78E+04	2.20E+05				
Lanthanum (57)	La-135	3.96E-13	6.70E-14	1.46E-13	2.11E-13	5.03E-14	5.21E-08	2.00E+04	1.99E+04	3.26E+04	7.34E+04	3.26E+02	8.36E+00		
Lanthanum (57)	La-137	9.44E-13	1.67E-13	3.48E-13	5.00E-13	1.39E-11	6.75E-09	1.61E+01	1.18E+01	3.23E+01	7.26E+01	1.37E+02	3.53E+00		

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Lanthanum (57)	La-138	8.81E-12	2.03E-12	3.53E-12	4.96E-12	3.05E-10	6.07E-06	1.84E-02	1.38E-02	3.60E-02	8.10E-02	1.35E+01	3.56E-01		
Lanthanum (57)	La-140	3.05E-11	4.85E-12	1.10E-11	1.59E-11	4.77E-12	1.15E-05	4.38E+01	4.38E+01	7.15E+01	1.61E+02	4.33E+00	1.11E-01		
Lanthanum (57)	La-141	5.37E-12	8.18E-13	1.88E-12	2.74E-12	7.44E-13	2.37E-07	2.17E+04	2.16E+04	3.56E+04	8.01E+04	2.53E+01	6.44E-01		
Lanthanum (57)	La-142	1.48E-12	3.23E-13	5.77E-13	8.21E-13	2.42E-13	1.44E-05	9.15E+02	9.15E+02	1.49E+03	3.36E+03	8.25E+01	2.15E+00		
Lanthanum (57)	La-143	3.14E-13	8.03E-14	1.26E-13	1.78E-13	5.66E-14	5.11E-07	1.68E+05	1.68E+05	2.74E+05	6.17E+05	3.78E+02	9.91E+00		
Lead (82)	Pb-195m	1.20E-13	4.18E-14	5.48E-14	7.55E-14	4.37E-14	6.90E-06	1.12E+04	1.11E+04	1.82E+04	4.11E+04	8.69E+02	2.34E+01	5.15E+13	2.58E+12
Lead (82)	Pb-198	6.18E-13	1.62E-13	2.60E-13	3.63E-13	1.43E-13	1.62E-06	5.23E+03	4.55E+03	8.53E+03	1.92E+04	1.83E+02	4.86E+00	1.31E+11	6.54E+09
Lead (82)	Pb-199	3.28E-13	9.29E-14	1.42E-13	1.97E-13	7.44E-14	6.87E-06	1.97E+03	1.93E+03	3.22E+03	7.24E+03	3.35E+02	8.95E+00	6.13E+11	3.06E+10
Lead (82)	Pb-200	4.03E-12	8.70E-13	1.58E-12	2.24E-12	1.16E-12	5.97E-07	1.58E+03	4.54E+02	2.58E+03	5.81E+03	3.01E+01	7.87E-01	2.68E+08	1.34E+07
Lead (82)	Pb-201	1.47E-12	3.41E-13	5.92E-13	8.36E-13	3.50E-13	3.18E-06	6.80E+02	5.79E+02	1.11E+03	2.50E+03	8.04E+01	2.11E+00	3.74E+09	1.87E+08
Lead (82)	Pb-202	3.74E-11	1.74E-11	2.22E-11	2.93E-11	1.43E-11	3.09E-12	9.48E+00	4.31E-03	1.02E+02	1.84E+02	2.15E+00	6.02E-02	2.66E-01	1.33E-02
Lead (82)	Pb-202m	9.84E-13	2.65E-13	4.18E-13	5.85E-13	2.25E-13	9.32E-06	6.02E+02	5.78E+02	9.83E+02	2.21E+03	1.14E+02	3.01E+00	3.58E+10	1.79E+09
Lead (82)	Pb-203	2.65E-12	5.59E-13	1.02E-12	1.46E-12	7.55E-13	1.09E-06	3.58E+02	1.90E+02	5.84E+02	1.31E+03	4.67E+01	1.21E+00	7.07E+07	3.54E+06
Lead (82)	Pb-205	1.26E-12	4.92E-13	6.33E-13	8.25E-13	6.44E-13	3.50E-12	3.07E+02	1.53E-01	3.42E+03	6.22E+03	7.52E+01	2.14E+00	9.33E+00	4.66E-01
Lead (82)	Pb-209	6.55E-13	1.22E-13	2.41E-13	3.49E-13	1.90E-13	5.37E-10	8.85E+06	2.70E+04	1.85E+07	4.13E+07	1.98E+02	5.05E+00	7.69E+10	3.85E+09
Lead (82)	Pb-210	1.84E-09	5.99E-10	8.81E-10	1.18E-09	2.77E-09	1.41E-09	3.28E-01	1.87E-04	4.19E+00	7.56E+00	5.41E-02	1.49E-03	1.58E-02	7.92E-04
Lead (82)	Pb-210+D	2.66E-09	2.04E-09	1.27E-09	3.44E-09	1.39E-08	4.21E-09	1.50E-01	6.42E-05	1.23E+00	2.22E+00	3.75E-02	5.13E-04	1.10E-02	5.50E-04
Lead (82)	Pb-211	1.04E-12	2.63E-13	4.11E-13	5.81E-13	3.70E-11	2.29E-07	1.47E+05	5.50E+04	2.41E+05	5.41E+05	1.16E+02	3.04E+00	1.32E+12	6.58E+10
Lead (82)	Pb-212	6.70E-11	1.31E-11	2.50E-11	3.54E-11	5.77E-10	5.09E-07	3.64E+03	8.00E+01	6.13E+03	1.38E+04	1.90E+00	4.98E-02	6.97E+07	3.49E+06
Lead (82)	Pb-214	8.51E-13	2.21E-13	3.44E-13	4.85E-13	3.63E-11	9.82E-07	4.63E+04	3.49E+04	7.56E+04	1.70E+05	1.38E+02	3.64E+00	2.85E+12	1.43E+11
Lutetium (71)	Lu-169	5.03E-12	9.69E-13	1.94E-12	2.77E-12	1.33E-12	4.73E-06	1.26E+02	1.26E+02	2.06E+02	4.63E+02	2.45E+01	6.37E-01		
Lutetium (71)	Lu-170	1.06E-11	2.11E-12	4.14E-12	5.88E-12	2.25E-12	1.26E-05	3.36E+01	3.36E+01	5.48E+01	1.23E+02	1.15E+01	3.00E-01		
Lutetium (71)	Lu-171	8.84E-12	1.52E-12	3.27E-12	4.70E-12	3.50E-12	2.90E-06	3.55E+01	3.55E+01	5.80E+01	1.30E+02	1.46E+01	3.75E-01		
Lutetium (71)	Lu-172	1.47E-11	2.75E-12	5.59E-12	8.03E-12	6.03E-12	8.70E-06	1.45E+01	1.45E+01	2.37E+01	5.33E+01	8.52E+00	2.20E-01		
Lutetium (71)	Lu-173	3.74E-12	6.03E-13	1.35E-12	1.96E-12	8.70E-12	2.92E-07	5.79E+00	5.79E+00	9.46E+00	2.13E+01	3.53E+01	9.00E-01		
Lutetium (71)	Lu-174	4.11E-12	6.44E-13	1.46E-12	2.12E-12	1.42E-11	4.26E-07	1.65E+00	1.64E+00	2.70E+00	6.07E+00	3.26E+01	8.32E-01		
Lutetium (71)	Lu-174m	9.73E-12	1.39E-12	3.38E-12	4.96E-12	1.51E-11	9.88E-08	5.95E+01	5.96E+01	9.83E+01	2.21E+02	1.41E+01	3.56E-01		
Lutetium (71)	Lu-176	2.60E-11	4.11E-12	9.29E-12	1.35E-11	1.41E-10	1.83E-06	6.08E-02	4.56E-02	1.19E-01	2.69E-01	5.13E+00	1.31E-01		
Lutetium (71)	Lu-176m	2.43E-12	3.74E-13	8.55E-13	1.25E-12	4.55E-13	2.78E-08	1.96E+05	1.96E+05	3.24E+05	7.28E+05	5.57E+01	1.41E+00		
Lutetium (71)	Lu-177	1.02E-11	1.43E-12	3.53E-12	5.18E-12	4.66E-12	1.14E-07	1.09E+03	1.09E+03	1.80E+03	4.06E+03	1.35E+01	3.40E-01		
Lutetium (71)	Lu-177m	2.60E-11	4.14E-12	9.36E-12	1.36E-11	5.70E-11	3.63E-06	1.45E+00	1.45E+00	2.36E+00	5.32E+00	5.09E+00	1.30E-01		
Lutetium (71)	Lu-178	2.02E-13	6.25E-14	8.62E-14	1.20E-13	5.29E-14	6.76E-07	6.35E+04	6.35E+04	1.04E+05	2.33E+05	5.52E+02	1.47E+01		
Lutetium (71)	Lu-178m	1.59E-13	5.37E-14	7.10E-14	9.84E-14	5.85E-14	4.26E-06	1.26E+04	1.26E+04	2.06E+04	4.63E+04	6.71E+02	1.79E+01		
Lutetium (71)	Lu-179	3.21E-12	4.81E-13	1.12E-12	1.64E-12	5.14E-13	1.19E-07	3.71E+04	3.71E+04	6.07E+04	1.37E+05	4.25E+01	1.08E+00		
Magnesium (12)	Mg-28	3.06E-11	5.22E-12	1.14E-11	1.65E-11	5.14E-12	6.56E-06	1.48E+02	1.48E+02	2.42E+02	5.44E+02	4.18E+00	1.07E-01		
Manganese (25)	Mn-51	5.11E-13	1.37E-13	2.09E-13	2.95E-13	9.55E-14	4.37E-06	6.04E+03	5.62E+03	9.85E+03	2.22E+04	2.28E+02	5.98E+00	1.30E+12	6.50E+10
Manganese (25)	Mn-52	1.58E-11	3.60E-12	6.44E-12	9.07E-12	4.40E-12	1.67E-05	9.03E+00	5.67E+00	1.48E+01	3.33E+01	7.39E+00	1.94E-01	1.39E+06	6.95E+04
Manganese (25)	Mn-52m	2.82E-13	9.66E-14	1.27E-13	1.75E-13	5.07E-14	1.15E-05	5.02E+03	4.94E+03	8.20E+03	1.84E+04	3.75E+02	1.01E+01	1.03E+13	5.13E+11
Manganese (25)	Mn-53	4.37E-13	6.99E-14	1.56E-13	2.25E-13	2.17E-13	0.00E+00	7.14E+01	3.37E-01	2.54E+04	4.58E+04	3.05E+02	7.84E+00	3.11E+01	1.56E+00
Manganese (25)	Mn-54	5.14E-12	1.48E-12	2.28E-12	3.11E-12	5.88E-12	3.89E-06	6.92E-01	3.69E-01	1.13E+00	2.55E+00	2.09E+01	5.67E-01	7.42E+02	3.71E+01
Manganese (25)	Mn-56	2.78E-12	5.11E-13	1.03E-12	1.48E-12	4.14E-13	8.44E-06	9.32E+02	7.82E+02	1.52E+03	3.43E+03	4.62E+01	1.19E+00	2.35E+10	1.17E+09
Mendelevium (101)	Md-257	1.67E-12	2.59E-13	5.88E-13	8.58E-13	7.70E-11	3.62E-07	1.08E+04	1.08E+04	1.76E+04	3.96E+04	8.10E+01	2.06E+00		
Mendelevium (101)	Md-258	1.23E-10	1.95E-11	4.33E-11	6.25E-11	1.68E-08	1.31E-09	8.24E+02	8.56E+02	6.27E+03	1.23E+04	1.10E+00	2.82E-02		
Mercury (80)	Hg-193	1.14E-12	1.87E-13	4.11E-13	5.99E-13	2.53E-13	5.55E-07	1.04E+04	1.01E+04	1.71E+04	3.84E+04	1.16E+02	2.94E+00		
Mercury (80)	Hg-193m	5.37E-12	9.10E-13	1.97E-12	2.84E-12	9.40E-13	4.54E-06	4.01E+02	3.94E+02	6.58E+02	1.48E+03	2.42E+01	6.21E-01		
Mercury (80)	Hg-194	1.55E-10	2.00E-12	8.07E-11	1.06E-10	2.88E-11	5.04E-12	1.27E-01	2.33E-02	8.99E+02	1.62E+03	5.90E-01	1.66E-02		
Mercury (80)	Hg-195	1.41E-12	2.27E-13	5.07E-13	7.36E-13	2.84E-13	7.34E-07	2.77E+03	2.70E+03	4.56E+03	1.03E+04	9.39E+01	2.40E+00		
Mercury (80)	Hg-195m	9.55E-12	1.42E-12	3.36E-12	4.92E-12	2.33E-12	7.68E-07	6.02E+02	5.18E+02	1.04E+03	2.33E+03	1.42E+01	3.58E-01		
Mercury (80)	Hg-197	4.07E-12	5.99E-13	1.43E-12	2.09E-12	1.25E-12	1.14E-07	2.40E+03	1.68E+03	4.53E+03	1.02E+04	3.33E+01	8.44E-01		
Mercury (80)	Hg-197m	8.62E-12	1.24E-12	3.00E-12	4.40E-12	2.28E-12	2.50E-07	2.96E+03	2.10E+03	5.57E+03	1.25E+04	1.59E+01	4.01E-01		
Mercury (80)	Hg-199m	1.63E-13	4.44E-14	6.70E-14	9.44E-14	6.33E-14	5.77E-07	4.95E+04	4.93E+04	8.09E+04	1.82E+05	7.11E+02	1.87E+01		

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Mercury (80)	Hg-203	1.27E-11	1.35E-12	5.70E-12	7.62E-12	8.95E-12	9.21E-07	1.84E+01	1.52E+01	3.22E+01	7.24E+01	8.35E+00	2.31E-01		
Molybdenum (42)	Mo-101	1.48E-13	5.59E-14	6.88E-14	9.44E-14	4.33E-14	6.62E-06	1.26E+04	1.26E+04	2.06E+04	4.63E+04	6.92E+02	1.87E+01		
Molybdenum (42)	Mo-90	1.39E-12	5.03E-13	6.59E-13	8.73E-13	1.24E-12	3.41E-06	1.05E+03	1.05E+03	1.71E+03	3.86E+03	7.23E+01	2.02E+00		
Molybdenum (42)	Mo-93	5.29E-12	3.38E-12	3.35E-12	4.18E-12	1.27E-12	2.17E-10	8.58E+00	1.05E+00	3.46E+02	6.69E+02	1.42E+01	4.22E-01		
Molybdenum (42)	Mo-93m	6.62E-13	2.51E-13	3.20E-13	4.26E-13	4.33E-13	1.09E-05	2.72E+02	2.72E+02	4.44E+02	9.99E+02	1.49E+02	4.14E+00		
Molybdenum (42)	Mo-99	3.50E-12	1.18E-12	1.60E-12	2.11E-12	4.29E-12	6.64E-07	4.59E+02	4.37E+02	7.56E+02	1.70E+03	2.98E+01	8.36E-01		
Neodymium (60)	Nd-136	6.70E-13	1.64E-13	2.70E-13	3.81E-13	1.34E-13	1.01E-06	2.38E+04	2.38E+04	3.89E+04	8.74E+04	1.76E+02	4.63E+00		
Neodymium (60)	Nd-138	9.69E-12	1.49E-12	3.42E-12	5.00E-12	1.24E-12	6.73E-08	5.85E+04	5.70E+04	9.75E+04	2.19E+05	1.39E+01	3.53E-01		
Neodymium (60)	Nd-139	1.21E-13	3.11E-14	4.96E-14	6.96E-14	2.37E-14	1.72E-06	2.39E+04	2.39E+04	3.89E+04	8.76E+04	9.60E+02	2.53E+01		
Neodymium (60)	Nd-139m	2.86E-12	5.37E-13	1.08E-12	1.56E-12	4.96E-13	7.13E-06	5.18E+02	5.18E+02	8.46E+02	1.90E+03	4.41E+01	1.13E+00		
Neodymium (60)	Nd-141	8.07E-14	1.61E-14	3.09E-14	4.40E-14	1.34E-14	2.28E-07	3.58E+04	3.58E+04	5.84E+04	1.31E+05	1.54E+03	4.01E+01		
Neodymium (60)	Nd-141m						3.48E-06	3.37E+05	3.37E+05	5.50E+05	1.24E+06				
Neodymium (60)	Nd-147	2.01E-11	2.86E-12	6.96E-12	1.02E-11	9.36E-12	4.87E-07	1.57E+02	1.56E+02	2.58E+02	5.80E+02	6.84E+00	1.73E-01		
Neodymium (60)	Nd-149	1.51E-12	2.58E-13	5.44E-13	7.92E-13	3.19E-13	1.49E-06	7.88E+03	7.88E+03	1.29E+04	2.89E+04	8.75E+01	2.23E+00		
Neodymium (60)	Nd-151	1.83E-13	4.63E-14	7.36E-14	1.04E-13	3.92E-14	4.10E-06	2.40E+04	2.40E+04	3.91E+04	8.80E+04	6.47E+02	1.70E+01		
Neon (10)	Ne-19						4.47E-06	9.51E+05	9.51E+05	1.55E+06	3.49E+06				
Neptunium (93)	Np-232	4.14E-14	1.57E-14	1.97E-14	2.70E-14	3.17E-14	5.25E-06	1.58E+04	1.56E+04	2.58E+04	5.80E+04	2.42E+03	6.53E+01	8.01E+12	4.01E+11
Neptunium (93)	Np-233	1.14E-14	3.58E-15	5.03E-15	6.99E-15	2.49E-15	2.29E-07	1.47E+05	1.38E+05	2.40E+05	5.40E+05	9.47E+03	2.52E+02	5.18E+12	2.59E+11
Neptunium (93)	Np-234	8.77E-12	1.72E-12	3.40E-12	4.85E-12	1.86E-12	7.06E-06	2.72E+01	1.13E+01	4.45E+01	1.00E+02	1.40E+01	3.64E-01	2.50E+05	1.25E+04
Neptunium (93)	Np-235	9.99E-13	1.42E-13	3.46E-13	5.07E-13	1.15E-12	2.13E-09	8.57E+02	2.06E+00	1.62E+03	3.65E+03	1.38E+02	3.48E+00	3.03E+02	1.52E+01
Neptunium (93)	Np-236a	2.56E-11	7.18E-12	1.05E-11	1.44E-11	9.77E-10	3.25E-07	3.33E-01	2.81E-03	6.70E-01	1.51E+00	4.54E+00	1.22E-01	2.72E-02	1.36E-03
Neptunium (93)	Np-236b	3.19E-12	4.74E-13	1.11E-12	1.63E-12	8.07E-12	1.34E-07	6.68E+03	2.60E+02	1.10E+04	2.47E+04	4.29E+01	1.08E+00	1.69E+07	8.43E+05
Neptunium (93)	Np-237	1.46E-10	4.70E-11	6.18E-11	8.29E-11	1.77E-08	5.36E-08	1.00E+00	4.93E-04	3.66E+00	8.04E+00	7.71E-01	2.13E-02	9.00E-02	4.50E-03
Neptunium (93)	Np-237+D	1.62E-10	4.92E-11	6.74E-11	9.10E-11	1.77E-08	7.97E-07	1.30E-01	4.48E-04	2.72E-01	6.11E-01	7.07E-01	1.94E-02	9.00E-02	4.50E-03
Neptunium (93)	Np-238	1.52E-11	2.33E-12	5.40E-12	7.88E-12	4.18E-12	2.62E-06	1.52E+02	2.13E+01	2.49E+02	5.60E+02	8.82E+00	2.24E-01	6.78E+05	3.39E+04
Neptunium (93)	Np-239	1.47E-11	2.15E-12	5.14E-12	7.51E-12	4.00E-12	5.41E-07	6.57E+02	2.26E+01	1.08E+03	2.43E+03	9.26E+00	2.35E-01	5.75E+05	2.87E+04
Neptunium (93)	Np-240	5.55E-13	1.37E-13	2.23E-13	3.16E-13	1.95E-13	5.80E-06	3.23E+03	2.91E+03	5.28E+03	1.19E+04	2.14E+02	5.58E+00	3.62E+10	1.81E+09
Neptunium (93)	Np-240m						1.51E-06	1.09E+05	1.09E+05	1.78E+05	4.01E+05				
Nickel (28)	Ni-56	6.70E-12	1.64E-12	2.83E-12	3.96E-12	2.88E-12	7.74E-06	1.79E+01	1.71E+01	2.93E+01	6.58E+01	1.68E+01	4.45E-01	1.78E+07	8.91E+05
Nickel (28)	Ni-57	1.02E-11	1.89E-12	3.89E-12	5.55E-12	1.78E-12	9.43E-06	5.96E+01	5.64E+01	9.74E+01	2.19E+02	1.22E+01	3.18E-01	2.13E+08	1.07E+07
Nickel (28)	Ni-59	7.33E-13	1.44E-13	2.74E-13	3.89E-13	4.66E-13	0.00E+00	2.08E+02	2.15E+00	1.23E+04	2.22E+04	1.74E+02	4.53E+00	2.05E+02	1.03E+01
Nickel (28)	Ni-63	1.79E-12	3.50E-13	6.70E-13	9.51E-13	1.64E-12	0.00E+00	9.48E+01	1.01E+00	5.55E+03	9.99E+03	7.11E+01	1.85E+00	3.80E+01	1.90E+00
Nickel (28)	Ni-65	1.92E-12	3.34E-13	6.96E-13	1.01E-12	3.03E-13	2.74E-06	2.94E+03	2.84E+03	4.80E+03	1.08E+04	6.84E+01	1.75E+00	2.44E+11	1.22E+10
Nickel (28)	Ni-66	5.77E-11	8.18E-12	2.00E-11	2.94E-11	8.99E-12	2.67E-11	9.12E+03	1.26E+02	5.88E+05	1.06E+06	2.38E+00	6.00E-02	1.81E+07	9.06E+05
Niobium (41)	Nb-88	2.45E-13	8.92E-14	1.13E-13	1.55E-13	4.51E-14	1.89E-05	4.51E+03	4.51E+03	7.36E+03	1.66E+04	4.21E+02	1.14E+01		
Niobium (41)	Nb-89a	1.01E-12	2.35E-13	4.00E-13	5.66E-13	1.74E-13	8.48E-06	2.18E+03	2.18E+03	3.55E+03	8.00E+03	1.19E+02	3.12E+00		
Niobium (41)	Nb-89b	2.82E-12	5.22E-13	1.04E-12	1.51E-12	4.07E-13	6.64E-06	1.50E+03	1.50E+03	2.46E+03	5.53E+03	4.58E+01	1.17E+00		
Niobium (41)	Nb-90	1.52E-11	2.75E-12	5.70E-12	8.21E-12	2.27E-12	2.13E-05	6.53E+01	6.53E+01	1.07E+02	2.40E+02	8.35E+00	2.15E-01		
Niobium (41)	Nb-93m	2.31E-12	3.32E-13	8.03E-13	1.17E-12	1.90E-12	3.83E-11	3.50E+02	1.37E+02	4.88E+03	9.73E+03	5.93E+01	1.51E+00		
Niobium (41)	Nb-94	2.05E-11	3.89E-12	7.77E-12	1.11E-11	3.77E-11	7.29E-06	1.53E-02	1.15E-02	3.00E-02	6.75E-02	6.13E+00	1.59E-01		
Niobium (41)	Nb-95	6.36E-12	1.23E-12	2.45E-12	3.50E-12	5.44E-12	3.53E-06	6.81E+00	6.81E+00	1.11E+01	2.50E+01	1.94E+01	5.04E-01		
Niobium (41)	Nb-95m	1.05E-11	1.50E-12	3.66E-12	5.37E-12	3.27E-12	2.32E-07	1.00E+03	9.84E+02	1.65E+03	3.71E+03	1.30E+01	3.28E-01		
Niobium (41)	Nb-96	1.35E-11	2.41E-12	5.03E-12	7.25E-12	2.28E-12	1.15E-05	7.55E+01	7.54E+01	1.23E+02	2.77E+02	9.47E+00	2.43E-01		
Niobium (41)	Nb-97	5.00E-13	1.14E-13	1.96E-13	2.79E-13	1.07E-13	2.97E-06	5.69E+03	5.69E+03	9.29E+03	2.09E+04	2.43E+02	6.32E+00		
Niobium (41)	Nb-97m						3.34E-06	3.65E+05	3.65E+05	5.96E+05	1.34E+06				
Niobium (41)	Nb-98	6.73E-13	1.81E-13	2.80E-13	3.92E-13	1.23E-13	1.16E-05	2.04E+03	2.04E+03	3.33E+03	7.49E+03	1.70E+02	4.50E+00		
Nitrogen (7)	N-13						4.45E-06	2.75E+04	2.75E+04	4.48E+04	1.01E+05				
Osmium (76)	Os-180	7.92E-14	2.72E-14	3.63E-14	5.00E-14	2.62E-14	1.08E-07	5.13E+05	5.13E+05	8.37E+05	1.88E+06	1.31E+03	3.53E+01		
Osmium (76)	Os-181	9.21E-13	1.83E-13	3.54E-13	5.07E-13	1.95E-13	5.41E-06	2.15E+03	2.15E+03	3.50E+03	7.88E+03	1.35E+02	3.48E+00		
Osmium (76)	Os-182	6.92E-12	1.23E-12	2.59E-12	3.74E-12	1.45E-12	1.63E-06	5.66E+02	5.66E+02	9.25E+02	2.08E+03	1.84E+01	4.72E-01		
Osmium (76)	Os-185	4.77E-12	1.04E-12	1.92E-12	2.70E-12	6.14E-12	3.11E-06	2.90E+00	2.90E+00	4.73E+00	1.06E+01	2.48E+01	6.53E-01		

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Osmium (76)	Os-189m	2.94E-13	4.29E-14	1.02E-13	1.50E-13	3.44E-14	7.20E-13	8.05E+07	8.40E+07	9.22E+08	1.70E+09	4.67E+02	1.18E+01		
Osmium (76)	Os-190m						6.76E-06	1.82E+04	1.82E+04	2.97E+04	6.69E+04				
Osmium (76)	Os-191	1.05E-11	1.50E-12	3.64E-12	5.33E-12	7.10E-12	1.66E-07	3.28E+02	3.28E+02	5.40E+02	1.21E+03	1.31E+01	3.31E-01		
Osmium (76)	Os-191m	1.76E-12	2.51E-13	6.11E-13	8.95E-13	6.36E-13	1.05E-08	1.45E+05	1.46E+05	2.42E+05	5.45E+05	7.79E+01	1.97E+00		
Osmium (76)	Os-193	1.53E-11	2.16E-12	5.29E-12	7.77E-12	2.71E-12	2.69E-07	2.50E+03	2.50E+03	4.10E+03	9.23E+03	9.00E+00	2.27E-01		
Osmium (76)	Os-194	4.37E-11	6.55E-12	1.53E-11	2.23E-11	2.55E-10	6.57E-10	5.87E+01	5.96E+01	4.56E+02	9.01E+02	3.11E+00	7.91E-02		
Oxygen (8)	O-15						4.46E-06	1.34E+05	1.34E+05	2.19E+05	4.94E+05				
Palladium (46)	Pd-100	1.05E-11	1.99E-12	4.03E-12	5.77E-12	3.10E-12	2.22E-07	9.87E+02	8.43E+02	1.71E+03	3.85E+03	1.18E+01	3.06E-01		
Palladium (46)	Pd-101	1.12E-12	2.03E-13	4.22E-13	6.07E-13	1.97E-13	1.38E-06	1.78E+03	1.77E+03	2.91E+03	6.54E+03	1.13E+02	2.91E+00		
Palladium (46)	Pd-103	3.61E-12	5.07E-13	1.25E-12	1.84E-12	1.77E-12	1.15E-09	8.67E+03	2.67E+03	6.70E+04	1.49E+05	3.81E+01	9.59E-01		
Palladium (46)	Pd-107	7.25E-13	1.01E-13	2.50E-13	3.67E-13	1.69E-12	0.00E+00	1.22E+02	2.40E+01	1.76E+04	3.16E+04	1.90E+02	4.81E+00		
Palladium (46)	Pd-109	1.01E-11	1.43E-12	3.50E-12	5.14E-12	1.85E-12	1.27E-08	5.94E+04	2.46E+04	1.92E+05	4.31E+05	1.36E+01	3.43E-01		
Phosphorus (15)	P-30						4.50E-06	1.08E+05	1.08E+05	1.77E+05	3.98E+05				
Phosphorus (15)	P-32	2.21E-11	5.37E-12	8.95E-12	1.23E-11	1.22E-11	9.41E-09	2.07E+02	5.15E+01	9.59E+03	2.12E+04	5.32E+00	1.43E-01		
Phosphorus (15)	P-33	2.47E-12	5.62E-13	9.81E-13	1.36E-12	5.11E-12	3.72E-11	1.09E+03	2.64E+02	5.11E+05	9.90E+05	4.85E+01	1.30E+00		
Platinum (78)	Pt-186	1.03E-12	1.97E-13	3.92E-13	5.62E-13	8.25E-14	3.20E-06	3.17E+03	3.17E+03	5.18E+03	1.17E+04	1.21E+02	3.14E+00		
Platinum (78)	Pt-188	1.03E-11	1.74E-12	3.77E-12	5.44E-12	1.88E-12	6.02E-07	1.38E+02	1.38E+02	2.25E+02	5.06E+02	1.26E+01	3.24E-01		
Platinum (78)	Pt-189	1.61E-12	2.76E-13	5.92E-13	8.55E-13	1.32E-13	1.17E-06	1.59E+03	1.59E+03	2.60E+03	5.85E+03	8.04E+01	2.06E+00		
Platinum (78)	Pt-191	4.85E-12	7.88E-13	1.76E-12	2.55E-12	4.63E-13	9.78E-07	3.09E+02	3.09E+02	5.04E+02	1.14E+03	2.71E+01	6.92E-01		
Platinum (78)	Pt-193	6.14E-13	8.51E-14	2.11E-13	3.09E-13	1.11E-13	2.78E-12	1.53E+03	1.27E+03	1.95E+04	3.67E+04	2.26E+02	5.71E+00		
Platinum (78)	Pt-193m	8.81E-12	1.23E-12	3.03E-12	4.44E-12	7.73E-13	1.68E-08	1.08E+04	1.09E+04	1.88E+04	4.23E+04	1.57E+01	3.97E-01		
Platinum (78)	Pt-195m	1.19E-11	1.69E-12	4.11E-12	6.03E-12	1.05E-12	1.26E-07	1.65E+03	1.65E+03	2.72E+03	6.12E+03	1.16E+01	2.92E-01		
Platinum (78)	Pt-197	7.59E-12	1.07E-12	2.62E-12	3.85E-12	5.22E-13	5.63E-08	1.94E+04	1.94E+04	3.21E+04	7.22E+04	1.82E+01	4.58E-01		
Platinum (78)	Pt-197m	1.12E-12	1.81E-13	4.00E-13	5.81E-13	8.66E-14	2.38E-07	5.42E+04	5.42E+04	8.85E+04	1.99E+05	1.19E+02	3.04E+00		
Platinum (78)	Pt-199	2.18E-13	5.66E-14	8.84E-14	1.25E-13	2.48E-14	8.69E-07	4.55E+04	4.55E+04	7.43E+04	1.67E+05	5.39E+02	1.41E+01		
Platinum (78)	Pt-200	2.23E-11	3.16E-12	7.73E-12	1.13E-11	1.48E-12	1.58E-07	1.01E+04	1.01E+04	1.67E+04	3.77E+04	6.16E+00	1.56E-01		
Plutonium (94)	Pu-234	2.39E-12	3.85E-13	8.58E-13	1.25E-12	6.85E-11	1.61E-07	1.43E+04	8.89E+03	2.34E+04	5.26E+04	5.55E+01	1.41E+00	2.47E+09	1.24E+08
Plutonium (94)	Pu-235	9.73E-15	3.24E-15	4.37E-15	6.03E-15	2.39E-15	2.37E-07	2.03E+05	2.03E+05	3.32E+05	7.47E+05	1.09E+04	2.92E+02	2.11E+14	1.06E+13
Plutonium (94)	Pu-236	1.74E-10	5.55E-11	7.47E-11	9.92E-11	2.28E-08	1.19E-10	3.03E+01	1.04E-01	1.81E+02	3.31E+02	6.37E-01	1.78E-02	3.53E+00	1.77E-01
Plutonium (94)	Pu-237	1.62E-12	2.53E-13	5.77E-13	8.40E-13	1.27E-12	1.12E-07	1.66E+02	1.05E+02	2.72E+02	6.12E+02	8.25E+01	2.10E+00	2.41E+05	1.20E+04
Plutonium (94)	Pu-238	2.72E-10	1.17E-10	1.31E-10	1.69E-10	3.36E-08	7.22E-11	2.97E+00	7.31E-03	1.60E+01	2.91E+01	3.64E-01	1.04E-02	1.75E+00	8.76E-02
Plutonium (94)	Pu-239	2.76E-10	1.21E-10	1.35E-10	1.74E-10	3.33E-08	2.00E-10	2.59E+00	6.09E-03	1.40E+01	2.54E+01	3.53E-01	1.01E-02	1.56E+00	7.80E-02
Plutonium (94)	Pu-240	2.77E-10	1.21E-10	1.35E-10	1.74E-10	3.33E-08	6.98E-11	2.60E+00	6.10E-03	1.41E+01	2.56E+01	3.53E-01	1.01E-02	1.56E+00	7.81E-02
Plutonium (94)	Pu-241	3.29E-12	1.73E-12	1.76E-12	2.28E-12	3.34E-10	4.11E-12	4.06E+02	1.05E+00	1.69E+03	3.06E+03	2.71E+01	7.74E-01	1.00E+01	5.02E-01
Plutonium (94)	Pu-242	2.63E-10	1.15E-10	1.28E-10	1.65E-10	3.13E-08	6.25E-11	2.73E+00	6.42E-03	1.48E+01	2.69E+01	3.72E-01	1.07E-02	1.56E+00	7.80E-02
Plutonium (94)	Pu-243	1.34E-12	2.06E-13	4.74E-13	6.92E-13	2.94E-13	5.50E-08	7.42E+04	3.73E+04	1.21E+05	2.73E+05	1.00E+02	2.55E+00	1.41E+10	7.04E+08
Plutonium (94)	Pu-244	2.94E-10	1.15E-10	1.37E-10	1.80E-10	2.93E-08	3.01E-11	2.45E+00	5.88E-03	1.49E+01	2.70E+01	3.48E-01	9.80E-03	1.56E+00	7.80E-02
Plutonium (94)	Pu-244+D	3.14E-10		1.44E-10	1.90E-10	2.93E-08	1.51E-06	7.16E-02	5.06E-03	1.45E-01	3.25E-01	3.31E-01	9.28E-03	1.56E+00	7.80E-02
Plutonium (94)	Pu-245	1.28E-11	1.89E-12	4.48E-12	6.55E-12	2.07E-12	1.77E-06	1.09E+03	8.46E+02	1.78E+03	4.01E+03	1.06E+01	2.69E-01	3.33E+08	1.66E+07
Plutonium (94)	Pu-246	4.92E-11	7.40E-12	1.73E-11	2.53E-11	1.73E-11	4.04E-07	1.89E+02	3.23E+01	3.13E+02	7.04E+02	2.75E+00	6.97E-02	1.39E+05	6.94E+03
Polonium (84)	Po-203	3.92E-13	9.77E-14	1.63E-13	1.88E-13	7.73E-14	7.65E-06	4.34E+03	4.34E+03	7.09E+03	1.59E+04	2.92E+02	9.38E+00		
Polonium (84)	Po-205	4.26E-13	1.12E-13	1.81E-13	2.41E-13	1.72E-13	7.36E-06	1.53E+03	1.53E+03	2.50E+03	5.63E+03	2.63E+02	7.32E+00		
Polonium (84)	Po-207	1.28E-12	2.86E-13	5.18E-13	5.55E-13	1.99E-13	6.08E-06	5.73E+02	5.73E+02	9.35E+02	2.10E+03	9.19E+01	3.18E+00		
Polonium (84)	Po-210	7.96E-10	2.96E-10	3.77E-10	2.25E-09	1.08E-08	3.95E-11	3.79E+01	1.94E+01	2.73E+02	4.93E+02	1.26E-01	7.84E-04		
Polonium (84)	Po-211						3.58E-08	3.96E+09	3.96E+09	6.46E+09	1.45E+10				
Polonium (84)	Po-212						0.00E+00								
Polonium (84)	Po-213						0.00E+00								
Polonium (84)	Po-214						3.86E-10	1.16E+15	1.16E+15	1.89E+15	4.24E+15				
Polonium (84)	Po-215						7.48E-10	5.49E+13	5.49E+13	8.97E+13	2.02E+14				
Polonium (84)	Po-216						7.87E-11	6.20E+12	6.20E+12	1.01E+13	2.28E+13				
Polonium (84)	Po-218						4.26E-11	9.38E+09	9.38E+09	1.53E+10	3.45E+10				

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Potassium (19)	K-38						1.61E-05	9.91E+03	9.91E+03	1.62E+04	3.64E+04				
Potassium (19)	K-40	6.18E-11	1.51E-11	2.47E-11	3.43E-11	1.03E-11	7.97E-07	1.08E-01	4.45E-02	2.73E-01	6.15E-01	1.93E+00	5.14E-02		
Potassium (19)	K-42	3.06E-12	8.40E-13	1.26E-12	1.74E-12	4.33E-13	1.46E-06	1.11E+03	1.08E+03	1.83E+03	4.12E+03	3.78E+01	1.01E+00		
Potassium (19)	K-43	1.81E-12	5.48E-13	7.88E-13	1.07E-12	3.09E-13	4.23E-06	2.12E+02	2.11E+02	3.47E+02	7.80E+02	6.04E+01	1.65E+00		
Potassium (19)	K-44	3.00E-13	1.13E-13	1.39E-13	1.91E-13	3.39E-14	1.19E-05	4.64E+03	4.63E+03	7.56E+03	1.70E+04	3.43E+02	9.23E+00		
Potassium (19)	K-45	1.93E-13	7.29E-14	8.95E-14	1.22E-13	2.33E-14	9.53E-06	6.40E+03	6.39E+03	1.04E+04	2.35E+04	5.32E+02	1.45E+01		
Praseodymium (59)	Pr-136	1.27E-13	4.66E-14	5.88E-14	8.07E-14	2.15E-14	9.74E-06	9.55E+03	9.55E+03	1.56E+04	3.51E+04	8.10E+02	2.19E+01		
Praseodymium (59)	Pr-137	3.22E-13	6.99E-14	1.25E-13	1.78E-13	5.55E-14	2.14E-06	7.44E+03	7.44E+03	1.21E+04	2.73E+04	3.81E+02	9.91E+00		
Praseodymium (59)	Pr-138						3.57E-06	2.36E+05	2.36E+05	3.84E+05	8.65E+05				
Praseodymium (59)	Pr-138m	1.03E-12	2.41E-13	4.18E-13	5.92E-13	1.76E-13	1.13E-05	8.56E+02	8.56E+02	1.40E+03	3.14E+03	1.14E+02	2.98E+00		
Praseodymium (59)	Pr-139	4.03E-13	6.85E-14	1.47E-13	2.12E-13	6.96E-14	4.41E-07	1.02E+04	1.02E+04	1.67E+04	3.75E+04	3.24E+02	8.32E+00		
Praseodymium (59)	Pr-142	2.49E-11	3.50E-12	8.58E-12	1.26E-11	3.38E-12	3.14E-07	3.34E+03	3.31E+03	5.52E+03	1.24E+04	5.55E+00	1.40E-01		
Praseodymium (59)	Pr-142m	3.20E-13	4.48E-14	1.10E-13	1.62E-13	4.33E-14	0.00E+00	1.55E+09	9.00E+08	2.47E+10	4.45E+10	4.33E+02	1.09E+01		
Praseodymium (59)	Pr-143	2.29E-11	3.19E-12	7.92E-12	1.16E-11	9.73E-12	1.63E-09	1.13E+04	7.53E+03	5.02E+04	1.08E+05	6.01E+00	1.52E-01		
Praseodymium (59)	Pr-144	1.82E-13	6.33E-14	8.10E-14	1.12E-13	3.58E-14	1.94E-07	3.63E+05	3.63E+05	5.93E+05	1.33E+06	5.88E+02	1.57E+01		
Praseodymium (59)	Pr-144m						8.73E-09	1.94E+07	1.94E+07	3.17E+07	7.12E+07				
Praseodymium (59)	Pr-145	6.59E-12	9.66E-13	2.29E-12	3.36E-12	9.25E-13	6.95E-08	4.81E+04	4.76E+04	7.96E+04	1.79E+05	2.08E+01	5.25E-01		
Praseodymium (59)	Pr-147	1.32E-13	4.40E-14	5.85E-14	8.10E-14	3.59E-14	3.78E-06	2.37E+04	2.37E+04	3.87E+04	8.71E+04	8.14E+02	2.18E+01		
Promethium (61)	Pm-141	1.52E-13	4.96E-14	6.66E-14	9.25E-14	2.85E-14	3.33E-06	1.75E+04	1.75E+04	2.86E+04	6.43E+04	7.15E+02	1.91E+01		
Promethium (61)	Pm-142						3.86E-06	4.68E+05	4.68E+05	7.64E+05	1.72E+06				
Promethium (61)	Pm-143	2.20E-12	4.59E-13	8.73E-13	1.24E-12	5.37E-12	1.33E-06	2.40E+00	2.40E+00	3.92E+00	8.82E+00	5.45E+01	1.42E+00		
Promethium (61)	Pm-144	8.10E-12	1.86E-12	3.34E-12	4.66E-12	2.76E-11	6.90E-06	3.38E-01	3.38E-01	5.52E-01	1.24E+00	1.43E+01	3.78E-01		
Promethium (61)	Pm-145	1.54E-12	2.54E-13	5.59E-13	8.07E-13	6.59E-12	1.61E-08	1.16E+01	1.00E+01	2.12E+01	4.78E+01	8.52E+01	2.19E+00		
Promethium (61)	Pm-146	1.12E-11	2.00E-12	4.18E-12	5.99E-12	5.40E-11	3.29E-06	1.30E-01	1.28E-01	2.17E-01	4.89E-01	1.14E+01	2.94E-01		
Promethium (61)	Pm-147	4.88E-12	6.92E-13	1.69E-12	2.48E-12	1.61E-11	3.21E-11	1.03E+03	6.69E+02	1.23E+04	2.35E+04	2.82E+01	7.11E-01		
Promethium (61)	Pm-148	4.96E-11	7.07E-12	1.72E-11	2.52E-11	1.05E-11	2.80E-06	5.61E+01	5.60E+01	9.19E+01	2.07E+02	2.77E+00	7.00E-02		
Promethium (61)	Pm-148m	2.13E-11	3.85E-12	7.99E-12	1.15E-11	2.12E-11	8.98E-06	2.28E+00	2.28E+00	3.73E+00	8.38E+00	5.96E+00	1.53E-01		
Promethium (61)	Pm-149	1.93E-11	2.69E-12	6.66E-12	9.77E-12	3.66E-12	4.60E-08	7.77E+03	7.49E+03	1.35E+04	3.03E+04	7.15E+00	1.81E-01		
Promethium (61)	Pm-150	2.94E-12	5.25E-13	1.08E-12	1.56E-12	4.63E-13	6.87E-06	1.10E+03	1.10E+03	1.80E+03	4.05E+03	4.41E+01	1.13E+00		
Promethium (61)	Pm-151	1.28E-11	1.88E-12	4.51E-12	6.59E-12	2.36E-12	1.27E-06	5.62E+02	5.62E+02	9.19E+02	2.07E+03	1.06E+01	2.68E-01		
Protactinium (91)	Pa-227	2.38E-12	6.48E-13	9.69E-13	1.37E-12	2.12E-10	4.37E-08	7.18E+05	7.03E+05	1.19E+06	2.67E+06	4.91E+01	1.29E+00		
Protactinium (91)	Pa-228	9.84E-12	1.68E-12	3.60E-12	5.18E-12	2.33E-10	5.10E-06	1.81E+02	1.81E+02	2.96E+02	6.65E+02	1.32E+01	3.40E-01		
Protactinium (91)	Pa-230	1.02E-11	1.80E-12	3.77E-12	5.40E-12	2.58E-09	2.86E-06	1.70E+01	1.70E+01	2.78E+01	6.25E+01	1.26E+01	3.27E-01		
Protactinium (91)	Pa-231	3.74E-10	1.54E-10	1.73E-10	2.26E-10	4.55E-08	1.39E-07	4.61E-01	2.10E-01	1.38E+00	3.01E+00	2.75E-01	7.80E-03		
Protactinium (91)	Pa-232	9.55E-12	1.59E-12	3.48E-12	5.03E-12	6.81E-12	4.29E-06	1.51E+02	1.50E+02	2.46E+02	5.53E+02	1.37E+01	3.51E-01		
Protactinium (91)	Pa-233	1.59E-11	2.34E-12	5.55E-12	8.14E-12	1.42E-11	7.43E-07	4.20E+01	4.17E+01	6.88E+01	1.55E+02	8.58E+00	2.17E-01		
Protactinium (91)	Pa-234	7.03E-12	1.20E-12	2.56E-12	3.70E-12	1.46E-12	8.71E-06	3.48E+02	3.48E+02	5.68E+02	1.28E+03	1.86E+01	4.77E-01		
Protactinium (91)	Pa-234m						6.87E-08	1.52E+07	1.52E+07	2.48E+07	5.57E+07				
Radium (88)	Ra-222						3.71E-08	5.19E+07	5.19E+07	8.47E+07	1.91E+08				
Radium (88)	Ra-223	6.44E-10	1.23E-10	2.38E-10	3.39E-10	2.50E-08	4.34E-07	8.99E+01	8.97E-01	2.70E+02	6.01E+02	2.00E-01	5.20E-03	5.67E+03	2.84E+02
Radium (88)	Ra-224	4.51E-10	8.44E-11	1.67E-10	2.38E-10	9.99E-09	3.72E-08	7.41E+02	4.00E+00	7.91E+03	1.69E+04	9.50E-04	7.41E-03	7.84E+04	3.92E+03
Radium (88)	Ra-225	2.72E-10	7.44E-11	1.14E-10	1.54E-10	2.10E-08	5.91E-09	3.16E+02	1.53E+00	6.05E+03	1.19E+04	4.18E-01	1.15E-02	7.03E+03	3.51E+02
Radium (88)	Ra-226	7.29E-10	2.95E-10	3.85E-10	5.14E-10	1.15E-08	2.29E-08	1.93E-01	6.76E-04	3.70E+00	7.22E+00	8.23E-04	3.43E-03	3.22E-01	1.61E-02
Radium (88)	Ra-226+D	7.30E-10	2.95E-10	3.86E-10	5.15E-10	1.16E-08	8.49E-06	1.24E-02	6.32E-04	2.58E-02	5.79E-02	8.16E-04	3.42E-03	3.22E-01	1.61E-02
Radium (88)	Ra-227	2.48E-13	7.44E-14	1.05E-13	1.46E-13	3.13E-13	6.22E-07	4.64E+04	4.39E+04	7.58E+04	1.71E+05	4.54E+02	1.21E+01	1.95E+12	9.73E+10
Radium (88)	Ra-228	2.28E-09	6.70E-10	1.04E-09	1.43E-09	5.18E-09	0.00E+00	2.60E-01	1.17E-03	8.40E+00	1.51E+01	4.58E-02	1.23E-03	1.19E+00	5.94E-02
Radium (88)	Ra-228+D	2.29E-09	6.70E-10	1.04E-09	1.43E-09	5.23E-09	4.53E-06	6.77E-02	1.16E-03	1.50E-01	3.36E-01	4.58E-02	1.23E-03	1.19E+00	5.94E-02
Radon (86)	Rn-218						3.39E-09	6.16E+11	6.16E+11	1.01E+12	2.26E+12				
Radon (86)	Rn-219						2.25E-07	8.21E+07	8.21E+07	1.34E+08	3.01E+08				
Radon (86)	Rn-220						1.70E-09	7.74E+08	7.74E+08	1.26E+09	2.84E+09				
Radon (86)	Rn-222						1.74E-09	1.27E+05	1.27E+05	2.08E+05	4.68E+05			2.38E+03	1.19E+02

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Radon (86)	Rn-222+D					7.57E-12		5.45E+09	5.30E+09	2.67E+09	6.01E+09	1.26E+00		2.38E+03	1.19E+02
Rhenium (75)	Re-177	1.05E-13	3.28E-14	4.55E-14	6.33E-14	2.97E-14	2.62E-06	3.32E+04	3.32E+04	5.42E+04	1.22E+05	1.05E+03	2.79E+01		
Rhenium (75)	Re-178	9.32E-14	3.37E-14	4.26E-14	5.85E-14	2.33E-14	5.65E-06	1.63E+04	1.63E+04	2.67E+04	6.00E+04	1.12E+03	3.01E+01		
Rhenium (75)	Re-180						5.29E-06	9.48E+04	9.48E+04	1.55E+05	3.48E+05				
Rhenium (75)	Re-181	3.64E-12	7.96E-13	1.41E-12	2.00E-12	7.96E-13	3.18E-06	3.19E+02	3.19E+02	5.21E+02	1.17E+03	3.38E+01	8.82E-01		
Rhenium (75)	Re-182a	2.16E-12	5.22E-13	8.70E-13	1.22E-12	5.51E-13	5.37E-06	2.98E+02	2.98E+02	4.86E+02	1.09E+03	5.47E+01	1.45E+00		
Rhenium (75)	Re-182b	1.26E-11	2.86E-12	4.96E-12	6.99E-12	4.44E-12	8.22E-06	3.86E+01	3.86E+01	6.30E+01	1.42E+02	9.60E+00	2.52E-01		
Rhenium (75)	Re-184	7.66E-12	1.94E-12	3.16E-12	4.40E-12	6.73E-12	3.93E-06	5.67E+00	5.67E+00	9.25E+00	2.08E+01	1.51E+01	4.01E-01		
Rhenium (75)	Re-184m	1.27E-11	2.78E-12	4.88E-12	6.96E-12	2.26E-11	1.52E-06	3.37E+00	3.37E+00	5.51E+00	1.24E+01	9.76E+00	2.53E-01		
Rhenium (75)	Re-186	1.53E-11	2.84E-12	5.59E-12	8.03E-12	4.26E-12	5.49E-08	3.93E+03	3.94E+03	6.62E+03	1.49E+04	8.52E+00	2.20E-01		
Rhenium (75)	Re-186m	1.95E-11	4.03E-12	7.33E-12	1.05E-11	4.18E-11	1.75E-08	5.51E+00	4.16E+00	1.21E+01	2.71E+01	6.50E+00	1.68E-01		
Rhenium (75)	Re-187	4.81E-14	9.47E-15	1.79E-14	2.56E-14	2.51E-14	0.00E+00	1.65E+04	1.29E+04	1.88E+05	3.38E+05	2.66E+03	6.89E+01		
Rhenium (75)	Re-188	1.35E-11	2.52E-12	4.88E-12	7.07E-12	2.22E-12	2.38E-07	4.98E+03	4.98E+03	8.18E+03	1.84E+04	9.76E+00	2.49E-01		
Rhenium (75)	Re-188m	2.69E-13	5.29E-14	9.92E-14	1.42E-13	5.07E-14	1.28E-07	5.12E+05	5.12E+05	8.36E+05	1.88E+06	4.80E+02	1.24E+01		
Rhenium (75)	Re-189	7.84E-12	1.47E-12	2.86E-12	4.11E-12	1.73E-12	2.42E-07	3.44E+03	3.44E+03	5.63E+03	1.27E+04	1.67E+01	4.29E-01		
Rhodium (45)	Rh-100	6.62E-12	1.42E-12	2.65E-12	3.74E-12	1.04E-12	1.38E-05	7.07E+01	7.06E+01	1.16E+02	2.60E+02	1.80E+01	4.72E-01		
Rhodium (45)	Rh-101	5.37E-12	1.22E-12	2.15E-12	3.01E-12	1.81E-11	8.84E-07	8.12E-01	7.87E-01	1.34E+00	3.02E+00	2.21E+01	5.86E-01		
Rhodium (45)	Rh-101m	2.46E-12	4.63E-13	9.40E-13	1.34E-12	7.14E-13	1.19E-06	1.63E+02	1.62E+02	2.67E+02	6.02E+02	5.07E+01	1.32E+00		
Rhodium (45)	Rh-102	1.71E-11	5.22E-12	7.70E-12	1.04E-11	5.99E-11	9.73E-06	8.20E-02	8.11E-02	1.34E-01	3.03E-01	6.18E+00	1.70E-01		
Rhodium (45)	Rh-102m	1.66E-11	2.85E-12	6.07E-12	8.73E-12	2.56E-11	2.11E-06	1.91E+00	1.84E+00	3.16E+00	7.12E+00	7.84E+00	2.02E-01		
Rhodium (45)	Rh-103m	2.40E-14	5.66E-15	9.40E-15	1.34E-14	9.14E-15	9.31E-11	1.61E+08	8.44E+07	3.78E+08	8.49E+08	5.07E+03	1.32E+02		
Rhodium (45)	Rh-105	6.73E-12	9.66E-13	2.34E-12	3.43E-12	1.59E-12	3.15E-07	1.76E+03	1.61E+03	2.97E+03	6.69E+03	2.04E+01	5.14E-01		
Rhodium (45)	Rh-106						9.66E-07	2.53E+06	2.53E+06	4.13E+06	9.30E+06				
Rhodium (45)	Rh-106m	1.37E-12	3.09E-13	5.48E-13	7.73E-13	2.71E-13	1.37E-05	6.74E+02	6.74E+02	1.10E+03	2.48E+03	8.69E+01	2.28E+00		
Rhodium (45)	Rh-107	9.51E-14	3.19E-14	4.18E-14	5.81E-14	2.88E-14	1.28E-06	4.39E+04	4.39E+04	7.16E+04	1.61E+05	1.14E+03	3.04E+01		
Rhodium (45)	Rh-99	5.77E-12	1.10E-12	2.21E-12	3.15E-12	3.33E-12	2.50E-06	2.11E+01	2.08E+01	3.45E+01	7.77E+01	2.15E+01	5.60E-01		
Rhodium (45)	Rh-99m	6.03E-13	1.32E-13	2.42E-13	3.42E-13	9.99E-14	3.02E-06	1.43E+03	1.43E+03	2.34E+03	5.26E+03	1.97E+02	5.16E+00		
Rubidium (37)	Rb-79	1.79E-13	6.77E-14	8.36E-14	1.14E-13	2.37E-14	5.85E-06	9.10E+03	9.10E+03	1.49E+04	3.34E+04	5.70E+02	1.55E+01		
Rubidium (37)	Rb-80						5.56E-06	3.87E+05	3.87E+05	6.31E+05	1.42E+06				
Rubidium (37)	Rb-81	2.83E-13	9.69E-14	1.28E-13	1.74E-13	4.63E-14	2.59E-06	1.71E+03	1.71E+03	2.80E+03	6.29E+03	3.72E+02	1.01E+01		
Rubidium (37)	Rb-81m	4.55E-14	1.57E-14	2.05E-14	2.80E-14	1.10E-14	9.08E-09	4.16E+06	4.04E+06	6.85E+06	1.54E+07	2.32E+03	6.30E+01		
Rubidium (37)	Rb-82						4.85E-06	1.93E+05	1.93E+05	3.16E+05	7.10E+05				
Rubidium (37)	Rb-82m	7.25E-13	2.75E-13	3.51E-13	4.70E-13	1.35E-13	1.35E-05	2.43E+02	2.43E+02	3.96E+02	8.91E+02	1.36E+02	3.75E+00		
Rubidium (37)	Rb-83	1.18E-11	4.40E-12	5.70E-12	7.51E-12	2.32E-12	2.18E-06	4.46E+00	4.32E+00	7.35E+00	1.65E+01	8.35E+00	2.35E-01		
Rubidium (37)	Rb-84	1.91E-11	6.55E-12	8.81E-12	1.17E-11	3.59E-12	4.22E-06	6.06E+00	5.92E+00	9.98E+00	2.25E+01	5.41E+00	1.51E-01		
Rubidium (37)	Rb-86	2.37E-11	6.59E-12	9.88E-12	1.34E-11	4.00E-12	4.67E-07	8.89E+01	7.17E+01	1.58E+02	3.55E+02	4.82E+00	1.32E-01		
Rubidium (37)	Rb-87	1.25E-11	3.43E-12	5.22E-12	7.07E-12	2.14E-12	9.11E-11	5.01E+00	9.64E-01	4.26E+02	7.95E+02	9.12E+00	2.49E-01		
Rubidium (37)	Rb-88	3.06E-13	1.14E-13	1.40E-13	1.92E-13	3.17E-14	3.36E-06	2.04E+04	2.04E+04	3.33E+04	7.48E+04	3.40E+02	9.19E+00		
Rubidium (37)	Rb-89	1.70E-13	6.40E-14	7.88E-14	1.08E-13	2.09E-14	1.05E-05	7.64E+03	7.64E+03	1.25E+04	2.80E+04	6.04E+02	1.63E+01		
Ruthenium (44)	Ru-103	1.05E-11	1.76E-12	3.85E-12	5.55E-12	8.92E-12	2.04E-06	1.05E+01	6.81E+00	1.72E+01	3.88E+01	1.24E+01	3.18E-01	4.80E+04	2.40E+03
Ruthenium (44)	Ru-105	3.77E-12	6.07E-13	1.35E-12	1.96E-12	6.48E-13	3.51E-06	1.30E+03	1.17E+03	2.13E+03	4.79E+03	3.53E+01	9.00E-01	6.17E+09	3.09E+08
Ruthenium (44)	Ru-106	1.19E-10	1.84E-11	4.22E-11	6.11E-11	1.02E-10	0.00E+00	4.00E+01	1.86E-01	1.66E+03	2.99E+03	1.13E+00	2.89E-02	6.43E+01	3.22E+00
Ruthenium (44)	Ru-106+D	1.19E-10		4.22E-11	6.11E-11	1.02E-10	9.66E-07	2.25E+00	1.72E-01	3.89E+00	8.74E+00	1.13E+00	2.89E-02	6.43E+01	3.22E+00
Ruthenium (44)	Ru-94	8.03E-13	1.61E-13	3.06E-13	4.37E-13	1.23E-13	2.31E-06	1.02E+04	9.81E+03	1.66E+04	3.74E+04	1.56E+02	4.04E+00	7.20E+11	3.60E+10
Ruthenium (44)	Ru-97	1.65E-12	3.15E-13	6.36E-13	9.07E-13	3.36E-13	8.63E-07	3.38E+02	2.79E+02	5.52E+02	1.24E+03	7.49E+01	1.94E+00	5.33E+07	2.67E+06
Samarium (62)	Sm-141	1.59E-13	5.37E-14	7.10E-14	9.81E-14	2.79E-14	6.39E-06	1.87E+04	1.87E+04	3.05E+04	6.87E+04	6.71E+02	1.80E+01		
Samarium (62)	Sm-141m	3.26E-13	9.81E-14	1.40E-13	1.95E-13	6.29E-14	9.04E-06	5.97E+03	5.97E+03	9.74E+03	2.19E+04	3.40E+02	9.04E+00		
Samarium (62)	Sm-142	1.40E-12	3.05E-13	5.37E-13	7.70E-13	2.13E-13	2.99E-07	5.62E+04	5.62E+04	9.18E+04	2.06E+05	8.87E+01	2.29E+00		
Samarium (62)	Sm-145	3.27E-12	5.11E-13	1.17E-12	1.70E-12	4.51E-12	3.83E-08	6.41E+01	6.36E+01	1.06E+02	2.38E+02	4.07E+01	1.04E+00		
Samarium (62)	Sm-146	8.36E-11	3.49E-11	4.11E-11	5.25E-11	7.88E-09	0.00E+00	7.58E+00	3.57E+00	4.93E+01	8.93E+01	1.16E+00	3.36E-02		
Samarium (62)	Sm-147	7.59E-11	3.17E-11	3.74E-11	4.77E-11	6.88E-09	0.00E+00	8.35E+00	3.93E+00	5.44E+01	9.85E+01	1.27E+00	3.70E-02		

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Samarium (62)	Sm-151	1.59E-12	2.35E-13	5.55E-13	8.07E-13	4.88E-12	3.60E-13	4.65E+02	2.42E+02	8.19E+03	1.48E+04	8.58E+01	2.19E+00		
Samarium (62)	Sm-153	1.40E-11	1.97E-12	4.85E-12	7.10E-12	2.95E-12	1.06E-07	4.02E+03	3.97E+03	6.68E+03	1.50E+04	9.82E+00	2.48E-01		
Samarium (62)	Sm-155	1.13E-13	3.74E-14	4.96E-14	6.88E-14	3.15E-14	2.81E-07	1.96E+05	1.96E+05	3.20E+05	7.21E+05	9.60E+02	2.56E+01		
Samarium (62)	Sm-156	4.26E-12	6.29E-13	1.49E-12	2.18E-12	9.69E-13	3.79E-07	5.69E+03	5.69E+03	9.31E+03	2.09E+04	3.20E+01	8.09E-01		
Scandium (21)	Sc-43	2.21E-12	3.96E-13	8.18E-13	1.18E-12	3.81E-13	4.73E-06	1.10E+03	1.10E+03	1.80E+03	4.05E+03	5.82E+01	1.49E+00		
Scandium (21)	Sc-44	4.22E-12	7.51E-13	1.56E-12	2.25E-12	6.44E-13	9.95E-06	5.20E+02	5.20E+02	8.48E+02	1.91E+03	3.05E+01	7.84E-01		
Scandium (21)	Sc-44m	3.89E-11	6.03E-12	1.38E-11	2.01E-11	6.96E-12	1.15E-06	3.00E+02	2.99E+02	4.92E+02	1.11E+03	3.45E+00	8.77E-02		
Scandium (21)	Sc-46	1.62E-11	3.07E-12	6.22E-12	8.88E-12	2.47E-11	9.63E-06	1.05E+00	1.05E+00	1.71E+00	3.85E+00	7.66E+00	1.99E-01		
Scandium (21)	Sc-47	1.00E-11	1.44E-12	3.49E-12	5.11E-12	3.05E-12	3.62E-07	6.95E+02	6.94E+02	1.14E+03	2.56E+03	1.36E+01	3.45E-01		
Scandium (21)	Sc-48	1.93E-11	3.59E-12	7.33E-12	1.05E-11	3.96E-12	1.62E-05	2.87E+01	2.87E+01	4.68E+01	1.05E+02	6.50E+00	1.68E-01		
Scandium (21)	Sc-49	5.25E-13	1.22E-13	2.05E-13	2.92E-13	1.07E-13	1.90E-08	1.11E+06	1.11E+06	1.82E+06	4.10E+06	2.32E+02	6.04E+00		
Selenium (34)	Se-70	6.92E-13	1.95E-13	2.95E-13	4.11E-13	7.36E-14	4.22E-06	7.04E+03	7.00E+03	1.15E+04	2.59E+04	1.61E+02	4.29E+00		
Selenium (34)	Se-73	1.99E-12	4.48E-13	7.96E-13	1.13E-12	1.99E-13	4.52E-06	6.28E+02	6.19E+02	1.03E+03	2.31E+03	5.98E+01	1.56E+00		
Selenium (34)	Se-73m	2.02E-13	5.07E-14	8.29E-14	1.17E-13	2.06E-14	1.06E-06	2.95E+04	2.93E+04	4.81E+04	1.08E+05	5.74E+02	1.51E+01		
Selenium (34)	Se-75	1.67E-11	6.25E-12	8.14E-12	1.08E-11	3.77E-12	1.45E-06	4.78E+00	3.27E+00	7.94E+00	1.79E+01	5.85E+00	1.63E-01		
Selenium (34)	Se-77m						2.85E-07	1.47E+07	1.47E+07	2.39E+07	5.39E+07				
Selenium (34)	Se-79	1.60E-11	5.29E-12	7.29E-12	9.69E-12	3.33E-12	1.10E-11	4.69E+00	1.32E-01	3.30E+02	5.97E+02	6.53E+00	1.82E-01		
Selenium (34)	Se-81	9.58E-14	3.36E-14	4.29E-14	5.92E-14	1.27E-14	4.68E-08	1.40E+06	1.30E+06	2.30E+06	5.17E+06	1.11E+03	2.98E+01		
Selenium (34)	Se-81m	3.24E-13	8.07E-14	1.30E-13	1.85E-13	3.54E-14	3.56E-08	5.90E+05	4.46E+05	9.75E+05	2.19E+06	3.66E+02	9.53E+00		
Selenium (34)	Se-83	2.33E-13	7.33E-14	1.02E-13	1.43E-13	2.72E-14	1.15E-05	4.71E+03	4.71E+03	7.69E+03	1.73E+04	4.67E+02	1.23E+01		
Silicon (14)	Si-31	1.81E-12	2.97E-13	6.48E-13	9.40E-13	3.05E-13	1.11E-08	6.84E+05	6.85E+05	1.14E+06	2.56E+06	7.35E+01	1.88E+00		
Silicon (14)	Si-32	9.81E-12	1.50E-12	3.44E-12	5.00E-12	2.93E-10	2.18E-11	8.14E+01	6.41E+01	1.05E+03	1.95E+03	1.38E+01	3.53E-01		
Silver (47)	Ag-102	1.56E-13	5.74E-14	7.25E-14	9.95E-14	2.56E-14	1.60E-05	5.91E+03	5.88E+03	9.64E+03	2.17E+04	6.57E+02	1.77E+01	2.73E+13	1.37E+12
Silver (47)	Ag-103	2.96E-13	7.22E-14	1.20E-13	1.69E-13	6.07E-14	3.33E-06	5.57E+03	5.39E+03	9.09E+03	2.05E+04	3.97E+02	1.04E+01	6.37E+11	3.18E+10
Silver (47)	Ag-104	3.77E-13	1.10E-13	1.65E-13	2.29E-13	6.25E-14	1.25E-05	1.41E+03	1.39E+03	2.30E+03	5.17E+03	2.89E+02	7.70E+00	4.17E+11	2.09E+10
Silver (47)	Ag-104m	2.81E-13	8.29E-14	1.21E-13	1.68E-13	4.92E-14	5.50E-06	6.62E+03	6.48E+03	1.08E+04	2.43E+04	3.94E+02	1.05E+01	2.43E+12	1.21E+11
Silver (47)	Ag-105	4.40E-12	9.77E-13	1.77E-12	2.49E-12	2.83E-12	2.15E-06	9.56E+00	5.37E+00	1.57E+01	3.53E+01	2.69E+01	7.08E-01	5.35E+04	2.67E+03
Silver (47)	Ag-106	1.34E-13	4.44E-14	5.92E-14	8.21E-14	2.72E-14	3.08E-06	1.65E+04	1.62E+04	2.69E+04	6.06E+04	8.04E+02	2.15E+01	9.67E+12	4.84E+11
Silver (47)	Ag-106m	1.14E-11	2.82E-12	4.81E-12	6.73E-12	3.54E-12	1.31E-05	7.67E+00	5.69E+00	1.25E+01	2.82E+01	9.90E+00	2.62E-01	4.67E+05	2.34E+04
Silver (47)	Ag-108						8.56E-08	6.01E+06	6.01E+06	9.81E+06	2.21E+07				
Silver (47)	Ag-108m	1.92E-11	5.07E-12	8.14E-12	1.12E-11	2.67E-11	7.18E-06	1.68E-02	6.29E-03	3.25E-02	7.32E-02	5.85E+00	1.57E-01	3.99E-01	1.99E-02
Silver (47)	Ag-109m						7.66E-09	2.41E+08	2.41E+08	3.94E+08	8.85E+08				
Silver (47)	Ag-110						1.69E-07	1.76E+07	1.76E+07	2.87E+07	6.46E+07				
Silver (47)	Ag-110m	2.37E-11	5.96E-12	9.88E-12	1.37E-11	2.83E-11	1.30E-05	2.60E-01	1.52E-01	4.25E-01	9.56E-01	4.82E+00	1.29E-01	1.58E+02	7.92E+00
Silver (47)	Ag-111	2.37E-11	3.36E-12	8.21E-12	1.21E-11	6.66E-12	1.09E-07	7.44E+02	1.36E+01	1.69E+03	3.81E+03	5.80E+00	1.46E-01	3.49E+05	1.75E+04
Silver (47)	Ag-112	5.59E-12	9.10E-13	1.99E-12	2.90E-12	7.25E-13	3.23E-06	2.01E+03	1.25E+03	3.29E+03	7.40E+03	2.39E+01	6.08E-01	4.73E+09	2.36E+08
Silver (47)	Ag-115	3.46E-13	8.92E-14	1.40E-13	1.98E-13	6.81E-14	3.44E-06	1.77E+04	1.71E+04	2.89E+04	6.51E+04	3.40E+02	8.91E+00	5.89E+12	2.94E+11
Sodium (11)	Na-22	1.97E-11	7.47E-12	9.62E-12	1.26E-11	3.89E-12	1.03E-05	8.65E-02	8.52E-02	1.42E-01	3.18E-01	4.95E+00	1.40E-01		
Sodium (11)	Na-24	2.64E-12	9.29E-13	1.23E-12	1.65E-12	4.74E-13	2.20E-05	6.16E+01	6.15E+01	1.00E+02	2.26E+02	3.87E+01	1.07E+00		
Strontium (38)	Sr-80	2.83E-12	6.11E-13	1.09E-12	1.55E-12	4.51E-13	5.08E-11	1.13E+06	8.03E+03	1.58E+08	3.09E+08	4.37E+01	1.14E+00	1.25E+10	6.26E+08
Strontium (38)	Sr-81	4.03E-13	1.17E-13	1.71E-13	2.39E-13	8.07E-14	5.97E-06	8.01E+03	7.71E+03	1.31E+04	2.94E+04	2.78E+02	7.38E+00	1.23E+12	6.14E+10
Strontium (38)	Sr-82	8.47E-11	1.57E-11	3.13E-11	4.48E-11	3.69E-11	5.00E-11	1.09E+02	7.71E-01	2.79E+04	5.05E+04	1.52E+00	3.94E-02	3.36E+03	1.68E+02
Strontium (38)	Sr-83	5.85E-12	1.14E-12	2.21E-12	3.17E-12	1.26E-12	3.60E-06	1.73E+02	9.35E+01	2.84E+02	6.40E+02	2.15E+01	5.56E-01	1.63E+07	8.17E+05
Strontium (38)	Sr-85	5.03E-12	1.42E-12	2.26E-12	3.11E-12	2.56E-12	2.20E-06	5.88E+00	2.49E+00	9.69E+00	2.18E+01	2.11E+01	5.67E-01	6.93E+03	3.47E+02
Strontium (38)	Sr-85m	3.74E-14	1.14E-14	1.67E-14	2.31E-14	8.32E-15	8.21E-07	2.14E+04	2.08E+04	3.49E+04	7.85E+04	2.85E+03	7.63E+01	1.69E+12	8.46E+10
Strontium (38)	Sr-87m	2.69E-13	6.03E-14	1.07E-13	1.51E-13	5.62E-14	1.33E-06	5.43E+03	4.89E+03	8.87E+03	2.00E+04	4.45E+02	1.17E+01	4.49E+10	2.24E+09
Strontium (38)	Sr-89	3.47E-11	6.48E-12	1.28E-11	1.84E-11	2.34E-11	7.19E-09	1.24E+02	9.29E-01	3.43E+03	7.52E+03	3.72E+00	9.59E-02	2.02E+03	1.01E+02
Strontium (38)	Sr-90	9.18E-11	5.18E-11	5.59E-11	6.88E-11	1.05E-10	4.82E-10	3.31E-01	1.92E-03	4.23E+01	7.73E+01	8.52E-01	2.56E-02	2.69E-01	1.34E-02
Strontium (38)	Sr-90+D	1.44E-10	5.92E-11	7.40E-11	9.53E-11	1.13E-10	1.96E-08	2.31E-01	1.39E-03	1.08E+01	2.27E+01	6.44E-01	1.85E-02	2.69E-01	1.34E-02
Strontium (38)	Sr-91	8.81E-12	1.57E-12	3.22E-12	4.66E-12	1.70E-12	3.30E-06	6.42E+02	2.72E+02	1.06E+03	2.38E+03	1.48E+01	3.78E-01	1.30E+08	6.52E+06
Strontium (38)	Sr-92	6.18E-12	1.07E-12	2.25E-12	3.26E-12	1.03E-12	6.69E-06	1.12E+03	7.58E+02	1.83E+03	4.11E+03	2.12E+01	5.41E-01	2.29E+09	1.15E+08

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Sulfur (16)	S-35	1.24E-12	3.27E-13	5.14E-13	3.70E-12	5.03E-12	8.77E-12	1.96E+02	4.71E+01	3.22E+05	6.02E+05	9.26E+01	4.77E-01		
Tantalum (73)	Ta-172	2.64E-13	7.96E-14	1.14E-13	1.59E-13	7.22E-14	7.04E-06	4.71E+03	4.71E+03	7.68E+03	1.73E+04	4.18E+02	1.11E+01		
Tantalum (73)	Ta-173	2.49E-12	4.22E-13	9.03E-13	1.31E-12	4.44E-13	2.38E-06	2.34E+03	2.34E+03	3.82E+03	8.59E+03	5.27E+01	1.35E+00		
Tantalum (73)	Ta-174	4.11E-13	9.47E-14	1.62E-13	2.30E-13	1.11E-13	2.55E-06	6.64E+03	6.64E+03	1.08E+04	2.44E+04	2.94E+02	7.67E+00		
Tantalum (73)	Ta-175	2.25E-12	4.37E-13	8.70E-13	1.24E-12	4.37E-13	4.16E-06	4.65E+02	4.65E+02	7.59E+02	1.71E+03	5.47E+01	1.42E+00		
Tantalum (73)	Ta-176	3.18E-12	6.55E-13	1.25E-12	1.78E-12	5.96E-13	1.06E-05	2.37E+02	2.37E+02	3.87E+02	8.71E+02	3.81E+01	9.91E-01		
Tantalum (73)	Ta-177	1.65E-12	2.58E-13	5.88E-13	8.58E-13	4.44E-13	1.20E-07	2.98E+03	2.95E+03	4.88E+03	1.10E+04	8.10E+01	2.06E+00		
Tantalum (73)	Ta-178a						3.29E-07	3.98E+05	3.98E+05	6.50E+05	1.46E+06				
Tantalum (73)	Ta-178b	6.29E-13	1.38E-13	2.49E-13	3.53E-13	1.79E-13	3.78E-06	2.44E+03	2.44E+03	3.99E+03	8.97E+03	1.91E+02	5.00E+00		
Tantalum (73)	Ta-179	9.51E-13	1.54E-13	3.44E-13	5.00E-13	2.05E-12	3.62E-08	3.48E+01	3.42E+01	5.74E+01	1.29E+02	1.38E+02	3.53E+00		
Tantalum (73)	Ta-180	1.23E-11	1.99E-12	4.44E-12	6.44E-12	7.25E-11	2.03E-06	5.48E-02	4.09E-02	1.08E-01	2.42E-01	1.07E+01	2.74E-01		
Tantalum (73)	Ta-180m	8.58E-13	1.31E-13	3.03E-13	4.40E-13	1.86E-13	6.13E-08	4.07E+04	4.03E+04	6.68E+04	1.50E+05	1.57E+02	4.01E+00		
Tantalum (73)	Ta-182	2.19E-11	3.59E-12	7.96E-12	1.15E-11	3.74E-11	6.04E-06	1.22E+00	1.21E+00	1.99E+00	4.47E+00	5.98E+00	1.53E-01		
Tantalum (73)	Ta-182m	4.44E-14	1.54E-14	1.99E-14	2.76E-14	3.41E-14	7.38E-07	1.05E+05	1.05E+05	1.71E+05	3.84E+05	2.39E+03	6.39E+01		
Tantalum (73)	Ta-183	2.38E-11	3.44E-12	8.33E-12	1.22E-11	8.81E-12	9.40E-07	1.75E+02	1.72E+02	2.88E+02	6.48E+02	5.72E+00	1.45E-01		
Tantalum (73)	Ta-184	9.81E-12	1.58E-12	3.53E-12	5.11E-12	1.73E-12	7.02E-06	3.33E+02	3.32E+02	5.43E+02	1.22E+03	1.35E+01	3.45E-01		
Tantalum (73)	Ta-185	3.92E-13	9.88E-14	1.57E-13	2.22E-13	1.18E-13	6.24E-07	3.99E+04	3.98E+04	6.51E+04	1.46E+05	3.03E+02	7.94E+00		
Tantalum (73)	Ta-186	1.19E-13	4.44E-14	5.51E-14	7.55E-14	2.69E-14	6.69E-06	1.74E+04	1.74E+04	2.83E+04	6.37E+04	8.64E+02	2.34E+01		
Technetium (43)	Tc-101	6.81E-14	2.42E-14	3.06E-14	4.22E-14	1.85E-14	1.37E-06	6.25E+04	5.62E+04	1.02E+05	2.30E+05	1.56E+03	4.18E+01	3.82E+12	1.91E+11
Technetium (43)	Tc-104	3.09E-13	1.07E-13	1.38E-13	1.90E-13	5.33E-14	9.75E-06	6.86E+03	6.40E+03	1.12E+04	2.52E+04	3.45E+02	9.28E+00	5.15E+11	2.57E+10
Technetium (43)	Tc-93	3.55E-13	1.04E-13	1.59E-13	2.20E-13	6.36E-14	7.31E-06	1.01E+03	9.08E+02	1.65E+03	3.71E+03	2.99E+02	8.02E+00	5.44E+09	2.72E+08
Technetium (43)	Tc-93m	1.55E-13	4.51E-14	6.81E-14	9.44E-14	3.17E-14	3.62E-06	7.72E+03	7.05E+03	1.26E+04	2.84E+04	6.99E+02	1.87E+01	1.83E+11	9.13E+09
Technetium (43)	Tc-94	1.48E-12	3.92E-13	6.36E-13	8.88E-13	2.80E-13	1.24E-05	3.33E+02	2.64E+02	5.48E+02	1.23E+03	7.49E+01	1.99E+00	4.31E+08	2.16E+07
Technetium (43)	Tc-94m	5.74E-13	1.55E-13	2.36E-13	3.32E-13	1.03E-13	8.70E-06	2.68E+03	2.36E+03	4.40E+03	9.89E+03	2.02E+02	5.31E+00	3.69E+10	1.84E+09
Technetium (43)	Tc-95	1.35E-12	3.50E-13	5.77E-13	8.03E-13	2.63E-13	3.63E-06	2.73E+02	1.53E+02	4.57E+02	1.03E+03	8.25E+01	2.20E+00	2.83E+07	1.42E+06
Technetium (43)	Tc-95m	4.29E-12	1.10E-12	1.80E-12	2.51E-12	3.40E-12	2.93E-06	4.32E+00	1.12E+00	7.73E+00	1.74E+01	2.65E+01	7.03E-01	1.69E+03	8.47E+01
Technetium (43)	Tc-96	7.81E-12	2.15E-12	3.42E-12	4.74E-12	2.00E-12	1.16E-05	1.63E+01	6.73E+00	2.78E+01	6.26E+01	1.39E+01	3.72E-01	1.81E+05	9.06E+03
Technetium (43)	Tc-96m	8.36E-14	2.27E-14	3.59E-14	5.00E-14	2.05E-14	2.13E-07	1.08E+05	5.91E+04	1.81E+05	4.08E+05	1.33E+03	3.53E+01	2.47E+11	1.24E+10
Technetium (43)	Tc-97	7.40E-13	1.34E-13	2.70E-13	3.89E-13	8.51E-13	2.94E-10	2.56E+00	5.73E-02	7.04E+02	1.56E+03	1.76E+02	4.53E+00	7.30E-01	3.65E-02
Technetium (43)	Tc-97m	6.62E-12	1.14E-12	2.38E-12	3.44E-12	1.12E-11	1.04E-09	2.53E+01	7.54E-01	1.35E+04	2.94E+04	2.00E+01	5.13E-01	6.30E+02	3.15E+01
Technetium (43)	Tc-98	1.83E-11	3.92E-12	7.10E-12	1.01E-11	3.01E-11	6.45E-06	1.47E-02	1.89E-03	3.39E-02	7.62E-02	6.71E+00	1.75E-01	2.78E-02	1.39E-03
Technetium (43)	Tc-99	7.66E-12	1.32E-12	2.75E-12	4.00E-12	1.41E-11	8.14E-11	2.50E-01	5.57E-03	8.96E+02	1.73E+03	1.73E+01	4.41E-01	3.73E+00	1.86E-01
Technetium (43)	Tc-99m	2.03E-13	4.37E-14	7.96E-14	1.14E-13	5.70E-14	3.93E-07	8.32E+03	4.11E+03	1.40E+04	3.15E+04	5.98E+02	1.55E+01	2.27E+09	1.13E+08
Tellurium (52)	Te-116	1.75E-12	3.48E-13	6.73E-13	9.62E-13	3.20E-13	1.34E-07	5.55E+04	3.61E+04	9.93E+04	2.24E+05	7.08E+01	1.83E+00		
Tellurium (52)	Te-121	3.40E-12	9.07E-13	1.46E-12	2.01E-12	1.30E-12	2.46E-06	2.00E+01	1.88E+01	3.30E+01	7.43E+01	3.26E+01	8.77E-01		
Tellurium (52)	Te-121m	1.42E-11	4.51E-12	6.40E-12	8.51E-12	1.44E-11	7.83E-07	6.12E+00	3.44E+00	1.14E+01	2.58E+01	7.44E+00	2.07E-01		
Tellurium (52)	Te-123	6.77E-12	4.07E-12	4.11E-12	5.11E-12	2.50E-12	2.73E-09	1.55E+00	1.71E-01	6.76E+01	1.47E+02	1.16E+01	3.45E-01		
Tellurium (52)	Te-123m	1.02E-11	2.46E-12	4.14E-12	5.66E-12	1.36E-11	4.48E-07	1.34E+01	7.13E+00	2.57E+01	5.78E+01	1.15E+01	3.12E-01		
Tellurium (52)	Te-125m	8.92E-12	1.70E-12	3.33E-12	4.70E-12	1.17E-11	6.95E-09	2.06E+02	3.20E+01	3.33E+03	7.43E+03	1.43E+01	3.75E-01		
Tellurium (52)	Te-127	2.87E-12	4.22E-13	1.00E-12	1.48E-12	6.11E-13	2.10E-08	5.28E+04	1.34E+04	1.68E+05	3.79E+05	4.76E+01	1.19E+00		
Tellurium (52)	Te-127m	2.25E-11	4.77E-12	8.62E-12	1.20E-11	2.58E-11	2.73E-09	4.68E+01	6.76E+00	3.82E+03	8.23E+03	5.52E+00	1.47E-01		
Tellurium (52)	Te-129	4.40E-13	9.88E-14	1.71E-13	2.44E-13	9.95E-14	2.45E-07	7.05E+04	6.53E+04	1.17E+05	2.62E+05	2.78E+02	7.23E+00		
Tellurium (52)	Te-129m	4.26E-11	7.18E-12	1.53E-11	2.20E-11	2.49E-11	1.38E-07	5.76E+01	1.12E+01	2.96E+02	6.65E+02	3.11E+00	8.02E-02		
Tellurium (52)	Te-131	5.62E-13	1.31E-13	2.17E-13	3.05E-13	6.40E-14	1.79E-06	2.72E+04	2.68E+04	4.45E+04	1.00E+05	2.19E+02	5.78E+00		
Tellurium (52)	Te-131m	2.28E-11	4.00E-12	8.25E-12	1.19E-11	4.22E-12	6.61E-06	1.00E+02	8.74E+01	1.67E+02	3.76E+02	5.77E+00	1.48E-01		
Tellurium (52)	Te-132	4.77E-11	8.25E-12	1.70E-11	2.44E-11	9.32E-12	7.83E-07	2.33E+02	8.34E+01	5.41E+02	1.22E+03	2.80E+00	7.23E-02		
Tellurium (52)	Te-133	5.29E-13	1.11E-13	1.92E-13	2.73E-13	4.92E-14	4.29E-06	2.27E+04	2.26E+04	3.71E+04	8.35E+04	2.48E+02	6.46E+00		
Tellurium (52)	Te-133m	2.42E-12	4.74E-13	8.73E-13	1.24E-12	2.64E-13	1.09E-05	2.02E+03	2.00E+03	3.29E+03	7.41E+03	5.45E+01	1.42E+00		
Tellurium (52)	Te-134	7.51E-13	1.89E-13	3.01E-13	4.18E-13	1.60E-13	3.78E-06	7.70E+03	7.64E+03	1.26E+04	2.83E+04	1.58E+02	4.22E+00		
Terbium (65)	Tb-147	1.37E-12	2.88E-13	5.33E-13	7.59E-13	2.26E-13	7.30E-06	1.69E+03	1.69E+03	2.75E+03	6.19E+03	8.93E+01	2.32E+00		
Terbium (65)	Tb-149	2.90E-12	5.25E-13	1.08E-12	1.56E-12	1.65E-11	7.60E-06	6.44E+02	6.44E+02	1.05E+03	2.37E+03	4.41E+01	1.13E+00		

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Terbium (65)	Tb-150	2.92E-12	5.25E-13	1.08E-12	1.56E-12	3.88E-13	7.79E-06	7.98E+02	7.98E+02	1.30E+03	2.93E+03	4.41E+01	1.13E+00		
Terbium (65)	Tb-151	3.92E-12	7.25E-13	1.49E-12	2.13E-12	7.73E-13	3.65E-06	3.16E+02	3.16E+02	5.16E+02	1.16E+03	3.20E+01	8.28E-01		
Terbium (65)	Tb-153	3.54E-12	5.77E-13	1.28E-12	1.86E-12	8.18E-13	7.24E-07	4.99E+02	4.99E+02	8.15E+02	1.83E+03	3.72E+01	9.48E-01		
Terbium (65)	Tb-154	6.51E-12	1.34E-12	2.57E-12	3.64E-12	1.14E-12	1.18E-05	8.05E+01	8.05E+01	1.31E+02	2.95E+02	1.85E+01	4.85E-01		
Terbium (65)	Tb-155	2.97E-12	4.81E-13	1.08E-12	1.56E-12	8.99E-13	3.26E-07	4.87E+02	4.87E+02	7.96E+02	1.79E+03	4.41E+01	1.13E+00		
Terbium (65)	Tb-156	1.30E-11	2.46E-12	4.96E-12	7.10E-12	4.22E-12	8.37E-06	1.89E+01	1.89E+01	3.09E+01	6.95E+01	9.60E+00	2.48E-01		
Terbium (65)	Tb-156m	2.29E-12	3.92E-13	8.44E-13	1.22E-12	8.47E-13	2.16E-08	3.79E+04	3.75E+04	6.28E+04	1.41E+05	5.64E+01	1.45E+00		
Terbium (65)	Tb-156n	1.11E-12	1.82E-13	4.03E-13	5.85E-13	3.77E-13	4.06E-09	9.56E+05	9.34E+05	1.62E+06	3.65E+06	1.18E+02	3.01E+00		
Terbium (65)	Tb-157	5.29E-13	7.99E-14	1.86E-13	2.70E-13	1.46E-12	1.63E-09	6.95E+01	5.19E+01	1.41E+02	3.17E+02	2.56E+02	6.53E+00		
Terbium (65)	Tb-158	1.32E-11	2.38E-12	4.88E-12	6.99E-12	8.29E-11	3.57E-06	3.34E-02	2.56E-02	6.48E-02	1.46E-01	9.76E+00	2.52E-01		
Terbium (65)	Tb-160	2.42E-11	3.85E-12	8.70E-12	1.27E-11	2.45E-11	5.23E-06	2.24E+00	2.24E+00	3.65E+00	8.22E+00	5.47E+00	1.39E-01		
Terbium (65)	Tb-161	1.38E-11	1.95E-12	4.77E-12	7.03E-12	5.03E-12	3.44E-08	3.33E+03	3.23E+03	5.77E+03	1.30E+04	9.98E+00	2.51E-01		
Thallium (81)	Tl-194	3.68E-14	1.48E-14	1.81E-14	2.45E-14	5.11E-15	3.25E-06	1.14E+04	1.14E+04	1.86E+04	4.17E+04	2.63E+03	7.20E+01		
Thallium (81)	Tl-194m	1.63E-13	6.36E-14	7.81E-14	1.06E-13	2.50E-14	1.01E-05	3.68E+03	3.68E+03	6.01E+03	1.35E+04	6.10E+02	1.66E+01		
Thallium (81)	Tl-195	1.36E-13	5.00E-14	6.40E-14	8.70E-14	2.08E-14	6.02E-06	2.91E+03	2.91E+03	4.75E+03	1.07E+04	7.44E+02	2.03E+01		
Thallium (81)	Tl-197	1.41E-13	4.51E-14	6.25E-14	8.55E-14	2.39E-14	1.65E-06	4.33E+03	4.33E+03	7.08E+03	1.59E+04	7.62E+02	2.06E+01		
Thallium (81)	Tl-198	4.26E-13	1.61E-13	2.06E-13	2.75E-13	7.92E-14	9.67E-06	3.96E+02	3.96E+02	6.47E+02	1.46E+03	2.31E+02	6.41E+00		
Thallium (81)	Tl-198m	2.76E-13	1.01E-13	1.30E-13	1.75E-13	4.92E-14	5.04E-06	2.16E+03	2.15E+03	3.52E+03	7.92E+03	3.66E+02	1.01E+01		
Thallium (81)	Tl-199	1.64E-13	5.33E-14	7.36E-14	9.99E-14	2.89E-14	8.56E-07	3.20E+03	3.19E+03	5.22E+03	1.17E+04	6.47E+02	1.77E+01		
Thallium (81)	Tl-200	1.31E-12	4.55E-13	6.14E-13	8.21E-13	2.52E-13	5.93E-06	1.31E+02	1.31E+02	2.14E+02	4.82E+02	7.76E+01	2.15E+00		
Thallium (81)	Tl-201	8.81E-13	2.23E-13	3.61E-13	5.00E-13	1.49E-13	1.88E-07	1.46E+03	1.41E+03	2.42E+03	5.44E+03	1.32E+02	3.53E+00		
Thallium (81)	Tl-202	3.28E-12	1.05E-12	1.49E-12	2.01E-12	6.14E-13	1.83E-06	3.77E+01	3.72E+01	6.19E+01	1.39E+02	3.20E+01	8.77E-01		
Thallium (81)	Tl-204	1.54E-11	3.16E-12	5.85E-12	8.25E-12	2.45E-12	2.76E-09	1.48E+01	3.90E+00	3.21E+02	7.01E+02	8.14E+00	2.14E-01		
Thallium (81)	Tl-206						6.05E-09	4.80E+07	4.80E+07	7.83E+07	1.76E+08				
Thallium (81)	Tl-207						1.52E-08	1.68E+07	1.68E+07	2.74E+07	6.17E+07				
Thallium (81)	Tl-208						1.76E-05	2.26E+04	2.26E+04	3.68E+04	8.28E+04				
Thallium (81)	Tl-209						9.83E-06	5.64E+04	5.64E+04	9.20E+04	2.07E+05				
Thorium (90)	Th-226	1.58E-12	4.77E-13	6.66E-13	9.32E-13	1.56E-10	2.36E-08	1.65E+06	4.59E+05	2.72E+06	6.12E+06	7.15E+01	1.89E+00	3.61E+12	1.81E+11
Thorium (90)	Th-227	1.37E-10	2.03E-11	4.74E-11	6.92E-11	3.51E-08	3.78E-07	1.13E+02	9.05E+00	1.94E+02	4.35E+02	1.00E+00	2.55E-02	6.68E+04	3.34E+03
Thorium (90)	Th-228	2.89E-10	6.40E-11	1.07E-10	1.48E-10	1.32E-07	5.59E-09	2.42E+01	1.23E-01	1.25E+02	2.51E+02	4.45E-01	1.19E-02	6.60E+01	3.30E+00
Thorium (90)	Th-228+D	8.09E-10	1.62E-10	3.00E-10	4.22E-10	1.43E-07	7.76E-06	1.54E-01	3.38E-02	2.55E-01	5.73E-01	1.59E-01	4.18E-03	6.60E+01	3.30E+00
Thorium (90)	Th-229	4.96E-10	1.97E-10	2.24E-10	2.90E-10	1.75E-07	2.25E-07	3.70E-01	4.28E-03	8.67E-01	1.90E+00	2.13E-01	6.08E-03	6.07E+00	3.03E-01
Thorium (90)	Th-229+D	1.29E-09	3.63E-10	5.28E-10	7.16E-10	2.25E-07	1.17E-06	8.16E-02	1.71E-03	1.79E-01	4.00E-01	9.02E-02	2.46E-03	6.07E+00	3.03E-01
Thorium (90)	Th-230	2.02E-10	7.73E-11	9.10E-11	1.19E-10	2.85E-08	8.19E-10	3.49E+00	1.05E-02	2.02E+01	3.72E+01	5.23E-01	1.48E-02	6.06E+00	3.03E-01
Thorium (90)	Th-231	6.36E-12	9.14E-13	2.21E-12	3.24E-12	1.52E-12	2.45E-08	3.13E+04	3.31E+03	5.28E+04	1.19E+05	2.15E+01	5.44E-01	4.44E+08	2.22E+07
Thorium (90)	Th-232	2.31E-10	8.47E-11	1.01E-10	1.33E-10	4.33E-08	3.42E-10	3.10E+00	9.42E-03	1.90E+01	3.48E+01	4.71E-01	1.33E-02	6.06E+00	3.03E-01
Thorium (90)	Th-234	6.70E-11	9.51E-12	2.31E-11	3.40E-11	3.07E-11	1.63E-08	1.33E+03	1.53E+01	3.28E+03	7.26E+03	2.06E+00	5.19E-02	8.26E+04	4.13E+03
Thulium (69)	Tm-162	1.24E-13	4.29E-14	5.66E-14	7.77E-14	2.72E-14	8.69E-06	6.46E+03	6.46E+03	1.06E+04	2.37E+04	8.41E+02	2.27E+01		
Thulium (69)	Tm-166	2.86E-12	5.85E-13	1.12E-12	1.59E-12	5.14E-13	8.98E-06	2.94E+02	2.94E+02	4.80E+02	1.08E+03	4.25E+01	1.11E+00		
Thulium (69)	Tm-167	9.88E-12	1.44E-12	3.46E-12	5.07E-12	4.37E-12	3.97E-07	2.30E+02	2.30E+02	3.76E+02	8.47E+02	1.38E+01	3.48E-01		
Thulium (69)	Tm-170	2.59E-11	3.61E-12	8.92E-12	1.31E-11	2.43E-11	1.01E-08	4.78E+02	4.83E+02	1.02E+03	2.26E+03	5.34E+00	1.35E-01		
Thulium (69)	Tm-171	2.02E-12	2.85E-13	6.99E-13	1.02E-12	3.33E-12	6.97E-10	1.23E+03	1.25E+03	2.69E+03	5.99E+03	6.81E+01	1.73E+00		
Thulium (69)	Tm-172	3.09E-11	4.44E-12	1.08E-11	1.57E-11	5.62E-12	2.35E-06	1.36E+02	1.36E+02	2.22E+02	4.99E+02	4.41E+00	1.12E-01		
Thulium (69)	Tm-173	4.88E-12	7.44E-13	1.72E-12	2.52E-12	7.73E-13	1.62E-06	1.52E+03	1.52E+03	2.48E+03	5.59E+03	2.77E+01	7.00E-01		
Thulium (69)	Tm-175	1.19E-13	3.85E-14	5.22E-14	7.25E-14	3.26E-14	4.78E-06	1.68E+04	1.68E+04	2.74E+04	6.16E+04	9.12E+02	2.43E+01		
Tin (50)	Sn-110	5.18E-12	8.36E-13	1.87E-12	2.71E-12	6.70E-13	1.13E-06	4.49E+03	4.49E+03	7.34E+03	1.65E+04	2.55E+01	6.51E-01		
Tin (50)	Sn-111	1.32E-13	3.61E-14	5.51E-14	7.70E-14	2.83E-14	2.29E-06	1.51E+04	1.51E+04	2.46E+04	5.54E+04	8.64E+02	2.29E+01		
Tin (50)	Sn-113	1.22E-11	1.86E-12	4.33E-12	6.33E-12	1.00E-11	2.02E-08	3.31E+02	3.16E+02	5.88E+02	1.32E+03	1.10E+01	2.79E-01		
Tin (50)	Sn-117m	1.25E-11	1.83E-12	4.37E-12	6.40E-12	8.84E-12	4.69E-07	1.32E+02	1.32E+02	2.17E+02	4.87E+02	1.09E+01	2.76E-01		
Tin (50)	Sn-119m	6.36E-12	9.14E-13	2.21E-12	3.24E-12	7.81E-12	1.20E-09	1.27E+03	1.03E+03	3.59E+03	7.91E+03	2.15E+01	5.44E-01		
Tin (50)	Sn-121	4.33E-12	6.11E-13	1.50E-12	2.20E-12	1.02E-12	1.30E-10	8.71E+05	6.13E+05	5.97E+06	1.23E+07	3.17E+01	8.02E-01		

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Tin (50)	Sn-121m	6.66E-12	9.99E-13	2.34E-12	3.41E-12	1.54E-11	8.85E-10	6.66E+01	4.14E+01	2.53E+02	5.52E+02	2.04E+01	5.17E-01		
Tin (50)	Sn-123	4.03E-11	5.70E-12	1.40E-11	2.05E-11	3.03E-11	3.88E-08	1.44E+02	1.34E+02	2.71E+02	6.07E+02	3.40E+00	8.60E-02		
Tin (50)	Sn-123m	1.94E-13	5.33E-14	7.96E-14	1.12E-13	5.62E-14	4.62E-07	6.58E+04	6.58E+04	1.07E+05	2.42E+05	5.98E+02	1.57E+01		
Tin (50)	Sn-125	5.81E-11	8.25E-12	2.01E-11	2.95E-11	1.41E-11	1.53E-06	5.70E+01	5.69E+01	9.36E+01	2.11E+02	2.37E+00	5.98E-02		
Tin (50)	Sn-126	7.07E-11	1.17E-11	2.56E-11	3.69E-11	9.95E-11	9.96E-08	1.00E+00	7.11E-01	2.16E+00	4.85E+00	1.86E+00	4.78E-02		
Tin (50)	Sn-127	2.22E-12	4.11E-13	8.25E-13	1.19E-12	4.40E-13	9.25E-06	1.05E+03	1.05E+03	1.71E+03	3.84E+03	5.77E+01	1.48E+00		
Tin (50)	Sn-128	1.09E-12	2.57E-13	4.33E-13	6.14E-13	2.29E-13	2.62E-06	7.87E+03	7.87E+03	1.28E+04	2.89E+04	1.10E+02	2.87E+00		
Titanium (22)	Ti-44	6.73E-11	1.34E-11	2.56E-11	3.64E-11	3.41E-10	2.39E-07	5.55E-01	4.46E-01	1.08E+00	2.44E+00	1.86E+00	4.85E-02		
Titanium (22)	Ti-45	1.75E-12	3.12E-13	6.44E-13	9.32E-13	3.09E-13	3.79E-06	1.74E+03	1.74E+03	2.84E+03	6.39E+03	7.39E+01	1.89E+00		
Tungsten (74)	W-176	1.05E-12	2.13E-13	4.11E-13	5.88E-13	1.24E-13	3.20E-07	2.76E+04	2.75E+04	4.50E+04	1.01E+05	1.16E+02	3.00E+00		
Tungsten (74)	W-177	5.00E-13	1.13E-13	2.01E-13	2.84E-13	5.99E-14	3.63E-06	2.49E+03	2.49E+03	4.06E+03	9.13E+03	2.37E+02	6.21E+00		
Tungsten (74)	W-178	3.33E-12	5.37E-13	1.21E-12	1.75E-12	3.85E-13	1.59E-08	2.29E+03	2.03E+03	3.99E+03	8.96E+03	3.94E+01	1.01E+00		
Tungsten (74)	W-179	1.68E-14	5.00E-15	7.22E-15	1.01E-14	1.83E-15	6.01E-08	5.41E+05	5.41E+05	8.83E+05	1.99E+06	6.60E+03	1.75E+02		
Tungsten (74)	W-181	1.07E-12	1.83E-13	3.96E-13	5.70E-13	1.35E-13	4.86E-08	1.43E+02	1.41E+02	2.35E+02	5.28E+02	1.20E+02	3.09E+00		
Tungsten (74)	W-185	8.36E-12	1.21E-12	2.93E-12	4.29E-12	9.36E-13	2.92E-10	3.54E+03	1.32E+03	4.17E+04	8.66E+04	1.63E+01	4.11E-01		
Tungsten (74)	W-187	1.03E-11	1.59E-12	3.67E-12	5.37E-12	1.11E-12	2.04E-06	4.16E+02	4.15E+02	6.80E+02	1.53E+03	1.30E+01	3.28E-01		
Tungsten (74)	W-188	4.00E-11	5.77E-12	1.40E-11	2.05E-11	4.63E-12	7.02E-09	5.85E+02	2.62E+02	2.58E+03	5.67E+03	3.40E+00	8.60E-02		
Uranium (92)	U-230	5.66E-10	1.04E-10	2.09E-10	2.98E-10	4.55E-08	3.07E-09	4.09E+02	2.91E-01	3.99E+03	7.52E+03	2.28E-01	5.92E-03	3.58E+12	1.79E+11
Uranium (92)	U-231	5.00E-12	7.40E-13	1.75E-12	2.56E-12	1.80E-12	1.60E-07	1.25E+03	1.48E+02	2.05E+03	4.62E+03	2.72E+01	6.89E-01	8.74E+13	4.37E+12
Uranium (92)	U-232	5.74E-10	2.45E-10	2.92E-10	3.85E-10	1.95E-08	5.98E-10	1.25E+00	5.59E-04	7.92E+00	1.43E+01	1.63E-01	4.58E-03	8.86E+06	4.43E+05
Uranium (92)	U-233	1.60E-10	5.22E-11	7.18E-11	9.69E-11	1.16E-08	9.82E-10	3.86E+00	1.84E-03	2.87E+01	5.34E+01	6.63E-01	1.82E-02	3.47E+03	1.74E+02
Uranium (92)	U-234	1.58E-10	5.11E-11	7.07E-11	9.55E-11	1.14E-08	2.52E-10	4.01E+00	1.87E-03	3.24E+01	5.92E+01	6.74E-01	1.85E-02	2.24E+03	1.12E+02
Uranium (92)	U-235	1.57E-10	4.92E-11	6.96E-11	9.44E-11	1.01E-08	5.18E-07	2.05E-01	1.87E-03	4.17E-01	9.35E-01	6.84E-01	1.87E-02	7.77E-01	3.89E-02
Uranium (92)	U-235+D	1.63E-10	5.03E-11	7.18E-11	9.76E-11	1.01E-08	5.43E-07	1.95E-01	1.81E-03	3.98E-01	8.92E-01	6.63E-01	1.81E-02	7.77E-01	3.89E-02
Uranium (92)	U-236	1.49E-10	4.85E-11	6.70E-11	9.03E-11	1.05E-08	1.25E-10	4.27E+00	1.98E-03	3.48E+01	6.33E+01	7.11E-01	1.95E-02	2.33E+01	1.16E+00
Uranium (92)	U-237	1.39E-11	2.05E-12	4.88E-12	7.14E-12	6.44E-12	3.76E-07	3.31E+02	3.37E+01	5.44E+02	1.22E+03	9.76E+00	2.47E-01	3.30E+13	1.65E+12
Uranium (92)	U-238	1.43E-10	4.66E-11	6.40E-11	8.66E-11	9.32E-09	4.99E-11	4.46E+00	2.06E-03	3.68E+01	6.67E+01	7.44E-01	2.04E-02	1.21E-01	6.04E-03
Uranium (92)	U-238+D	2.10E-10	5.62E-11	8.71E-11	1.21E-10	9.35E-09	1.14E-07	7.42E-01	1.47E-03	1.80E+00	4.00E+00	5.47E-01	1.46E-02	1.21E-01	6.04E-03
Uranium (92)	U-239	1.90E-13	4.40E-14	7.40E-14	1.06E-13	5.70E-14	1.21E-07	4.29E+05	3.04E+05	7.00E+05	1.57E+06	6.44E+02	1.66E+01	5.59E+18	2.80E+17
Uranium (92)	U-240	2.02E-11	2.96E-12	7.03E-12	1.03E-11	2.96E-12	7.33E-10	3.48E+05	2.98E+02	2.14E+06	4.45E+06	6.77E+00	1.71E-01	4.30E+15	2.15E+14
Vanadium (23)	V-47	2.92E-13	8.88E-14	1.25E-13	1.74E-13	5.96E-14	4.36E-06	8.58E+03	8.58E+03	1.40E+04	3.15E+04	3.81E+02	1.01E+01		
Vanadium (23)	V-48	2.13E-11	4.11E-12	8.21E-12	1.17E-11	9.29E-12	1.40E-05	3.73E+00	3.73E+00	6.09E+00	1.37E+01	5.80E+00	1.51E-01		
Vanadium (23)	V-49	3.53E-13	5.00E-14	1.22E-13	1.79E-13	1.47E-13	0.00E+00	5.17E+04	5.39E+04	6.81E+05	1.23E+06	3.90E+02	9.85E+00		
Xenon (54)	Xe-120						1.70E-06	1.79E+04	1.79E+04	2.93E+04	6.58E+04				
Xenon (54)	Xe-121						8.73E-06	3.48E+03	3.48E+03	5.68E+03	1.28E+04				
Xenon (54)	Xe-122						1.83E-07	5.52E+03	5.52E+03	9.01E+03	2.03E+04				
Xenon (54)	Xe-123						2.72E-06	3.59E+03	3.59E+03	5.86E+03	1.32E+04				
Xenon (54)	Xe-125						9.38E-07	1.27E+03	1.27E+03	2.08E+03	4.68E+03				
Xenon (54)	Xe-127						9.52E-07	2.44E+01	2.44E+01	3.99E+01	8.97E+01				
Xenon (54)	Xe-129m						4.25E-08	2.49E+03	2.49E+03	4.06E+03	9.14E+03				
Xenon (54)	Xe-131m						1.41E-08	5.05E+03	5.05E+03	8.23E+03	1.85E+04				
Xenon (54)	Xe-133						6.62E-08	2.44E+03	2.44E+03	3.98E+03	8.94E+03				
Xenon (54)	Xe-133m						9.25E-08	4.18E+03	4.18E+03	6.82E+03	1.53E+04				
Xenon (54)	Xe-135						9.70E-07	2.30E+03	2.30E+03	3.76E+03	8.46E+03				
Xenon (54)	Xe-135m						1.86E-06	4.28E+04	4.28E+04	6.99E+04	1.57E+05				
Xenon (54)	Xe-138						5.62E-06	1.53E+04	1.53E+04	2.49E+04	5.61E+04				
Ytterbium (70)	Yb-162	1.21E-13	3.62E-14	5.22E-14	7.29E-14	3.00E-14	3.26E-07	1.98E+05	1.98E+05	3.23E+05	7.27E+05	9.12E+02	2.42E+01		
Ytterbium (70)	Yb-166	1.17E-11	2.08E-12	4.37E-12	6.29E-12	2.89E-12	9.46E-08	3.72E+03	3.73E+03	6.17E+03	1.39E+04	1.09E+01	2.80E-01		
Ytterbium (70)	Yb-167	3.70E-14	1.04E-14	1.56E-14	2.18E-14	1.71E-14	6.21E-07	1.12E+05	1.12E+05	1.83E+05	4.12E+05	3.05E+03	8.09E+01		
Ytterbium (70)	Yb-169	1.12E-11	1.73E-12	4.00E-12	5.85E-12	1.08E-11	7.75E-07	3.41E+01	3.41E+01	5.57E+01	1.25E+02	1.19E+01	3.01E-01		
Ytterbium (70)	Yb-175	8.29E-12	1.17E-12	2.87E-12	4.22E-12	2.95E-12	1.54E-07	1.30E+03	1.30E+03	2.14E+03	4.81E+03	1.66E+01	4.18E-01		

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor-Adult (risk/pCi)	Water Ingestion Slope Factor (risk/pCi)	Food Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/y per pCi/g)	PRG: Residential Soil (pCi/g)	Agricultural Soil (pCi/g)	Outdoor Worker Soil (pCi/g)	Indoor Worker Soil (pCi/g)	Tap Water (pCi/L)	Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	DAF=1 (pCi/g)
Ytterbium (70)	Yb-177	9.51E-13	1.69E-13	3.46E-13	5.03E-13	2.29E-13	8.35E-07	1.28E+04	1.28E+04	2.09E+04	4.70E+04	1.38E+02	3.51E+00		
Ytterbium (70)	Yb-178	1.06E-12	1.92E-13	3.89E-13	5.59E-13	2.38E-13	1.44E-07	1.14E+05	1.14E+05	1.87E+05	4.20E+05	1.22E+02	3.16E+00		
Yttrium (39)	Y-86	1.05E-11	2.03E-12	4.07E-12	5.81E-12	1.58E-12	1.73E-05	7.99E+01	7.99E+01	1.30E+02	2.93E+02	1.17E+01	3.04E-01		
Yttrium (39)	Y-86m	6.11E-13	1.18E-13	2.35E-13	3.35E-13	9.29E-14	8.35E-07	3.04E+04	3.04E+04	4.96E+04	1.12E+05	2.03E+02	5.26E+00		
Yttrium (39)	Y-87	6.92E-12	1.21E-12	2.58E-12	3.70E-12	1.49E-12	1.94E-06	1.30E+02	1.30E+02	2.13E+02	4.79E+02	1.85E+01	4.77E-01		
Yttrium (39)	Y-88	9.92E-12	2.40E-12	4.18E-12	5.85E-12	1.70E-11	1.37E-05	5.77E-01	5.77E-01	9.42E-01	2.12E+00	1.14E+01	3.01E-01		
Yttrium (39)	Y-90	5.25E-11	7.29E-12	1.81E-11	2.65E-11	8.40E-12	1.91E-08	1.14E+04	9.63E+03	2.59E+04	5.77E+04	2.63E+00	6.66E-02		
Yttrium (39)	Y-90m	2.95E-12	4.40E-13	1.04E-12	1.51E-12	4.81E-13	2.58E-06	2.47E+03	2.47E+03	4.03E+03	9.06E+03	4.58E+01	1.17E+00		
Yttrium (39)	Y-91	4.66E-11	6.48E-12	1.60E-11	2.35E-11	3.36E-11	2.51E-08	4.39E+02	3.87E+02	9.12E+02	2.04E+03	2.98E+00	7.50E-02		
Yttrium (39)	Y-91m	8.51E-14	2.15E-14	3.52E-14	4.96E-14	3.01E-14	2.34E-06	1.05E+04	1.05E+04	1.71E+04	3.85E+04	1.35E+03	3.56E+01		
Yttrium (39)	Y-92	7.03E-12	1.10E-12	2.48E-12	3.61E-12	9.32E-13	1.26E-06	4.55E+03	4.55E+03	7.43E+03	1.67E+04	1.92E+01	4.89E-01		
Yttrium (39)	Y-93	2.08E-11	2.96E-12	7.18E-12	1.05E-11	2.64E-12	4.60E-07	4.34E+03	4.32E+03	7.13E+03	1.60E+04	6.63E+00	1.68E-01		
Yttrium (39)	Y-94	3.08E-13	1.06E-13	1.37E-13	1.90E-13	5.51E-14	5.45E-06	1.17E+04	1.17E+04	1.91E+04	4.30E+04	3.48E+02	9.28E+00		
Yttrium (39)	Y-95	1.59E-13	5.85E-14	7.25E-14	9.99E-14	2.92E-14	4.80E-06	2.37E+04	2.37E+04	3.87E+04	8.72E+04	6.57E+02	1.77E+01		
Zinc (30)	Zn-62	1.34E-11	2.25E-12	4.96E-12	7.25E-12	2.65E-12	1.87E-06	1.13E+03	4.04E+00	1.91E+03	4.31E+03	9.60E+00	2.43E-01	2.23E+07	1.11E+06
Zinc (30)	Zn-63	3.77E-13	1.13E-13	1.61E-13	2.26E-13	7.55E-14	4.87E-06	6.57E+03	1.47E+03	1.07E+04	2.41E+04	2.96E+02	7.80E+00	1.46E+11	7.30E+09
Zinc (30)	Zn-65	2.45E-11	8.95E-12	1.17E-11	1.54E-11	5.81E-12	2.81E-06	1.18E+00	3.01E-03	2.01E+00	4.53E+00	4.07E+00	1.15E-01	5.60E+01	2.80E+00
Zinc (30)	Zn-69	1.79E-13	4.51E-14	7.22E-14	1.03E-13	6.11E-14	1.67E-09	8.19E+06	2.78E+03	2.08E+07	4.68E+07	6.60E+02	1.71E+01	1.45E+11	7.27E+09
Zinc (30)	Zn-69m	5.07E-12	8.33E-13	1.86E-12	2.73E-12	1.28E-12	1.77E-06	8.20E+02	7.15E+00	1.36E+03	3.05E+03	2.56E+01	6.46E-01	2.68E+07	1.34E+06
Zinc (30)	Zn-71m	2.50E-12	4.92E-13	9.66E-13	1.39E-12	5.33E-13	6.84E-06	7.56E+02	4.68E+01	1.24E+03	2.78E+03	4.93E+01	1.27E+00	6.38E+08	3.19E+07
Zinc (30)	Zn-72	1.71E-11	3.34E-12	6.59E-12	9.44E-12	5.48E-12	4.68E-07	7.88E+02	6.19E-01	1.52E+03	3.42E+03	7.23E+00	1.87E-01	6.65E+05	3.33E+04
Zirconium (40)	Zr-86	1.02E-11	1.86E-12	3.85E-12	5.55E-12	1.56E-12	1.04E-06	1.18E+03	1.18E+03	1.93E+03	4.35E+03	1.24E+01	3.18E-01		
Zirconium (40)	Zr-88	3.74E-12	9.36E-13	1.58E-12	2.18E-12	8.95E-12	1.65E-06	6.15E+00	6.15E+00	1.00E+01	2.26E+01	3.01E+01	8.09E-01		
Zirconium (40)	Zr-89	9.58E-12	1.72E-12	3.60E-12	5.18E-12	1.92E-12	5.38E-06	4.82E+01	4.82E+01	7.86E+01	1.77E+02	1.32E+01	3.40E-01		
Zirconium (40)	Zr-93	2.12E-12	9.81E-13	1.11E-12	1.44E-12	7.29E-12	0.00E+00	3.38E+02	2.00E+02	1.81E+03	3.26E+03	4.29E+01	1.22E+00		
Zirconium (40)	Zr-95	1.23E-11	2.16E-12	4.59E-12	6.59E-12	1.65E-11	3.40E-06	3.89E+00	3.89E+00	6.35E+00	1.43E+01	1.04E+01	2.68E-01		