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Guidelines for Posting Soil Contamination Areas

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Introduction

The soil contamination guidelines in this document should be used for posting soil contamination areas as required by LANL LIR402-700-01 Section 727 (Reference 1). Further guidance is in References 2 through 5: DOE Order 5400.5, Chapter IV, Section 4; DOE/CH/8901; ANL/EAD/LD-2; and ANL/EAD-4.

All guidelines were determined using RESRAD, version 6.1. All offsite guidelines are based on 15 mrem/year. This dose rate is sufficiently low to protect human health and is in accordance with DOE guidance and the proposed EPA 40-CFR-196 regulations for members of the public (never promulgated).

For those onsite areas where general employees (non-radiological workers) could have routine access, soil concentrations should be based on a dose rate of 30 mrem/year (approximately one-third of the onsite LANL non-radiological worker dose of 100 mrem/year). In this case, soil concentration guidelines may be obtained by doubling the 15 mrem/year guidelines.

Several scenarios were developed to provide maximum flexibility for application of the guidelines. The offsite guidelines were developed using: residential scenarios for both adults and children; a construction worker scenario; a resource user (e.g., a hunter) scenario; a child playing within canyon reaches scenario, a trail using jogger within canyon reaches scenario, and a trail using hiker within canyon reaches scenario. The residential guidelines represent the lowest values from both the adult residential scenario and the child residential scenario.

The Recreational-user guidelines represent the lowest values from the child-playing-within-canyon-reaches scenario, the trail-using-jogger-within-canyon-reaches scenario, and the trail-using-hiker-within-canyon-reaches scenario. These three scenarios use "reasonable maximum exposure" parameters whereas the other scenarios use "most likely exposure" parameters, i.e., those parameters that represent central values for that particular parameter. The Recreational-user canyon-bottom scenarios and parameters were obtained from the Canyon-Bottom scenarios in Reference 6. All other scenarios were developed using scenarios and input parameters from reference 7. A summary of all scenario input parameters is found in Attachment B.

Procedure

1. Determine whether the area under consideration for posting is on Laboratory property or off Laboratory property. Any Laboratory rental property within the townsite is considered offsite. If the area is offsite, use Attachment A guidelines (which are based on 15 mrem/year) or develop and document an alternative scenario. If the area is onsite and is not posted as a radiological area, adjust the guidelines or alternative scenario for 30 mrem/year. Use the following table to further refine the choice of appropriate guidelines.

If the area under consideration is:	Then use:
Offsite and on residential or commercial property	Residential guidelines (Attachment A)
Offsite and slated for construction activities (e.g., digging or trenching with heavy equipment or shovels – anything that disturbs the soil)	Construction Worker guidelines (Attachment A)
Offsite and amenable to hunting or gathering native fruits and vegetables	Resource User guidelines (Attachment A)
Offsite and within a canyon bottom	Canyon Bottom (Recreational user) guidelines (Attachment A)
Onsite and routinely accessible by general employees who are not radiological workers	Multiply the Attachment-A guidelines by 2 to adjust to 30 mrem/year.

2. The guidelines are soil contamination concentrations above background. Background values should be determined, as appropriate, using the Environmental Restoration Project Standard Operating Procedure for "Performing Background Value Comparisons for Radionuclides," ER-SOP-15.13, http://erproject.lanl.gov/Common/Procedures/SOPs/ER-SOP-15.13-R0.pdf and subtract the appropriate background value.

3. Compare the background-corrected soil contamination concentrations in the sample(s) to the guidelines for the selected scenario. If the average (averaged over 100 m^2 in the horizontal plane and within a 0.15 m depth in the vertical plane) of the background-corrected soil contamination concentration from one or more samples is greater than or equal to the soil contamination guideline for that radionuclide, then the area must be posted as a soil contamination area in accordance with Chapter 7 and Article 727 in LIR402-700-01, "Occupational Radiation Protection Requirements, " and ESH-1-01-13, "Radiological Posting."

4. If there is more than one radionuclide present in the soil sample(s), then the sum of the fractions rule must be applied. That is, the average background-corrected soil contamination concentration in pCi/g must be divided by the soil contamination guideline for that radionuclide and summed over all radionuclides in the sample(s). If the sum equals or exceeds unity (1.0) then the area must be posted as a soil contamination area.

> **Caution:** The soil contamination guidelines are high enough in some cases to evoke the requirements in Article 727 of LIR402-700-01 for posting as a Contamination Area. That is, if the soil contamination concentrations are high enough to track out contamination exceeding the concentrations in Table 14-1 of the LIR then the area must be posted as a Contamination Area or High Contamination area as appropriate.

5. In some cases, soil contamination hot spots may be encountered. If the average of hot spot concentrations in any surface or below-surface area less than or equal to 25 m^2 exceeds the guideline by a factor of $(100/A)^{0.5}$ where A is the area (in square meters) of the region in which concentrations are elevated, the area must be posted as a soil contamination area. The table below may be used as an approximation. For those areas greater than 25 m^2, the guideline is considered sufficient for making the posting determination and no special hot spot limits are needed when hot spot concentrations are averaged over this greater than 25 m^2 area. In addition, reasonable efforts shall be made to remove any source of radionuclide that exceeds 30 times the appropriate guideline, irrespective of the average concentration in the soil.

Hot Spot Area Range	**Factor (multiple of authorized limit)**
<0.1 m^2	30[a]
0.1 - 1 m^2	10
1 - <3 m^2	6
3 - <10 m^2	3
10 – 25 m^2	2

[a] Areas less than 0.1 m^2 are to be averaged over a 0.1 m^2 area, and that average shall not exceed 30 times the guideline.

6. There are generic guidelines for Ra-226, Ra-228, Th-230, and Th-232. The guidelines for these radionuclides are 5 pCi/g, averaged over the first 15 cm of soil below the surface. The guidelines for these radionuclides 15-cm below the surface are 15 pCi/g averaged over 15-cm thick layers of soil.

   Note. These guidelines take into account ingrowth of Ra-226 from Th-230 and of Ra-228 from Th-232, and assume secular equilibrium. If both Th-230 and Ra-226 or both Th-232 and Ra-228 are present and not in secular equilibrium, the appropriate guideline is applied as a limit for the radionuclide with the higher concentration. If other mixtures of radionuclides occur, the sum of the fractions rule shall be applied as specified in step 4 above.

References:

1. LIR402-700-01, “Occupational Radiation Protection Requirements,” (most recent version)
2. DOE Order 5400.5, “Radiation Protection of the Public and the Environment.”
3. ANL/ES-160, DOE/CH/8901, “A Manual for Implementing Residual Radioactive Material Guidelines,” June 1989
4. ANL/EAD/LD-2, “A Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD,” September 1993
5. ANL/EAD-4, User’s Manual for RESRAD”, July 2001
6. LA-UR-00-1903, Interim Report on Sediment Contamination in the South Fork of Acid Canyon, Steven L. Reneau et al., April 27, 2000

7. LA-UR-00-4084, Standard Human Health Risk Assessment Scenarios, R. Mirenda, L. Soholt, September 1, 2000
8. Environmental Restoration Project Standard Operating Procedure for "Performing Background Value Comparisons for radionuclides," ER-SOP-15.13, http://erproject.lanl.gov/Common/Procedures/SOPs/ER-SOP-15.13-R0.pdf
9. ESH-1-01-13, "Radiological Posting." (most recent version)

Attachments:

Attachment A, Soil Contamination Guidelines for Posting Areas Offsite

Attachment B, Scenario-Specific Parameters

Attachment A: soil contamination guidelines for 15 mrem/year

Nuclide	Residential pCi/g	Construction Worker pCi/g	Resource User pCi/g	Canyon Bottom User pCi/g
Ac-227	4.200E+00	3.497E+00	7.197E+00	5.046E+01
Ag-108m	3.030E+00	2.023E+01	4.773E+01	7.294E+01
Ag-110m	2.698E+00	1.797E+01	4.435E+01	6.479E+01
Al-26	1.691E+00	1.115E+01	3.321E+01	4.019E+01
Am-241	4.364E+00	3.790E+01	6.855E+01	2.678E+02
Am-243	1.912E+01	3.258E+01	6.233E+01	2.015E+02
Au-195	2.421E+02	1.682E+03	2.264E+03	6.063E+03
Ba-133	1.525E+01	1.006E+02	2.967E+02	3.625E+02
Bi-207	3.151E+00	2.090E+01	5.555E+01	7.535E+01
C-14	3.624E+01	3.491E+05	2.610E+01	1.150E+06
Ca-41	4.051E+02	2.699E+05	4.242E+02	8.271E+05
Cd-109	8.217E+01	1.083E+04	9.311E+01	3.798E+04
Ce-144	1.357E+02	8.720E+02	2.131E+03	3.145E+03
Cf-252	1.782E+02	1.313E+02	2.625E+02	1.032E+03
Cl-36	4.247E+00	4.594E+04	1.369E+00	1.588E+05
Cm-243	2.907E+01	4.793E+01	9.254E+01	2.998E+02
Cm-244	8.576E+01	6.990E+01	1.276E+02	4.999E+02
Cm-245 (1000 years)	2.051E+01	2.141E+01	3.926E+01	1.469E+02
Cm-246	4.596E+01	3.760E+01	6.837E+01	2.679E+02
Cm-247 (1000 years)	1.132E+01	2.931E+01	5.499E+01	1.522E+02
Cm-248	1.251E+01	1.026E+01	1.860E+01	7.291E+01
Co-57	8.701E+01	5.850E+02	1.027E+03	2.109E+03
Co-60	1.908E+00	1.276E+01	2.537E+01	4.601E+01
Cs-134	3.549E+00	2.414E+01	2.851E+01	8.694E+01
Cs-135	9.022E+02	4.825E+04	4.130E+02	1.474E+05
Cs-137	8.214E+00	5.735E+01	4.407E+01	2.065E+02
Eu-152	4.312E+00	2.842E+01	8.477E+01	1.025E+02
Eu-154	3.978E+00	2.622E+01	7.805E+01	9.453E+01
Eu-155	1.684E+02	1.107E+03	3.160E+03	3.992E+03
Fe-55	3.241E+05	6.150E+05	6.731E+04	1.959E+06
Gd-153	1.875E+02	1.235E+03	3.599E+03	4.450E+03
Ge-68	7.814E+00	5.210E+01	5.372E+01	1.878E+02
H-3	1.124E+03	4.224E+05	7.451E+02	1.567E+06
I-129	4.497E+01	1.148E+03	3.716E+01	3.545E+03
K-40	1.752E+01	1.846E+02	2.664E+01	6.644E+02
Mn-54	8.183E+00	5.495E+01	1.236E+02	1.981E+02
Na-22	2.447E+00	1.620E+01	3.456E+01	5.841E+01
Nb-93m	4.162E+04	3.308E+05	5.533E+04	1.537E+06
Nb-94	3.054E+00	2.014E+01	5.953E+01	7.260E+01
Ni-59	2.436E+04	1.428E+06	2.211E+04	4.973E+06
Ni-63	8.899E+03	5.325E+05	8.077E+03	1.818E+06

Attachment A (continued): soil contamination guidelines for 15 mrem/year

Nuclide	Residential pCi/g	Construction Worker pCi/g	Resource User pCi/g	Canyon Bottom User pCi/g
Np-237	2.572E+00	2.660E+01	3.028E+00	1.649E+02
Pm-147	8.598E+04	2.435E+05	9.019E+04	1.043E+06
Pu-238	5.334E+01	4.352E+01	7.748E+01	3.109E+02
Pu-239	4.803E+01	3.944E+01	6.977E+01	2.801E+02
Pu-240	4.804E+01	3.944E+01	6.977E+01	2.801E+02
Pu-241 (60 years)	1.436E+03	1.246E+03	2.250E+03	8.803E+03
Pu-242	5.060E+01	4.132E+01	7.350E+01	2.949E+02
Pu-244 (1000-1600 years)	3.533E+00	1.476E+01	3.559E+01	6.668E+01
Ra-226	5.000E+00	5.000E+00	5.000E+00	5.000E+00
Ra-228	5.000E+00	5.000E+00	5.000E+00	5.000E+00
Ru-106	2.950E+01	2.059E+02	2.575E+02	7.423E+02
Sb-125	1.355E+01	8.940E+01	2.599E+02	3.222E+02
Se-79	2.951E+02	3.922E+04	6.110E+01	1.204E+05
Sm-147	4.657E+02	3.152E+02	4.478E+02	4.736E+03
Sm-151	2.322E+05	4.592E+05	2.159E+05	2.602E+06
Sr-90	5.641E+00	1.628E+03	4.738E+00	5.512E+03
Tc-99	3.527E+01	1.939E+05	3.921E+01	6.346E+05
Th-228	3.229E+00	1.764E+01	5.663E+01	7.668E+01
Th-229	1.249E+01	1.039E+01	5.073E+01	1.398E+02
Th-230	5.000E+00	5.000E+00	5.000E+00	5.000E+00
Th-232	5.000E+00	5.000E+00	5.000E+00	5.000E+00
Tl-204	3.973E+02	3.512E+04	2.524E+02	1.198E+05
U-232 (10 years)	2.873E+00	1.168E+01	3.259E+01	6.420E+01
U-233 (1000-1800 years)	8.257E+01	4.877E+01	2.184E+02	6.912E+02
U-234	7.945E+01	1.751E+02	2.805E+02	2.655E+03
U-235 (1000 years)	2.324E+01	6.045E+01	5.758E+01	4.898E+02
U-236	3.165E+02	1.926E+02	3.809E+02	3.174E+03
U-238 (1000 years)	1.281E+02	1.768E+02	3.492E+02	1.969E+03
Zn-65	1.085E+01	8.405E+01	1.459E+01	3.030E+02
Zr-93 (300 years)	3.028E+04	5.215E+04	4.012E+04	4.187E+05

Attachment B: Scenario-specific parameters

Parameter	**Residential Adult**[1]	**Residential Child**[2]	**Resource User**[3]	**Extended Backyard**[4]	**Trail User—Hiker**[5]	**Trail User-Jogger**[6]	**Construction Worker**[7] (on-site)
Dose Conversion Factors	RESRAD Defaults	RESRAD Defaults	RESRAD Defaults	RESRAD Defaults	RESRAD Defaults	RESRAD Defaults	RESRAD Defaults
Area of Contaminated Zone (m^2)	10000	10000	10000	10000	10000	10000	10000
Thickness of Contaminated Zone (m)	2	2	2	2	2	2	2
Basic Radiation Dose Limit (mrem/year)	15	15	15	15	15	15	15
Time since Placement of Material (years)	0	0	0	0	0	0	0
Cover Depth (m)	0	0	0	0	0	0	0
Density of Contaminated Zone (g/cm^3)	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Physical Parameters of Contaminated Zone	RESRAD Defaults	RESRAD Defaults	RESRAD Defaults	N/A	N/A	N/A	N/A
Evapotranspiration Coefficient	0.999	0.999	0.999	0.999	0.999	0.999	0.999
Precipitation (m/year)	0.35	0.35	0.35	0.35	0.35	0.35	0.35

Parameter	Residential Adult[1]	Residential Child[2]	Resource User[3]	Extended Backyard[4]	Trail User—Hiker[5]	Trail User-Jogger[6]	Construction Worker[7] (on-site)
Shielding Factors	RESRAD Default	RESRAD Default	N/A	N/A	N/A	N/A	N/A
Outside Occupancy	0.08	0.08	0.0274	0.0228	0.00761	0.00381	0.0822
Indoor Occupancy	0.66	0.66	0	0	0	0	0
Soil Ingestion Rate (g/year)	23.6	35	219	626	584	584	525.6
Inhalation Rate (m^3/year)	5320	2940	14016	10500	14000	14000	10950[8]
Dust Loading (g/m^3)	1E-04	1E-04	1E-04	2E-04	2E-05	4E-04	4E-03[8]
Exposure Duration (years)	9	6	30	6	30	30	1
Plant Ingestion Rate (kg/year)	Veg: 68.6 Fruit: 63.1	Veg: 30.3 Fruit: 84	RESRAD Defaults	N/A	N/A	N/A	N/A
Fraction of Plants Grown Onsite	0.4	0.4	RESRAD Defaults	N/A	N/A	N/A	N/A

Footnotes:

1. Residential Adult Pathways: external gamma exposure, dust inhalation, soil ingestion, plant ingestion, radon.
2. Residential Child Pathways: external gamma exposure, dust inhalation, soil ingestion, plant ingestion, radon.
3. Resource User Pathways: external gamma exposure, dust inhalation, soil ingestion, plant ingestion, meat ingestion, radon.
4. Extended Backyard Pathways: external gamma exposure, dust inhalation, soil ingestion.
5. Trail User – Hiker Pathways: external gamma exposure, dust inhalation, soil ingestion.
6. Trail User – Jogger Pathways: external gamma exposure, dust inhalation, soil ingestion.
7. Construction Worker Pathways: external gamma exposure, dust inhalation, soil ingestion, radon.
8. Based on 0.002 g/m^3 dust loading and a 21900 m^3/year inhalation rate (RESRAD does not allow inhalation rate greater than 20000 m^3/year so inhalation rate and dust loading were adjusted to compensate).