APPENDIX D

RADIATION REMEDIATION TECHNOLOGIES

This appendix presents two exhibits designed to assist the RPM with the process of using risk information to evaluate and select remediation technologies for sites contaminated with radioactive substances. The first exhibit, Exhibit D-1, summarizes the potential routes by which radioactivity may be released to the air, ground water, surface water, or other media when remedial technologies are implemented. Similar to Exhibit A-2 in Appendix A, Exhibit D-1 groups process variations with similar potential release mechanisms under the technology categories. Exhibit D-1 includes ground and surface water releases under the "water" column, and includes other unique release mechanisms under the "other" column. The reader is referred to EPA's report, *Assessment of Technologies for the Remediation of Radioactively Contaminated Superfund Sites* (EPA/540/2-90/001), for descriptions of each technology listed in Exhibits D-1 and D-2.

The second exhibit, Exhibit D-2, presents a qualitative estimate of the potential short-term risks posed by each technology during its implementation phase, and its potential long-term risks anticipated after cleanup. Potential short-term risks and potential long-term risks are classified as being low, moderate, or high, or some combination of these levels. This classification scheme is based on the potential for releases of radioactivity arising from the use of these technologies to lead to potential short- and long-term risks. Under this scheme, "low" means a low potential for releases of radioactivity assuming a reasonable worst-case scenario and therefore, a low potential for human health or environmental risk. "Moderate" means a moderate potential for release and risk, and "high" refers to a high potential for release and risk.

Although the determinations of low, moderate, and high potential risks presented in Exhibit D-2 are based on the professional judgment of experienced risk assessors, they are provided only to the RPMs for making preliminary technology screening decisions. The actual risks associated with a remedial alternative at a specific site must be evaluated on a case-by-case basis. That is, technologies rated as high potential risk should not necessarily be eliminated from consideration, nor should technologies rated as low potential risk be considered safe, without evaluation of site-specific factors.

The Agency recognizes that other determinations of degree of potential risks are possible and may be acceptable. (In fact, if remediation technologies are properly designed and excuted, few, if any, of the potential releases and risks may be expected.) Therefore, the RPM is encouraged to consider all qualified sources of technical information when selecting a radiation remedial technology based on site-specific conditions.

Potential releases of mixed radioactive and nonradioactive hazardous substances are not covered in this appendix due to the limited number of technologies currently available, and the complexities involved in identifying release pathways and mechanisms. Because releases of mixed waste contaminants will warrant additional risk evaluation and considerations, RPMs should consult with a radiation protection specialist prior to selecting a remedial design for these types of sites.

EXHIBIT D-1

POTENTIAL RELEASES OF RADIOACTIVITY ASSOCIATED WITH RADIATION REMEDIATION TECHNOLOGIES

Technologies[a]	Air	Water[a]	Other[b]
SOIL AND SLUDGE TECHNOLOGIES			
Natural Attenuation (Non-treatment Action)	• Potential emissions of radioactive particulates and volatiles	• Continued migration of radionuclides to ground water and possible transport to surface water	• External radiation exposure due to gamma-emitting radionuclides in soil
Soil Handling			
Soil Excavation, Transport, and Offsite Disposal	• Resuspension of radioactive particulates • Enhanced emissions of volatile radionuclides	• Enhanced runoff or leaching of radionuclides to surface water or ground water	• Seepage/runoff to soil • Enhanced external radiation exposure of workers during excavation, handling, shipping, and disposal • Offsite migration of radioactivity due to transport by contaminated vehicles or equipment
Soil Washing, Extraction, & Bioremediation			
Soil Washing with Water	• Resuspension of radioactive soil particles and enhanced emissions of volatile radionuclides during handling and treatment	• Spills, leaching, and/or runoff of residual radionuclides in washed soil or in process water • Accumulation of dissolved or suspended radionuclides in recycled water/solvents	• Enhanced external radiation exposure from gamma-emitting radionuclides in soil

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EXHIBIT D-1 (Continued)

POTENTIAL RELEASES OF RADIOACTIVITY ASSOCIATED WITH RADIATION REMEDIATION TECHNOLOGIES

Technologies[a]	Air	Water[a]	Other[b]
Soil Washing, Extraction, & Bioremediation (Continued)			
Chemical Extraction	• Potential emissions of volatile chemicals and radioactive particulates and volatiles during handling and treatment	• Spills, leaching, and/or runoff of residual radionuclides in process water • Accumulation of dissolved or suspended radionuclides in recycled water/solvents	• Spills or leakage of extract with high concentrations of radioactive contaminants and solvents from storage tanks
Bioremediation	• Areal or fugitive emissions of radioactive particulates and volatiles • Exhaust stack emissions of incinerated biosorbants containing residual radioactivity	• Discharge of process water containing residual radioactivity • Inadvertent spills or leaching of radionuclides	• External radiation exposure from biomass containing residual gamma-emitting radionuclides
Immobilization			
Capping	• Continued emissions of some volatile radionuclides after capping	• Leaching and horizontal migration of radionuclides to ground water with rain water infiltration	• Partial reduction of external radiation exposure

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EXHIBIT D-1 (Continued)

POTENTIAL RELEASES OF RADIOACTIVITY ASSOCIATED WITH RADIATION REMEDIATION TECHNOLOGIES

Technologies[a]	Air	Water[a]	Other[b]
In-situ Vitrification	• Volatilization of certain radionuclides during treatment • Cracks or fissures in vitrified mass may act as conduits for the release of volatile radionuclides	• Possible leaching and migration of radionuclides to ground water due to soil matrix destabilization	• External radiation exposure in radium contaminated soils due to the buildup of radon decay products
GROUND WATER AND SURFACE WATER TECHNOLOGIES			
Natural Attenuation (Non-treatment Action)	• Potential buildup of volatile radionuclides (eg, radon) in ground-water and municipal water distribution systems	• Continued transport of radionuclides to the aquifer and possible discharge to surface water	• Potential deposition of radioactive sediments in surface water over large areas (eg, river basins)
Filtration	• Fugitive emissions of volatile radionuclides	• Discharge of effluent water containing dissolved radioactive solids	• Potential leaching of radionuclides from filter cakes or sludge • External radiation exposure from radioactive cakes or sludge
Granular Activated Carbon Adsorption	• Potential stack emissions of volatile radionuclides upon saturation or breakthrough	• Discharge of treated water containing residual radioactive contamination • Possible release of radionuclides due to backflushing and/or regeneration	• Potential external radiation exposure due to the sorption and buildup of gamma-emitting radionuclides
Ion Exchange	• Potential for off-gassing of volatile radioactive decay products from parent nuclides on resin columns	• Discharge of treated water containing residual radioactive contamination • Possible release of radionuclides due to backflushing or regeneration	• Potential external radiation exposure due to the buildup of gamma-emitting radionuclides

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EXHIBIT D-1 (Continued)

POTENTIAL RELEASES OF RADIOACTIVITY ASSOCIATED WITH RADIATION REMEDIATION TECHNOLOGIES

NOTES

* Source for radiation remediation technologies: US Environmental Protection Agency (EPA). 1990. *Assessment of Technologies for the Remediation of Radioactively Contaminated Superfund Sites*. EPA/540/2-90/001.

[a] In general, seepage and leaching are more likely to affect ground water, but could also lead to surface water contamination. Runoff and discharge are releases that will most likely contaminate surface water, but may also lead to ground-water contamination.

[b] Other releases include treatment residuals requiring further remediation and/or special handling and disposal considerations. External radiation exposure due to the presence of gamma-emitting radionuclides in treatment residues should also be considered as a potential human health exposure pathway, even though this pathway does not involve the physical release of radionuclides into the environment. The risk assessor should also consider other common technologies used to remediate ground water and surface water contaminated with radioactive substances, such as aeration, evaporation, distillation and solvent extration, not included in Exhibits D-1 or D-2.

EXHIBIT D-2

DEGREE OF POTENTIAL SHORT- AND LONG-TERM RISKS ASSOCIATED WITH RADIATION REMEDIATION TECHNOLOGIES

Technologies*	Potential for Short-term Risks	Potential for Long-term Risks	Comments
SOIL AND SLUDGE TECHNOLOGIES			
Natural Attenuation (Non-treatment Action)	High	High	• The No Action alternative will not meet the two NCP threshold criteria: (1) protection of human health and environment, and (2) compliance with ARARs • Migration and release of radioactive contaminants would be expected to continue unless abated or mitigated
Soil Handling			
Soil Excavation, Transport, and Offsite Disposal	Moderate/High	None/Low	• During excavation, the potential for short-term radiation risks to remedial workers onsite and to the general public offsite may be moderate to high • Once the source or sources of radioactivity has or have been removed, the potential for long-term risks should be minimal or non-existent, depending on the level of residual radioactivity remaining onsite
Soil Washing, Extraction, & Bioremediation			
Soil Washing with Water	Moderate	Low	• During excavation and soil washing, the potential for short-term radiation risks to remedial workers onsite and to the general public offsite may be moderate • Depending on the level of residual radioactivity remaining, the potential for long-term risks may be low to moderate
Chemical Extraction	Moderate/High	Low/Moderate	• During excavation and chemical extraction, the potential for short-term radiation risks to workers onsite and to the general public offsite may be moderate to high • The potential for long-term risks depend upon the chemical and radiological characteristics of the treated soil recycled back into native soil

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EXHIBIT D-2 (Continued)

DEGREE OF POTENTIAL SHORT- AND LONG-TERM RISKS ASSOCIATED WITH RADIATION REMEDIATION TECHNOLOGIES

Technologies*	Potential for Short-term Risks	Potential for Long-term Risks	Comments
Soil Washing, Extraction, & Bioremediation (Continued)			
Bioremediation	Moderate	Moderate	• Accidental spillage of radioactivity from biotreatment solutions, off-gassing of volatile radionuclides, and elevated external radiation exposures may contribute to the potential for moderate short-term radiation risks • Long-term risks depend upon the chemical and radiological characteristics of the treated soil recycled back into native soil In general, these risks should be low to moderate
Immobilization			
Capping	Low/Moderate	Moderate/High	• Short-term radiation risks to workers and offsite populations should be low to moderate, provided that the source or sources of radioactivity are not excavated before capping • Since the sources of radioactivity will be left in place, long-term risks to human health and the environment may be moderate to high depending on the extent to which the cap is capable of preventing the migration of radionuclides in the future
In-situ Vitrification	Moderate/High	Moderate	• Initially, both radiation and physical hazards contribute to the moderate to high potential for short-term radiation risks posed by the use of this technology, primarily to onsite workers • Since the stability and long-term integrity of vitrified soils containing radioactive materials remain unverified in the field at the present time, and since the buildup of radon decay products in vitrified soils may increase external exposure rates with time, potential long-term radiation risks to the general public may be moderate to high

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EXHIBIT D-2 (Continued)

DEGREE OF POTENTIAL SHORT- AND LONG-TERM RISKS ASSOCIATED WITH RADIATION REMEDIATION TECHNOLOGIES

Technologies*	Potential for Short-term Risks	Potential for Long-term Risks	Comments
GROUND WATER AND SURFACE WATER TECHNOLOGIES			
Natural Attenuation (Non-treatment Action)	High	High	• The No Action alternative will not meet the two NCP threshold criteria: (1) protection of human health and environment, and (2) compliance with ARARs • Releases of radioactive contaminants to ground water and surface water would be expected to continue unless abated or mitigated
Filtration	Low/Moderate	Low	• The potential for short-term radiation risks to workers and the public will depend on a number of factors, including: (1) the concentrations of radionuclides in the ground or surface waters; (2) the efficiencies of filtration systems; (3) the breakthrough time, and; (4) the change-out or regeneration cycle time In general, these potential risks are expected to be low to moderate • The potential for long-term risks will also depend on the factors listed above, but will depend primarily on the concentration of radionuclides in ground water or surface water remaining to be treated (ie, concentrations (and risks) may be expected to fall off with treatment) Potential risks to the general public may be expected to be low The handling and disposal of filter materials and sludges containing radionuclides may pose risks to workers if radioactivity concentrations exceed federal or state standards

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EXHIBIT D-2 (Continued)

DEGREE OF POTENTIAL SHORT- AND LONG-TERM RISKS ASSOCIATED WITH RADIATION REMEDIATION TECHNOLOGIES

Technologies*	Potential for Short-term Risks	Potential for Long-term Risks	Comments
GROUND WATER AND SURFACE WATER TECHNOLOGIES			
Granular Activated Carbon Adsorption	Low/Moderate	Low	• The buildup of radon and radon progeny on activated charcoal may increase both potential short- and long-term risks of external radiation exposures to workers Regeneration of GAC may release radionuclides that are not well sorbed Disposal of spent GAC containing elevated concentrations of lead-210 (and chemical contaminants) may pose handling problems Buildup of radon and other radionuclides on GAC also depends on: (1) the concentrations of radionuclides in the ground or surface waters; (2) collection efficiencies; (3) GAC breakthrough time, and; (4) the change-out or regeneration cycle time
Ion Exchange	Low/Moderate	Low	• Similar to the potential risks posed by the treatment of radionuclides in ground water and surface water using filtration or carbon absorption techniques, the potential for short- and long-term risks posed by the collection of radionuclides on ion exchange resins depends primarily on the radionuclide-specific collection efficiency and water concentrations In general, these potential risks may be low to moderate

* Source for radiation remediation technologies: U.S. Environmental Protection Agency (EPA). 1990. *Assessment of Technologies for the Remediation of Radioactively Contaminated Superfund Sites.* Office of Solid Waste and Emergency Response. EPA/540/2-90/001.