Technical Feasibility of Detecting Radionuclide Contamination in Soil at a 10^{-6} Risk Level for Agricultural Land Use

In general, it is technically infeasible to distinguish radionuclide contamination in soil at a 1-in-a-million risk level above background for agricultural (rural residential) land use, because these levels (1) are usually less than the minimum detectable concentration (MDC) of laboratory soil analysis techniques, (2) are always less than the detection limits of field instrumentation, and (3) are frequently less than the variability of natural background soil radionuclide concentrations.

EPA Technical Support Document for the Development of Radionuclide Cleanup Levels for Soil

Technical feasibility is discussed in detail in EPA 402-R-96-011-A, “Radiation Site Cleanup Regulations – Technical Support Document for the Development of Radionuclide Cleanup Levels for Soil” (http://www.epa.gov/rpdweb00/docs/cleanup/402-r-96-011a.htm), Chapter 7.2 “Technical Feasibility Issues Associated with Implementation”, pages 7-14 through 7-41, Tables 7-4 through 7-10 and Table O-6.

EPA Document 402-R-96-011-A compares the soil concentrations to both laboratory detection capabilities, field survey detection capabilities and typical range of background and makes the following conclusions about the feasibility of using cleanup standards at the 10^{-4}, 3×10^{-4} and 15 mrem/y levels. The following are direct quotes from this EPA document.

- "An important consideration in the development of soil cleanup levels is the feasibility of implementing the cleanup criteria in actual practice in the field. If the cleanup levels are set below the lower limits of detection for laboratory and field measurement techniques, or if the background radiation or radioactivity levels are highly variable and comparable to the cleanup levels. It will be very difficult to implement and enforce the regulations based on those cleanup criteria." Section 7.2, page 7-14.

  "At the target risk level of 10^{-4}, no radionuclides can be detected using field measurements for the rural residential exposure scenario." Section 7.2.1.4. page 7-37. (*Comment: Obviously, at a target risk level of 10^{-6}, no radionuclides would be detectable above their respective background concentrations.*)

- "It is important to emphasize that in some situations, it is the spatial variability in the levels of naturally occurring or anthropogenic background radioactivity, rather than the minimum detectable concentration, that limits the technical feasibility of using field or laboratory techniques to assess contaminant concentrations at a site." Section 7.2.1.4. Page 7-39.

- "At a target risk level of 10^{-4}, all radionuclides may by detectable above their respective background concentrations [using soil analysis] for the rural residential exposure scenario, except C-14, Cs-137, K-40, Pa-231, Pb-210, Ra-226, Ra-228, Sr-90, Th-228, Th-230, Th-232, U-234, and U-238." Section 7.2.2.3. Page 7-42. (*Comment: Obviously, at a target risk level of 10^{-6}, few radionuclides would be detectable above their respective*

background concentrations.)

In summary, the EPA Document 402-R-96-011-A,

- Does not support the use of 10^{-6} risk levels
- Presents soil concentration data at 10^{-4}, 3 x 10^{-4} and 15 mrem/y levels
- Provides data to prove that cleanup to even 10^{-4} levels may be not always be feasible because of detectability and background variability issues
- Demonstrates that cleanup to 10^{-6} is technically unfeasible

More recently, EPA confirmed this belief. Paul A.Giardina, Branch Chief of EPA, Region 2, stated,

> "Cleanup of radiation sites under the authority of the EPA should meet the CERCLA risk range of 10^{-4} to 10^{-6}. If the residual risk from contaminants on the site is within this risk range, the remedial action is considered protective of human health. Since radionuclides are present in the natural environment, achievable radiation risk is closer to the upper end of the risk range (10^{-4}), rather than one-in-a-million risk (10^{-6})." (Summary of discussion and agreement from telephone conference, between EPA and NRC, held October 13, 2000, concerning cleanup standards for the West Valley Demonstration Project)

EPA Preliminary Remediation Goals

In February 2002, EPA published preliminary remediation goals for agricultural soil (rural residential) based on a 10^{-6} risk level (OSWER 9355.01-83A. "Distribution of OSWER Radionuclide Preliminary Remediation Goals (PRGs) Superfund Electronic Calculator." February 7, 2002. http://epa-prgs.ornl.gov/radionuclides). Using these PRGs, a comparison of detectability and distinguishability from background has been made using the same technical feasibility criteria employed in EPA 402-R-96-011-A. Table 1 demonstrates the following conclusions for an agricultural (rural residential) land use scenario.

- At the 10^{-6} PRG risk level for agricultural land use, no radionuclides can be detected by field instrument surveys.
- At the 10^{-6} PRG risk level for agricultural land use, the following radionuclides cannot be detected by laboratory analysis – Co-60, Cs-137, Fe-55, K-40, Ni-63, Pu-238, Pu-239, Pu-240, Pu-242, Ra-226, Sr-90, Th-228, Th-232, U-234, U-235 and U-238.
- At the 10^{-6} PRG risk level for agricultural land use, the following radionuclides cannot be distinguished from background variability by laboratory analysis – Am-241, Co-60, Cs-137, Fe-55, H-3, K-40, Ni-59, Ni-63, Pu-239, Pu-240, Pu-242, Ra-226, Sr-90, Th-228, Th-232, U-234, U-235 and U-238.

In conclusion, it is technically infeasible to distinguish radionuclide contamination in soil at a 1-in-a-million risk level above background for an agricultural (rural residential) land use scenario

for most radionuclides. These PRGs are, in general, less than laboratory soil detection limits and less than background soil variability.

Table 2 shows the same feasibility analysis for a residential (suburban residential) land use scenario. In general, no field instrumentation is capable of detecting any radionuclide at 10^{-6} PRG risk levels for residential land use. However many more radionuclides are detectable by soil laboratory analysis and are distinguishable from background.

There are some notable exceptions. Cesium-137 and strontium-90 are primary fission product contaminants of concern at SSFL.

According to the EPA data, although the cesium-137 residential soil 10^{-6} PRG risk level of 0.0597 pCi/g can be detected by laboratory analysis, the agricultural soil 10^{-6} PRG risk level of 0.0012 pCi/g cannot be detected by laboratory analysis. Furthermore, both the agricultural and residential soil 10^{-6} PRG risk level is not distinguishable from background or background variability.

According to the EPA data for strontium-90, neither the agricultural or residential soil 10^{-6} PRG risk levels can be detected by laboratory analysis or can be distinguished from background or background variability.

Impact on MARSSIM Survey Design

MARSSIM survey protocols require both soil sample analysis and field instrument scanning to be capable of detecting all contaminants of concern at or below the DCGL (derived concentration guideline level). This is not possible for the radionuclide 10^{-6} PRGs identified in the tables as "**No**."

DCGLs based on a dose limit of 15 mrem/y or a risk limit of 10^{-4} were, in general, sufficiently higher than background that the "sign test" could be used to determine if cleanup goals had been met. This eliminated the need for an approved reference background data set. When DCGLs become smaller than background levels, then MARSSIM protocols default to proving that a remediated site is "indistinguishable from background." This is the situation with most agricultural 10^{-6} PRGs and some residential 10^{-6} PRGs. This therefore requires an approved reference background data set, together with a significantly increased number of samples in order to prove indistinguishability from background.

Acceptance of an agricultural land use scenario using 10^{-6} PRGs, is equivalent to accepting a mandate of "cleanup to background."

How clean is clean? Background is clean.

Instead of using a technically defensible, safe and protective, health-based cleanup standard, we will debate forevermore what is, and what is not, background.

Table 1. Technical Feasibility of Detecting Radionuclide Contamination in Soil

Exposure Scenario: Agricultural Soil (30 years) **Excess Cancer Incidence Risk Goal:** 1.0E-06

Radio-nuclide	Soil Conc. Goal for EPA Risk Goal[1] (pCi/g)	Minimum Detectable Concentration (MDC)[2]		Background[3]		Detectable by Field Instrument Surveys?[4]	Detectable by Soil Analysis?[5]	Detectable above Background by Soil Analysis?[6]
		Laboratory Analysis	Field Surveys	Average	Range			
		pCi/g	pCi/g	pCi/g	pCi/g			
Am-241	0.0132	0.01	NR	0.009	0.003 - 0.015	No	Yes	No
Co-60	0.000901	0.01	4	0	NA - NA	No	No	No
Cs-134	0.00747	0.007	8	0	NA - NA	No	Yes	Yes
Cs-137	0.0012	0.01	17	0.7	0.1 - 3.5	No	No	No
Eu-152	0.0376	0.02	9	0	NA - NA	No	Yes	Yes
Eu-154	0.0472	0.007	8	0	NA - NA	No	Yes	Yes
Fe-55	0.821	1	NR	0	NA - NA	No	No	No
H-3	0.160	0.02	NR	7	0.8 - 20	No	Yes	No
K-40	0.0445	0.1	72	10	3 - 20	No	No	No
Mn-54	0.369	0.05	5	0	NA - NA	No	Yes	Yes
Na-22	0.0852	0.02	5	0	NA - NA	No	Yes	Yes
Ni-59	2.15	1	NR	0.25	0.01 - 2.5	No	Yes	No
Ni-63	1.01	2	NR	0	NA - NA	No	No	No
Pu-238	0.00731	0.03	NR	0.001	0.0005 - 0.002	No	No	Yes
Pu-239	0.00609	0.03	NR	0.025	0.009 - 0.04	No	No	No
Pu-240	0.0061	0.03	NR	0.025	0.009 - 0.04	No	No	No
Pu-241	1.05	1	NR	0	NA - NA	No	Yes	Yes
Pu-242	0.00642	0.03	NR	0	NA - NA	No	No	No
Ra-226	0.000676	0.15	5	1	0.23 - 4.2	No	No	No
Sr-90	0.00139	1	NR	0.7	0.2 - 4	No	No	No
Th-228	0.0338	0.05	6	0.87	0.1 - 3.4	No	No	No
Th-232	0.00942	0.05	NR	0.87	0.1 - 3.4	No	No	No
U-234	0.00187	0.03	NR	0.96	0.12 - 3.8	No	No	No
U-235	0.00181	0.03	95	0.007	0.001 - 0.03	No	No	No
U-238	0.00147	0.03	670	0.96	0.12 - 3.8	No	No	No

1 Based on EPA preliminary remediation guides (PRGs) for **agricultural soil** at a 10^{-6} risk level. OSWER 9355.01-83A. "Distribution of OSWER Radionuclide Preliminary Remediation Goals (PRGs) Superfund Electronic Calculator." February 7, 2002. http://epa-prgs.ornl.gov/radionuclides. Data retrieved October 26, 2006.

2 Minimum Detectable Concentrations (MDC) for lab and field survey techniques taken from EPA 402-R-96-011-A, "EPA Radiation Site Cleanup Regulations - Technical Support Document for the Development of Radionuclide Cleanup Levels for Soil", Review Draft, September 1994. http://www.epa.gov/rpdweb00/docs/cleanup/402-r-96-011a.htm.

3 Typical US background average and range for radioisotopes taken from EPA 402-R-96-011-A and NCRP 94, "Exposure of the Population in the United States and Canada to Natural Background Radiation", National Council on Radiation Protection and Measurements, 1987.

4 If goal is less than field survey MDC, then goal is not detectable (Based on EPA 402-R-96-011-A criterion).

5 If goal is less than lab soil analysis MDC, then goal is not detectable (Based on EPA 402-R-96-011-A criterion).

6 If naturally present in soil, and goal is less than than the 2σ variability, then goal is not distinguishable from background. If not naturally present in soil, and the goal is less than the lab soil analysis MDC, then goal is not distinguishable from background. (Based on EPA 402-R-96-011-A criterion, page 7-41).

NR = No response expected from selected detector because of absent, low abundance, or low energy gamma emissions.

NA = Not available.

Table 2. Technical Feasibility of Detecting Radionuclide Contamination in Soil

Exposure Scenario: Residential Soil (30 years) **Excess Cancer Incidence Risk:** 1.0E-06

Radio-nuclide	Soil Conc. Goal for EPA Risk Goal[1] (pCi/g)	Minimum Detectable Concentration (MDC)[2]		Background[3]		Detectable by Field Instrument Surveys?[4]	Detectable by Soil Analysis?[5]	Detectable above Background by Soil Analysis?[6]
		Laboratory Analysis	Field Surveys	Average	Range			
		pCi/g	pCi/g	pCi/g	pCi/g			
Am-241	1.87	0.01	NR	0.009	0.003 - 0.015	No	Yes	Yes
Co-60	0.0361	0.01	4	0	NA - NA	No	Yes	Yes
Cs-134	0.157	0.007	8	0	NA - NA	No	Yes	Yes
Cs-137	0.0597	0.01	17	0.7	0.1 - 3.5	No	Yes	No
Eu-152	0.0416	0.02	9	0	NA - NA	No	Yes	Yes
Eu-154	0.0499	0.007	8	0	NA - NA	No	Yes	Yes
Fe-55	2690	1	NR	0	NA - NA	No	Yes	Yes
H-3	2.28	0.02	NR	7	0.8 - 20	No	Yes	No
K-40	0.108	0.1	72	10	3 - 20	No	Yes	No
Mn-54	0.692	0.05	5	0	NA - NA	No	Yes	Yes
Na-22	0.0865	0.02	5	0	NA - NA	No	Yes	Yes
Ni-59	208	1	NR	0.25	0.01 - 2.5	No	Yes	Yes
Ni-63	94.8	2	NR	0	NA - NA	No	Yes	Yes
Pu-238	2.97	0.03	NR	0.001	0.0005 - 0.002	No	Yes	Yes
Pu-239	2.59	0.03	NR	0.025	0.009 - 0.04	No	Yes	Yes
Pu-240	2.60	0.03	NR	0.025	0.009 - 0.04	No	Yes	Yes
Pu-241	406	1	NR	0	NA - NA	No	Yes	Yes
Pu-242	2.73	0.03	NR	0	NA - NA	No	Yes	Yes
Ra-226	0.193	0.15	5	1	0.23 - 4.2	No	Yes	No
Sr-90	0.231	1	NR	0.7	0.2 - 4	No	No	No
Th-228	0.154	0.05	6	0.87	0.1 - 3.4	No	Yes	No
Th-232	3.10	0.05	NR	0.87	0.1 - 3.4	No	Yes	No
U-234	4.01	0.03	NR	0.96	0.12 - 3.8	No	Yes	Yes
U-235	0.195	0.03	95	0.007	0.001 - 0.03	No	Yes	Yes
U-238	0.742	0.03	670	0.96	0.12 - 3.8	No	Yes	No

1 Based on EPA preliminary remediation guides (PRGs) for **residential soil** at a 10^{-6} risk level. OSWER 9355.01-83A. "Distribution of OSWER Radionuclide Preliminary Remediation Goals (PRGs) Superfund Electronic Calculator." February 7, 2002. http://epa-prgs.ornl.gov/radionuclides. Data retrieved October 26, 2006.

2 Minimum Detectable Concentrations (MDC) for lab and field survey techniques taken from EPA 402-R-96-011-A, "EPA Radiation Site Cleanup Regulations - Technical Support Document for the Development of Radionuclide Cleanup Levels for Soil", Review Draft, September 1994. http://www.epa.gov/rpdweb00/docs/cleanup/402-r-96-011a.htm.

3 Typical US background average and range for radioisotopes taken from EPA 402-R-96-011-A and NCRP 94, "Exposure of the Population in the United States and Canada to Natural Background Radiation", National Council on Radiation Protection and Measurements, 1987.

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5 If goal is less than lab soil analysis MDC, then goal is not detectable (Based on EPA 402-R-96-011-A criterion).

6 If naturally present in soil, and goal is less than than the 2σ variability, then goal is not distinguishable from background. If not naturally present in soil, and the goal is less than the lab soil analysis MDC, then goal is not distinguishable from background. (Based on EPA 402-R-96-011-A criterion, page 7-41).

NR = No response expected from selected detector because of absent, low abundance, or low energy gamma emissions.

NA = Not available.