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A Regulators' Guide to the Management of Radioactive Residuals from Drinking Water Treatment Technologies

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Please note that the U.S. EPA statutes and regulations described in this document contain legally binding requirements. This guidance document replaces all earlier U.S. EPA draft guidance documents on radionuclides residual disposal for drinking water treatment. The recommendations in this document are not substitutes for those statutes or regulations, nor is this document a regulation. This guide is strictly voluntary and does not impose legally-binding requirements on U.S. EPA, states, local or tribal governments, or members of the public, and may not apply to a particular situation based upon the circumstances. Although U.S. EPA recommends the approaches outlined in this document, state and local decisionmakers are free to adopt approaches that differ from those presented in this guide. Interested parties are free to raise questions about the appropriateness of the application of this guide. Any U.S. EPA decisions regarding a particular water system or wastestream will be made based on the applicable statutes and regulations. U.S. EPA will continue to review and update this guide as appropriate.

Executive Summary

The revised Radionuclides Rule came into effect on December 8, 2003. U.S. EPA's revisions to the Rule provide standards that, if met, ensure that all customers served by community water systems (CWSs) receive water that meets the Maximum Contaminant Levels (MCLs) for radionuclides in drinking water. Regulated radionuclides include radium-226, radium-228, gross alpha particle activity, uranium, and beta particle and photon radioactivity.

In accordance with the Rule, all CWSs must complete initial compliance monitoring by December 8, 2007. While most systems will be in compliance with the revised Rule, systems in areas of the country with elevated levels of naturally occurring radionuclides, and the few systems located near facilities that could potentially contaminate source waters with radioactive substances, might have to install new or upgrade existing treatment to meet these revised standards. These treatment processes will produce residuals containing regulated radionuclides.

This guide is intended for state regulators, technical assistance providers, and field staff. It is designed to help states address radionuclide residual disposal by outlining options available to help systems address elevated radionuclide levels. It provides an overview of the types of treatment listed as Best Available Technologies (BATs) and Small System Compliance Technologies (SSCTs) by U.S. EPA, the wastes produced by these technologies, waste disposal options and considerations, and the federal statutes and regulations governing waste disposal. This guide, however, is not intended to identify concentrations of radionuclides that are appropriate for each disposal option. As part of U.S. EPA's Advance Notice of Proposed Rulemaking (ANPR) effort on low-activity waste (68 FR 65120, November 18, 2003), the Agency is evaluating the conditions under which various disposal options would be appropriate for radioactive material (with a focus on hazardous waste landfills); that guidance is still applicable.

Some states have been grappling with the issue of radioactive residual disposal for some time, while others are just beginning to address these waste disposal issues. Relevant state agencies and programs (e.g., drinking water, radiation control, solid waste) will benefit from coordinating with each other to determine appropriate disposal options. The challenge for states is to find a balance between appropriate treatment technologies, safe waste disposal practices, worker safety, and cost, yet ensure compliance with the Radionuclides Rule and other drinking water regulations. Note that this guide presents a generalized overview of residual management. Due to the variability in state regulations, waste concentration and characteristics, and removal efficiencies associated with treatment technologies, systems' residual management responsibilities may be more extensive or complex than presented.

The federal statutes and regulations discussed in the guide set the minimum standards by which systems must operate. States, however, have the authority to set more stringent standards. State treatment and waste disposal regulations may, as a result, be stricter and significantly more complex than those presented in this guide. Systems should always be reminded to check with their state before proceeding with treatment installation or modification and waste disposal to ensure they are meeting all relevant federal, state, and local requirements.

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Acronyms

AA	Activated Alumina
AEA	Atomic Energy Act
ALARA	As Low as Reasonably Achievable
AX	Anion Exchange
BAT	Best Available Technology
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CESQG	Conditionally Exempt Small Quantity Generator
CWA	Clean Water Act
CWS	Community Water System
CX	Cation Exchange
DOT	Department of Transportation
U.S. EPA	United States Environmental Protection Agency
FBRR	Filter Backwash Recycling Rule
HMO	Hydrous Manganese Oxide
ICRP	International Commission on Radiological Protection
ISCORS	Interagency Steering Committee on Radiation Standards
IX	Ion Exchange
LLRW	Low-Level Radioactive Waste
MARLAP	Multi-Agency Radiological Laboratory Analytical Protocols Manual
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCL	Maximum Contaminant Level
MPRSA	Marine Protection, Research, and Sanctuaries Act
MSWLF	Municipal Solid Waste Landfill
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
OGWDW	Office of Ground Water and Drinking Water
OSHA	Occupational Safety and Health Administration
PFLT	Paint Filter Liquids Test
POTW	Publicly Owned Treatment Works
POU	Point of Use
PPE	Personal Protection Equipment
RCRA	Resource Conservation and Recovery Act
RO	Reverse Osmosis
SDWA	Safe Drinking Water Act
SPARRC	Spreadsheet Program to Ascertain Radionuclides Residuals Concentration
SSCT	Small System Compliance Technology
TBLL	Technically Based Local Limit
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TENORM	Technologically Enhanced Naturally Occurring Radioactive Materials
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water

Introduction

The Radionuclides Rule

Community water systems (CWSs) were required to begin complying with the revised Radionuclides Rule on December 8, 2003. The Rule retained the maximum contaminant levels (MCLs) for combined radium-226/228, gross alpha particle activity, and beta particle and photon radioactivity. The Rule also revised and added to existing requirements, set a new MCL for uranium[1] and separate monitoring requirements for radium-228, and required CWSs to monitor at each entry point to the distribution system. For more information on the Rule's requirements, see: http://www.epa.gov/safewater/radionuc.html.

Table 1: Radionuclides MCLs

Combined radium-226 and 228	5 pCi/L
Gross alpha particle activity (excluding radon and uranium)	15 pCi/L
Beta particle and photon radioactivity	4 mrem/year
Uranium	30 µg/L

Public Health Risks of Exposure to Radionuclides in Drinking Water

Radiation exposure is regulated on the assumption that any exposure carries some risk of a health effect. Radiation-induced health effects can be *deterministic*, in which biological damage is readily observed and proportional to the level of exposure, or *stochastic*, in which the probability of a health effect is related to the level of exposure, but the severity is not. Deterministic effects have only been observed at relatively high exposures delivered over a short time. Doses associated with exposures to natural background radiation or typical radioactive materials in water treatment plants are generally many times lower than the high doses that are needed to cause such effects. Stochastic effects are more typical of low radiation doses, often delivered over a period of time (e.g., chronic exposures). The principal concern associated with low dose radiation exposure is the possible occurrence of cancer years after the exposure occurs. In addition, uranium can be chemically toxic to the kidneys.

Measuring Radiation

Quantities of radioactive material are measured as radioactivity or activity in curies, i.e., disintegrations (decays) per second. The potential for health hazards increases as activity increases. Radioactive material found in water treatment plant residuals or source water is usually measured in microcuries or picocuries (pCi).

The body's exposure to ionizing radiation is typically expressed in millirem (mrem). Dose standards are typically expressed as a rate of exposure, in millirems per unit of time (e.g., hours or years).

Fundamentals of Radiation

Human beings are constantly exposed to radiation from natural and manmade sources. The average radiation dose to an individual in the United States is about 360 mrem/yr (see Table 2 on the following page). On average, 80 percent of that exposure comes from natural sources including cosmic radiation from outer space; terrestrial radiation from natural radioactive materials in rocks, soil, and minerals; and radiation inhaled or ingested from food and water.[2] Additional exposure comes from manmade sources of radiation including medical X-rays and industrial use of radioactive material. Table 2 on the following page summarizes average annual exposures to radiation within the United States. Note that radiation exposure can vary greatly according to factors such as an individual's location, lifestyle, and daily activities.

Radiation is characterized as "ionizing" and "non-ionizing." Uranium and radium occur naturally in rocks and soil as the result of radioactive decay, or the release or transfer of excess energy, of uranium-238 and thorium-232. This excess energy is ionizing radiation. Ionizing radiation is of sufficient energy to break chemical bonds and remove electrons, potentially causing biological damage. Non-ionizing radiation, such as visible light and infrared, is lower

[1] "Uranium" refers to all isotopes that make up naturally occurring uranium: U-238, U-235, and U-234.

[2] U.S. Department of Energy and U.S. EPA Interagency Steering Committee on Radiation Standards (ISCORS), 2003-04.

energy (e.g., microwaves or radiowaves) and "bounces off or passes through matter without displacing electrons."[3] Its effect on human health is undetermined.

The four most common types of ionizing radiation are:

- Alpha radiation (emitted by radon, thorium, and uranium), which can occur naturally or as the result of manmade activities. It cannot penetrate the skin but can be a significant internal hazard if alpha-emitting radionuclides are ingested or inhaled.

- Beta radiation emitted by radium-228 and manmade contaminants from industrial uses of radioactive materials or facilities disposing of radioactive material. It can penetrate outer layers of skin, but beta-emitting radionuclides are more of a concern as an internal hazard if ingested or inhaled.

- Gamma radiation, also referred to as "photon" emissions (radium-226 emits both alpha and gamma radiation). Gamma radiation originates from processes inside the nucleus. Radioactive materials that emit gamma radiation are of concern because the gamma rays pose an external radiation exposure hazard and can penetrate the body.

- X-Ray radiation, which is also photon radiation, although x-rays originate from outside the nucleus. X-rays are slightly lower in energy than gamma radiation and are the single largest source of manmade radiation exposure.

Table 2: Average Annual Exposure to Radiation

Radiation Source	**Average Exposure[1]**	**Typical Range of Variability[2]**
	(mrem/year)	
Natural Sources		
Terrestrial	30	10-80
Radon	200	30-820
Cosmic	30	20-100
Internal	40	
Man-made Sources		
Medical	50	
Consumer products	10	
Other	1	
Total	**361**	**90-1080**

[1] National Council on Radiation Protection, 1987
[2] Huffert, A.M., et al, 1994; Fisher, Eugene.

Guide Overview
This guide is intended for regulators, technical assistance providers, and field staff helping drinking water systems protect the public from exposure to excessive levels of regulated radionuclides in drinking water through the use of treatment technology, and their staffs from exposure to radioactive wastes generated by treatment. It focuses primarily on treatment for radium and uranium, the most common naturally-occurring regulated radionuclides. This guide provides:

1. Information on how systems can determine whether installing additional or new treatment technologies is the best option for addressing radionuclides in source water, taking into account the residuals produced, disposal options, and required operator skill level.

2. Descriptions of the different treatment options listed by the U.S. Environmental Protection Agency (U.S. EPA) as Best Available Technologies (BATs) and Small System Compliance Technologies (SSCTs).[4]

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[3]Oak Ridge Reservation, 2000. p. G-5

[4]BATs are the best technologies, treatment techniques, or other means that the U.S. EPA administrator determines to be available, after examination for efficacy under field conditions and not solely under laboratory conditions (taking cost into consideration). SSCTs are technologies that have been federally approved for systems serving fewer than 10,000 persons to use in complying with

3. Details on the residual streams produced by these treatment technologies.

4. General options for disposal of the residuals produced by these treatment technologies.

5. Information on key issues related to the disposal of drinking water treatment residuals containing regulated radionuclides, including co-occurrence, applicable federal regulations, and worker safety concerns.

This guide has two main sections:

- **Section I** provides an **overview** of the removal of radionuclides from drinking water and a discussion of worker safety. It is an introduction to non-treatment options, treatment technologies, residuals, disposal options, and measures that systems can take to protect their staffs from radiation exposure.

- **Section II** provides a more **in-depth review of treatment technologies**, the residuals they produce, the disposal options for these residuals, and intermediate processing.

In addition, the appendices include a glossary, a list of references and contacts for more information, and a catalogue of resources that provide more information on the Radionuclides Rule and on the treatment, handling, and disposal of radionuclides.

MCLs.

Section I: Overview of the Removal of Radionuclides from Drinking Water

I-A Determining Whether Additional Treatment is Appropriate: Compliance Options Overview

Installing a new treatment technology requires an investment of both time and money. There are several alternative compliance options that may be more appropriate for some systems. Each option has its own considerations that should be weighed against a system's particular circumstances.

Option	Considerations
Developing a New Source	‣ Are there other sources available that will produce water that complies with all regulations? ‣ Will the new source meet demand? ‣ Is the new source close enough to the system to economically justify using it?
Blending Source Waters	‣ Are there other sources available with radionuclide levels below the MCLs that can be blended with existing sources? ‣ Is it economically feasible to blend sources? ‣ Is it possible to blend the sources so that the MCLs are met at every entry point to the distribution system and all required plant flow rates are maintained? ‣ If the system uses more than one problematic source, would abandoning any one source reduce the radionuclide concentrations?
Connecting With a Nearby System	‣ Is there a nearby system meeting the requirements of the Radionuclides Rule that is willing to interconnect? ‣ Is it economically feasible to connect to the nearby system? ‣ Can the nearby system handle the increased demand of additional customers?
Optimizing Existing Treatment	‣ Has the system attempted to optimize existing treatment? ‣ Is the system currently using a technology approved as a BAT or SSCT for radionuclide removal? ‣ Is it possible to treat the source water to precipitate competing ions for increased radionuclide removal?

If a system determines that the above options are not feasible, installing new or additional treatment may be the most suitable and cost-effective means of complying with the Radionuclides Rule.

I-B Choosing the Right Technology: An Overview of Listed Best Available Technologies and Small System Compliance Technologies

In promulgating the Radionuclides Rule, U.S. EPA listed BATs and SSCTs for removal of radionuclides from drinking water. Although a system can use any means available (if allowed by the state[5]) to achieve compliance, this guide focuses on the BATs and SSCTs that were listed by U.S. EPA on the basis of their efficacy and affordability in the removal of radionuclides from drinking water. If a system chooses to install new or additional treatment, several key factors should be considered.

Option	Considerations
Installing New or Additional Treatment	‣ Will the treatment technology be effective in removing radionuclides given the source water characteristics? Refer to the detailed treatment technology descriptions in Section II beginning on page 27 of this guide for more information. ‣ Will the technology be efficient at removing co-occurring contaminants, helping the system comply with other drinking water standards? ‣ Is the treatment type suitable for the system's size? ‣ Is the operator appropriately trained to operate and maintain the chosen technology? ‣ Can pilot testing be performed to ensure the suitability of the technology? ‣ Does the system have or can it raise or borrow the funds needed to cover the capital and operation and maintenance costs involved in installing and maintaining the treatment, including disposal costs? ‣ What residuals will be produced and can the system properly dispose of the residuals? ‣ Are there additional costs associated with the disposal of wastes generated by the technology selected? ‣ Will the treatment process or residuals generated pose a radiation hazard to workers or result in the need for the state radiation control agency to license the system?

In choosing a treatment technology, systems should also keep in mind that the characteristics of, and contaminant concentrations in the residuals will help to define a system's disposal options. The characteristics and contaminant concentrations will vary according to:

- The concentration of radionuclides in the source water.
- How efficient the treatment is at removing radionuclides.
- Frequency of regeneration (for ion exchange [IX] and activated alumina [AA]).
- Frequency of filter backwash (for treatment methods using granular media filters).
- Frequency of IX resin, AA media, granular filter media, or membrane replacement.
- Loading to the treatment unit.

If possible, systems should conduct pilot tests of the treatment technologies to determine, for example, the regeneration schedule that is most appropriate when using IX, or the frequency with which filters should be backwashed. Pilot tests are a good way to determine whether system operators will have the time and skill to handle the technology or whether a less complex option is more appropriate.

Table 3 on the following page outlines the treatment capabilities and applicability of the BATs and SSCTs listed in the Radionuclides Rule. It also lists the level of operator skill required to operate and maintain the technology. For additional information on each technology including removal efficiencies, see Section II and Appendix E of this guide.

[5]Note that "state" refers to the Drinking Water Primacy Agency and/or the Underground Injection Control (UIC) Primacy Agency.

Table 3: Applicability of Best Available Technologies and Small System Compliance Technologies[6]

Treatment Technology	Designation	Customers Served	Treatment Capabilities				Source Water Considerations	Operator Skill Required
	BAT and/or SSCT?	(SSCTs only)	*Radium (Ra)*	*Uranium (U)*	*Gross Alpha (G)*	*Beta/photon (B)*		
IX	BAT & SSCT	25-10,000	✓	✓		✓	All ground waters	Intermediate
Point of Use (POU) IX	SSCT	25-10,000	✓	✓		✓	All ground waters	Basic
Reverse Osmosis (RO)	BAT & SSCT	25-10,000 (Ra, G, B) 501-10,000 (U)	✓	✓	✓	✓	Surface waters usually requiring pre-filtration	Advanced
POU RO	SSCT	25-10,000	✓	✓	✓	✓	Surface waters usually requiring pre-filtration	Basic
Lime Softening	BAT & SSCT	25-10,000 (Ra) 501-10,000 (U)	✓	✓			All waters	Advanced
Green Sand Filtration	SSCT	25-10,000	✓				Typically ground waters	Basic
Co-precipitation with Barium Sulfate	SSCT	25-10,000	✓				Ground waters with suitable water quality	Intermediate to Advanced
Electrodialysis/ Electrodialysis Reversal	SSCT	25-10,000	✓				All ground waters	Basic to Intermediate
Pre-formed Hydrous Manganese Oxide Filtration	SSCT	25-10,000	✓				All ground waters	Intermediate
AA	SSCT	25-10,000		✓			All ground waters	Advanced
Coagulation/ Filtration	BAT & SSCT	25-10,000		✓			Wide range of water qualities	Advanced

[6]U.S. EPA, December 2000.

I-C Treatment Residuals: An Overview

Each treatment technology listed in Table 3 produces solid residuals (including spent resins, spent filter media, spent membranes, and sludges) and liquid residuals (including brines, backwash water, rinse water, acid neutralization streams, and concentrates).

Because disposal options may be limited, systems need to be aware of the types of residuals that will be generated by each treatment process in order to determine whether the treatment will be practical and affordable. Table 4 outlines the residuals produced by the BATs and SSCTs listed by U.S. EPA for radionuclide removal. For additional information on each technology, see Section II and Appendix E of this guide.

Table 4: Residual Type by Treatment Technology

Treatment	Types of Residuals							
	Solid			Liquid				
	Spent Resins/ Media	Spent Membranes	Sludge	Brine	Backwash Water	Rinse Water	Acid Neutralization Water	Concentrate
IX	✓			✓	✓	✓		
RO		✓						✓
Lime Softening	✓		✓		✓			
Green Sand Filtration	✓		✓		✓			
Co-precipitation with Barium Sulfate	✓		✓		✓			
Electrodialysis/ Electrodialysis Reversal		✓						✓
Pre-formed Hydrous Manganese Oxide Filtration	✓		✓		✓			
AA	✓			✓	✓	✓	✓	
Coagulation/Filtration	✓		✓		✓			

I-C.1 Residual Estimation: U.S. EPA Spreadsheet Program to Ascertain Radionuclides Residuals Concentration Model

U.S. EPA has developed a Spreadsheet Program to Ascertain Radionuclides Residuals Concentration (SPARRC) model that indicates potential concentrations of radioactivity in residuals and filters at the system. U.S. EPA began developing the model in 1998. This initial version focused on developing the contaminant mass balances in the sludge and other residuals using a complete set of input from the user. While the early version of SPARRC is useful in estimating the volume and concentrations of residuals, it lacked capabilities to estimate the removal efficiencies.

The current version of SPAARC[7] incorporates predictive algorithms to estimate radionuclides and co-contaminant removals, and focuses on a sound estimate of residual radionuclides concentrations and co-occurring pollutants rather than sizing and designing drinking water treatment technologies. It is a flexible and highly interactive tool requiring minimum learning time and was developed as a stand-alone desktop application using state of the art software development tools. The program allows the operator to select the type of treatment process, as well as input and output parameters such as water flows, doses of coagulant and polymer, and filter capacities.

The current SPARRC model covers six technologies and associated co-contaminants including:

Technology	**Radionuclides**	**Co-Contaminant**
Coagulation Filtration	Uranium	Arsenic
Lime Softening	Radium and Uranium	None
IX	Radium, Barium, and Uranium	None
RO	Radium and Uranium	None
AA	Uranium	Arsenic
Green Sand Filtration	Radium and Barium	None

The current version of SPARRC is available at http://www.npdespermits.com/sparrc. For questions concerning the model, contact Rajiv Khera at U.S. EPA's Office of Ground Water and Drinking Water at 202-564-4881 or khera.rajiv@epa.gov.

The concentration of radionuclides in the waste stream, the type of waste produced, and federal and state regulations are among the factors that dictate which disposal options are available to a system. Treated water pH, total dissolved solids (TDS), total suspended solids (TSS), and heavy metals concentrations in the waste stream can also limit disposal options. Section I-D provides an overview of applicable federal regulations and the disposal options that may be available to systems removing radionuclides from their source water.

[7] Version 1, July 2003. Note that this model is a draft version for which U.S. EPA is still seeking comment and has not gone through a peer review process.

I-D Disposal of Residuals: An Overview of Applicable Statutes, Regulations, and Disposal Options

Treating water for naturally occurring radionuclides will result in residual streams that are classified as "technologically enhanced naturally occurring radioactive materials," or TENORM.[8] TENORM is defined here as naturally occurring materials, such as rocks, minerals, soils, and water whose radionuclide concentrations or potential for exposure to humans or the environment is enhanced as a result of human activities (e.g., water treatment).[9] Pilot tests of treatment technologies are a good way for systems to determine how much waste will be produced, and whether the system will be capable of disposing of the amount, concentration, and type of waste.

Numerous regulations govern the disposal of waste streams containing radionuclides (although there are no federal waste disposal regulations specifically for TENORM wastes), and their interaction is complex. States and disposal facilities can place additional restrictions on systems' disposal options.

I-D.1 Applicable Federal Statutes and Federal Regulations

The following federal statutes and regulations could potentially apply to the disposal of water treatment residuals:

- The Resource Conservation and Recovery Act (RCRA; 40 CFR 239 to 282) establishes programs for regulating nonhazardous solid waste (Subtitle D), hazardous waste (Subtitle C), and Underground Storage Tanks (Subtitle I). RCRA governs the identification, classification, and management of solid[10] and hazardous wastes.[11] The RCRA regulations that apply to different types of disposal units depends on the types of wastes that are accepted.

  - Municipal solid waste landfills (MSWLF) are Subtitle D landfills that accept household and other municipal waste. A MSWLF may receive other types of RCRA Subtitle D wastes, such as commercial and industrial wastes. The Municipal Solid Waste Landfill (MSWLF) requirements (40 CFR 258), establish minimum national criteria for MSWLFs covering landfill location, operation, and design; ground water monitoring; corrective action; closure and post-closure, and financial assurance.

  - Subtitle D landfills that accept nonhazardous waste, but do not accept municipal waste ("industrial landfills"), are also subject to federal regulations (40 CFR Part 257, Subparts A and B). However, state regulations typically have additional requirements that apply to these industrial landfills.

  - Land disposal units that accept hazardous waste are regulated under Subtitle C, and include landfills, surface impoundments, waste piles, land treatment units, and underground injection wells. These disposal units are subject to stringent design and operating standards (40 Parts 264 and 265).

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[8]See http://www.epa.gov/radiation/tenorm/ for more information.

[9]This definition is in accordance with the concepts presented in National Academy of Sciences. 1999. *Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials.* Washington, D.C.: National Academies Press; and IAEA (2004).

[10]Any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility, and other discarded material, including solid, liquid, semisolid, or contained gaseous material, resulting from industrial, commercial, mining, and agricultural operations and from community activities. (U.S. EPA, *Mixed Waste Glossary*) For the purposes of hazardous waste regulation, a solid waste is a material that is discarded by being either abandoned, inherently waste-like, a certain waste military munition, or recycled. (U.S. EPA, 2003)

[11]Hazardous waste is defined under 40 CFR 261.3. Waste is considered hazardous if it is a solid waste (as defined under 40 CFR 261.2) that is not excluded from regulation as hazardous waste under 40 261.4(b) and when it meets the criteria listed under 40 CFR 261.3(a)(2) and (b).

- The Clean Water Act (CWA; 33 USC 1251 to 1387), under which U.S. EPA establishes requirements for direct discharges of liquid waste or the discharge of a liquid waste to publicly owned treatment works (POTW).

- The Safe Drinking Water Act (SDWA; 42 USC 300f et seq.), which requires that U.S. EPA develop minimum federal requirements for underground injection control (UIC) programs (state or primacy) to ensure that underground injection does not endanger current and future underground sources of drinking water (USDWs) (40 CFR 144-148).

- The Atomic Energy Act of 1954, as amended (AEA; 42 USC 2011 et seq.), which requires the Nuclear Regulatory Commission (NRC) to regulate the civilian commercial, industrial, academic, and medical use of nuclear materials. The Act enables the NRC to relinquish some of its regulatory authority over source materials to states through the signing of an agreement between the state's Governor and the NRC Chairperson. Currently, 33 states have entered such agreements and are referred to as "Agreement States." Agreement States must establish radiation protection programs compatible with the NRC's and the NRC remains involved with state licensing, inspection, and rule changes, among other things. For more information and a list of Agreement States, see http://www.hsrd.ornl.gov/nrc.

- Department of Transportation (DOT) regulations (49 CFR 171 to 180), which govern the shipping, labeling, and transport of hazardous (including radioactive) materials.[12]

- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 42 USC 9605 et seq.) National Oil and Hazardous Substances Pollution Contingency Plan (NCP, 40 CFR 300) applies to the release or threat of release of hazardous substances (including radionuclides) that many endanger human health and the environment. If disposal of radionuclide-contaminated residuals results in a release or threat of release that endangers human health or the environment, CERCLA may require cleanup of the hazardous substance.

[12]In 49 CFR 173.436, DOT provides levels for individual radionuclides (both in terms of concentration and a total consignment activity) that are exempt from the DOT requirements which would normally apply for transporting radioactive material. (See "Hazardous Materials Regulations; Compatibility With the Regulations of the International Atomic Energy Agency; Final Rule." 69 FR 3632, January 26, 2004, at http://www.tgainc.com/pdf/69fr-3631.pdf). In the preamble to the Rule, DOT explains that the exemptions apply to "other natural materials or ores...when those materials or ores are to be used because of some other physical or chemical characteristics...[or] when these have been subjected to physical or chemical processing, when the processing was not for the purpose of extracting radionuclides...provided that their radionuclide concentration does not exceed 10 times the activity concentration in the table in [section] 173.436."

To determine whether a system falls under the DOT radioactive material transport regulations, the system must determine the radionuclide activity concentrations and activities and calculate the effective exemption values (assuming that you have more than one radionuclide). Systems can use "process knowledge" to aid in making these determinations. See Appendix C for additional information.

State TENORM Regulations

States address TENORM in various ways. Although thirteen states currently have regulations addressing TENORM, some only regulate TENORM from specific industries (e.g., oil and gas or phosphate production), while others address all sources of TENORM. For example:

- In Maine, non-exempt facilities abiding by the state's standards for TENORM radiation protection, worker safety, disposal and transfer of waste, dilution of wastes, and unrestricted use and conditional release, may receive a license to transfer or dispose of TENORM wastes without quantity restrictions (10-144A CMR 220, Subpart N).
- Louisiana issues similar licenses to non-exempt facilities and requires that a manifest be obtained from the Department of Environmental Quality prior to shipping TENORM waste to a disposal facility (LAC 33:XV.1408 and 1418).
- Texas also issues general licenses to non-exempt facilities. Systems transferring waste for disposal must choose a facility licensed to accept TENORM wastes (25 TAC 289.25(f) and (h)).

Most states do not have specific TENORM regulations and regulate it the same way as all other sources of radiation. For more information on state regulations, see http://www.tenorm.com/regs2.htm#States.

The remainder of this section and Appendix C contain additional information on these and other applicable federal statutes and regulations as they apply to the disposal of water treatment plant residuals containing radionuclides. States may have additional requirements or restrictions on the disposal of water treatment residuals containing radionuclides. State radiation, hazardous waste, and drinking water programs should coordinate to provide systems with comprehensive information on all relevant requirements (see Appendix D for state contact information).

I-D.2 Applicable Federal Definitions for Waste

Systems should be aware that key definitions vary among regulations. For example, the UIC progam's regulations do not automatically assume the same exemptions as the NRC regulations (e.g., source material is of an "unimportant quantity" (10 CFR 40.13) and is *exempt* from NRC regulation if the uranium or thorium makes up less than 0.05 percent by weight of the material. For natural uranium, this is approximately 335 pCi/g, though this figure is an estimate and actual values may be obtained for different uranium and thorium isotopes). Making systems aware of these distinctions is important in ensuring that they adhere to all applicable federal statutes and regulations. In addition, systems should be made aware of any state licensing requirements related to the generation of non-exempt radioactive materials.

I-D.2.1 Hazardous Waste

Hazardous waste is defined under 40 CFR 261.3. Waste is considered hazardous if it is a solid waste (as defined under 40 CFR 261.2) that is not excluded from regulation as hazardous waste under 40 CFR 261.4(b) and when it meets the criteria listed under 40 CFR 261.3(a)(2) and (b). The RCRA regulations establish two ways of identifying wastes as hazardous under RCRA. A waste may be considered hazardous if it exhibits certain hazardous properties ("characteristics") or if it is included on a specific list of wastes EPA has determined are hazardous ("listing" a waste as hazardous in 40 CFR 261.31 to 261.33). RCRA defines four hazardous waste characteristic properties: ignitability, corrosivity, reactivity, or toxicity (see 40 CFR 261.21-261.24). The hazardous waste characteristics are most applicable to TENORM waste; the toxicity characteristic (40 CFR 261.24) is likely to be the most concern for generators of TENORM wastes.

The presence of radionuclides does not make waste hazardous; hazardous waste generation will most likely be the result of the removal of co-occurring contaminants, such as arsenic, in the waste. Some treatment technologies that are effective in removing radionuclides (e.g., IX) will also be effective in removing other contaminants (e.g., arsenic) that, in high enough concentrations, could make the resulting residuals hazardous or, in some cases, mixed waste. For more information, see *Regulations on the Disposal of Arsenic Residuals from Drinking Water Treatment Plants* (EPA/600/R-

00/025), *Treatment of Arsenic Residuals from Drinking Water Removal Processes* (EPA/600/R-01/033), and U.S. EPA's Arsenic Web page, at http://www.epa.gov/safewater/arsenic.html.

Water systems are required to determine whether the waste they generate is hazardous. This may be done using knowledge of the waste generation process, analytical testing, or a combination of both. Analytical testing may involve leachate tests such as the Toxicity Characteristic Leaching Procedure (TCLP) (Method 1311, as described in U.S. EPA publication SW-846, "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods"), which applies to 40 substances, including metals, pesticides, and other organic compounds. If the waste is hazardous, it must be managed under RCRA Subtitle C requirements.

Hazardous waste generators are classified as Large Quantity Generators, Small Quantity Generators, or Conditionally Exempt Small Quantity Generators,[13] depending on the amount of hazardous waste produced monthly and the amount of hazardous waste stored on site at any given time. RCRA requirements vary for each generator class. For more information on these requirements, see Section III, Chapter 3, of the *RCRA Orientation Manual* (EPA 530-R-02-016) at http://www.epa.gov/epaoswer/general/orientat/rom33.pdf.

A hazardous waste generator is always liable for the waste. In the event of future problems at the disposal site or with inappropriate handling, the generator remains partially liable.

I-D.2.2 Low-Level Radioactive Waste

The Low-Level Radioactive Waste Policy Act (42 USC 2021b(9)) defines low-level radioactive waste (LLRW) as "radioactive material that (A) is not high level radioactive waste, spent nuclear fuel, or byproduct material (as defined in section 2014(e)(2)...); and (B) the Nuclear Regulatory Commission...classifies as low-level radioactive waste." Generally, LLRW can be thought of as byproduct material as defined in 42 USC 2014(e)(1) (i.e., yielded in or made radioactive by the production or use of special nuclear material) that does not fall into any other category. In addition, LLRW can contain source or special nuclear material. Note that water treatment residuals would *not* meet the definition of byproduct material as defined under 42 USC 2014(e)(2) (waste from processing uranium or thorium ore).

Radium is not considered source material and would not be considered byproduct material when present in water treatment residuals. Uranium and thorium are considered "source material" (42 USC 2014(z)) and are subject to NRC or Agreement State licensing and regulation. However, source material is of an "unimportant quantity" (10 CFR 40.13) and is *exempt* from NRC or Agreement State regulation if the uranium or thorium makes up less than 0.05 percent by weight (or approximately 335 pCi/g for natural uranium) of the material. These limits apply to both liquid and solid residuals. For perspective, in a system with filter media weighing 30,000 pounds, 0.05 percent by weight would be equal to 15 pounds of uranium.

If a system has source material that contains more than 0.05 percent uranium or thorium by weight, and has a total of no more than 15 pounds in its possession at any time, it is considered to have a "small quantity" of source material and is subject to the general license requirements of 10 CFR 40.22 or equivalent Agreement State regulations. (Note that the 0.05 percent level is not health-based.) Under this general license, systems may not possess more than 150 pounds of source material in any one calendar year. Source material held under this general license normally requires disposal at facilities authorized to accept LLRW. In addition, although not licensable by itself, radium that co-occurs with licensable source material would be subject to the requirements of that license.

Systems that exceed the unimportant quantity and small quantity thresholds must apply for specific licenses from the NRC or Agreement State.

[13] While these generators are not subject to many RCRA requirements, they are subject to limited generator waste management standards (40 CFR 261.5). Conditionally Exempt Small Quantity Generators must identify their hazardous waste, comply with storage limit requirements, and ensure waste treatment or disposal in a landfill that is permitted under Subtitle C, a state MSWLF, or a state permitted or licensed solid waste landfill.

I-D.2.3 Mixed Waste

Mixed waste is regulated under RCRA and the Atomic Energy Act (AEA) of 1954. Mixed waste "contains both hazardous waste and source...or byproduct material subject to the Atomic Energy Act of 1954" (42 USC 6903.41). Therefore, although highly unlikely, systems generating waste containing uranium or thorium (source material) as well as hazardous waste could potentially have a mixed waste. If wastes contain licensable amounts of source material (any concentration exceeding the "unimportant quantity" in 10 CFR 40.13 (a)) and hazardous waste, these wastes must be disposed of at a facility authorized to accept mixed waste. Because there are limited disposal pathways, generation of a mixed waste should be avoided if at all possible. For more information on licensing requirements and Agreement States, see the discussion of the AEA in Appendix C.

If either portion of the waste is exempted or excluded under RCRA or the AEA (and the regulations promulgated under these Acts), it is not mixed waste. A system generating hazardous waste does not have mixed waste if the amount of source material generated is an "unimportant quantity" (uranium or thorium makes up less than 0.05 percent by weight of the material), or if the waste contains only radium (since radium is not considered source or byproduct material when present in water treatment residuals).

Hazardous waste that contains beta/photon emitters could be considered mixed waste if a licensed source of the contamination can be identified. A few beta/photon emitters occur naturally and can be present in source water; others remain as a legacy of fallout from nuclear weapons testing or originate from discharge from nuclear or medical facilities. Check with the state Radiation Program to see if beta/photon emitters are considered byproduct material. Note that because radium is not considered source or byproduct material, waste containing only radium would not legally be defined as a mixed waste under federal regulations.

I-D.3 Possible Disposal Options if Elevated TENORM is Present

The majority of water treatment systems should not have problems with radiation. The following discussion is intended as guidance for states on disposal options for systems that do have elevated levels of TENORM in their treatment residuals. Table 5 summarizes disposal options for TENORM residuals. Each option is discussed in more detail below.

Table 5: Disposal Options by Type of Residual Produced

Residual Waste	Disposal Options				
	Direct Discharge	Discharge to POTW	Recycle[14]	Underground Injection	Landfill
Liquid Wastes					
Acid Neutralization Water	✓	✓	✓	✓	
Backwash Water	✓	✓	✓	✓	
Brine	✓	✓	✓	✓	
Concentrate	✓	✓	✓	✓	
Rinse Water	✓	✓	✓	✓	
Solid Wastes					
Sludge		✓		✓	✓
Spent Media					✓
Spent Membranes					✓

I-D.3.1 Options for Disposal of Solid Residuals

Depending on the characteristics of the waste, state and landfill-specific disposal restrictions, cost, and system location, solid waste may be disposed of in a solid waste (RCRA Subtitle D), LLRW, or hazardous waste (RCRA Subtitle C) landfill. See Decision Tree 1 on page 17 of this guide for an overview of the decision making process for systems that generate solid residuals. Systems should also be aware that landfill owners can refuse to accept any waste and have the discretion to return any waste to the generator.[15]

U.S. EPA is aware that some states allow land spreading or soil mixing as an alternative to landfill disposal for water treatment residuals (for example, as a soil amendment on farm fields). One central concern with land spreading is the potential for build-up or movement of radionuclides to create contaminated sites that would require remediation and/or use of institutional and engineering controls. Other factors to take into account include the physical and chemical attributes of the material, the amount of radiation introduced into the soil over time, the mobility of radionuclides and their decay products along multiple pathways of exposure, and the consideration of future controls and future land use. Programs would need to be designed to provide adequate risk protection to human health and the environment.

Other options such as incineration, evaporation ponds, surface impoundments, and sludge dewatering are merely intermediate processing methods; each creates its own residual stream. Additional information appears in Section II-B of this guide, "Intermediate Processing." States should consult their relevant waste disposal programs to determine an appropriate disposal option for systems generating solid residuals containing radionuclides. See Appendix D for contact information.

[14]The return of the liquid waste stream into the water system's treatment process.

[15]Please note that if a load is rejected and the material is not identified, DOT exemption paperwork needs to be filled out by a state radiation protection or radiation control employee prior to the load going back on the road. More information about this can be found at the CRCPD Web site at: http://www.crcpd.org/Transportation_related_docs.asp

I-D.3.1.1 Testing for Free Liquids

Systems must perform the Paint Filter Liquids Test (or PFLT; EPA SW 846 Method 9095) to determine if the waste contains any "free liquids" because solid waste landfills cannot accept waste that contains free liquids. If free liquids are present, the system will need to employ an intermediate processing method and determine an appropriate method of disposal for the liquid residuals generated by dewatering. (See Section II-B of this guide, "Intermediate Processing," for more information.)

I-D.3.1.2 Testing for Radionuclides

There is no federal requirement to test waste residuals specifically for radionuclides, and no specific federal regulation governing landfill disposal of water treatment plant solids or sludges containing TENORM. However, systems must comply with more general requirements applicable to the disposal of solid waste.

It is the responsibility of the individual states to determine the most appropriate analytical method for testing water treatment plant waste containing TENORM (and possibly source material) and any requirements or guidelines for disposal. If allowed by the state, systems can use the NRC/U.S. EPA "Guidance on the Definition and Identification of Commercial Mixed Low-Level Radioactive and Hazardous Waste" (available at http://www.epa.gov/radiation/mixed-waste/mw_pg25.htm). If licensable concentrations of source material are found at systems in non-Agreement States, the appropriate NRC regional office should be consulted (see Appendix D).

U.S. EPA and other federal agencies have also developed the Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP), which addresses the need for a consistent national approach to producing radioanalytical laboratory data that meet a project's or program's data requirements. The manual provides guidance for the planning, implementation, and assessment phases of projects that require the laboratory analysis of radionuclides and is available on U.S. EPA's Web site at http://www.epa.gov/radiation/marlap.

States should consult with radiation program staff for more information (see Appendix D), and can also refer to U.S. EPA's list of approved analytical methods at http://www.epa.gov/safewater/methods/methods.html.

I-D.3.1.3 Choosing an Appropriate Landfill

There are several types of landfills that may provide protective disposal for residuals containing radionuclides. The appropriate landfill can depend on the amount, concentration, and physical and chemical attributes of the radiologically-contaminated material, the mobility of radionuclides and their decay products, the consideration of future controls and future land use, and state and local regulations.

I-D.3.1.3.1 Solid waste landfills

Municipal solid waste landfills may have restrictions on the amount of radioactivity they accept. Their ability to accept specific wastes should therefore be verified. These landfills may accept non-hazardous, solid, and TENORM wastes from all water systems, and hazardous waste from Conditionally Exempt Small Quantity Generators (see the MSWLF requirements at 40 CFR 258 and the information on hazardous waste on page 11 of this guide). Industrial solid waste landfills may also accept non-hazardous solid TENORM waste, and may be better equipped to handle such waste as it is more like the waste that industrial landfills typically handle (e.g., sludges and ash).

As they become more aware of issues surrounding disposal of radioactive materials, more landfills are now using monitors to scan incoming trucks for radiation. In some cases, wastes that had previously been accepted were found to contain elevated levels of TENORM. If the monitors are triggered, the source must be identified and evaluated. A list of municipal solid waste landfills (for non-hazardous waste) can be found at http://www.epa.gov/epaoswer/non-hw/muncpl/landfill/section3.pdf.

I-D.3.1.3.2 Hazardous waste landfills

Systems using treatment technologies that remove contaminants such as arsenic, in addition to radionuclides, could potentially generate hazardous waste. Hazardous waste from Large and Small Quantity Generators must meet RCRA Land Disposal Restriction treatment standards (40 CFR 268.40) prior to disposal in a hazardous waste landfill. Facilities permitted under Subtitle C may accept hazardous waste (though not mixed waste) from all generator classes, and vary in their ability to accept TENORM wastes. If hazardous residuals contain source material above 0.05% in weight or other AEA materials they must be disposed of at a facility authorized to accept mixed waste.

Hazardous waste landfills accept hazardous waste from all generator classes, and vary in their ability to accept TENORM wastes. Hazardous waste from Large and Small Quantity Generators must meet RCRA Land Disposal Restriction requirements (40 CFR 268.40). Some hazardous waste landfills have explicit permit conditions while others may have to request state approval before accepting TENORM wastes. Systems should check with the disposal facility to determine whether their TENORM waste is eligible for disposal at a particular hazardous waste landfill.

I-D.3.1.3.3 Low-level radioactive waste landfills

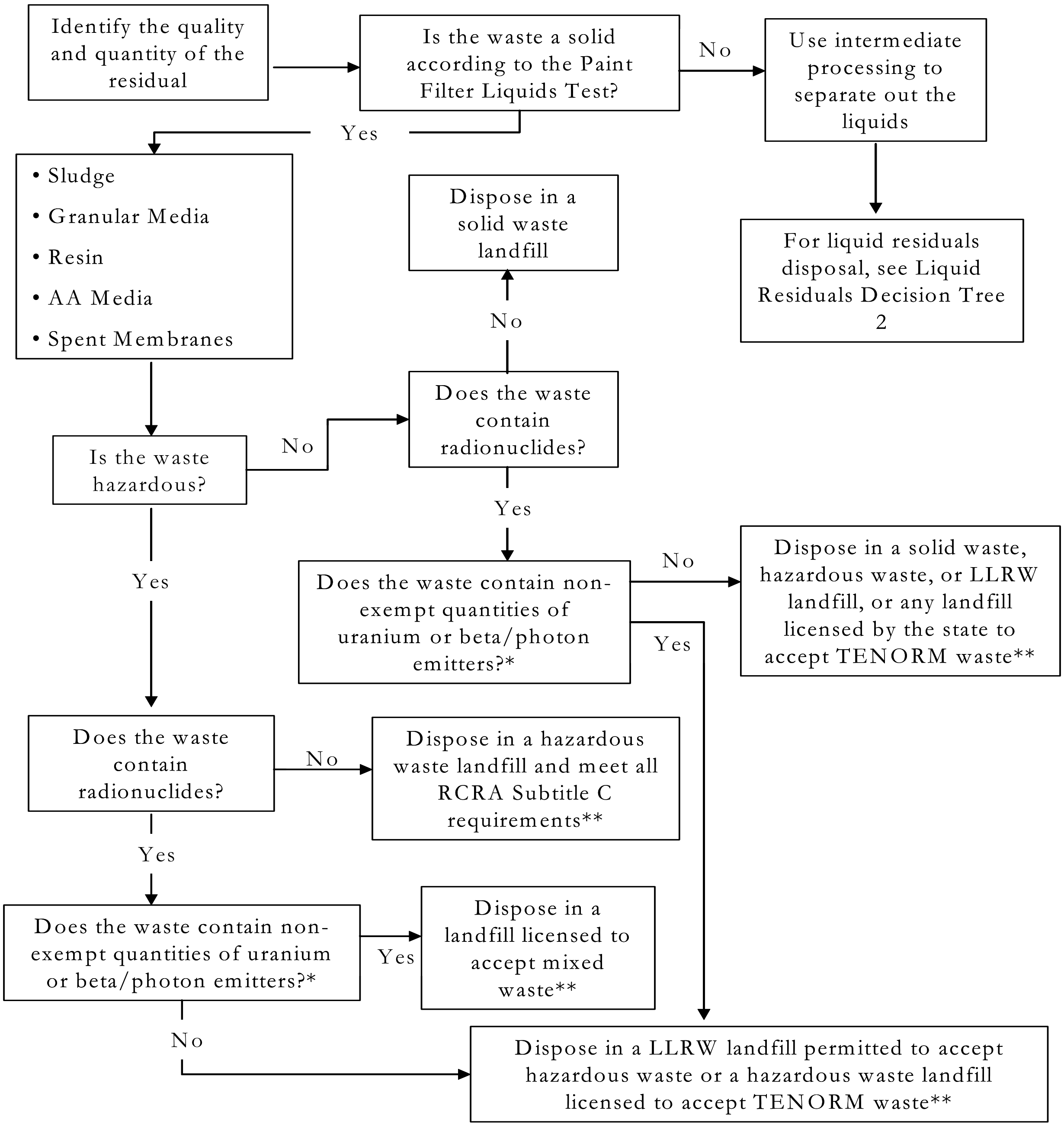
LLRW landfills may be an option for systems generating wastes with radionuclide concentrations deemed to be unacceptable for disposal at a solid or hazardous waste landfill. LLRW landfills are licensed by NRC or by a state under agreement with NRC, and guidelines for disposing of radioactive sludges and solids are more stringent than in a standard landfill. These facilities are licensed based on projected performance and have packaging and burial requirements that are progressively stricter as the radionuclide concentrations increase.

There are three LLRW disposal facilities currently in operation:

Barnwell - South Carolina	Will, after June 30, 2008, accept LLRW only from organizations in South Carolina, Connecticut, and New Jersey. For more information, including waste transport, disposal rates, and site availability, see http://www.state.sc.us/energy/RadWaste/rwdp_index.htm.
Richland - Washington	Accepts certain types of TENORM (although not hazardous or mixed) wastes from all states. Accepts licensed source material only from the 11 states in the Northwest and Rocky Mountain Compacts. State regulators anticipate including activity limits for uranium-238 and radium-226 in the facility's renewed license. For more information, including waste transport, disposal rates, and site availability, see http://www.ecy.wa.gov/programs/nwp/llrw/llrw.htm.
Envirocare - Utah	Has dedicated TENORM disposal and is the only LLRW landfill authorized to accept certain kinds of mixed waste. Does not accept LLRW from Northwest Interstate or Rocky Mountain Compact states. For more information, see http://www.envirocareutah.com.

The Low-Level Radioactive Waste Policy Act gave states the authority to form regional compacts to manage their commercial LLRW. Compact authority generally extends to the import and export of waste to and from states in the compact. If water treatment plants are licensed by the NRC or Agreement State, their disposal options may be limited. Systems should be made aware that compacts may have requirements beyond those of the NRC or Agreement State. For more information on interstate compacts and Agreement States, see http://www.nrc.gov/what-we-do/state-tribal/agreement-states.html.

Decision Tree 1: Solid Residuals Disposal



* Check with the state Radiation Program to see if beta/photon emitters are considered byproduct material and advise system to contact the NRC Regional office or relevant Agreement State agency to discuss potential licensing requirements.

** LDR treatment standards also apply. Check with the state Radiation Program to determine the proper disposal methods for waste containing radionuclides and hazardous waste.

I-D.3.2 Options for Disposal of Liquid Residuals

The options discussed below *may* be used for the disposal of liquid residuals including brines, concentrates, rinse waters, backwash waters, acid neutralization waters, spent filter backwash water, filter-to-waste waters, supernatants, and liquids from dewatering. A system's options will depend on state regulations, the characteristics of the waste, and cost-effectiveness. System location can also affect options; rural systems not located near a receiving body or POTW may have to bulk transport liquid wastes for disposal (which may present additional problems, as systems transporting over 270 pCi/g of uranium or 2,700 pCi/g of radium may be subject to DOT's radioactive material transport regulations). States should consult with the appropriate program contacts to discuss which of these options (or any alternative options) are available. See Appendix D for contact information, Decision Trees 2 and 3 for an overview of the decision making process for systems that generate liquid residuals, and Section II-B for information on intermediate processing methods for residuals.

I-D.3.2.1 Direct Discharge

Direct discharge may be an option for disposal of liquid wastes if a system has an accessible and appropriate receiving body. The CWA requires that anybody discharging pollutants into U.S. waters through a point source must obtain a National Pollutant Discharge Elimination System (NPDES) permit from the authorized state or U.S. EPA Region (CWA, Title IV, Section 402). These permits set limits on the amount of certain pollutants that can be discharged. They also set monitoring and reporting requirements and may include other provisions that protect water quality and public health.

Federal water quality criteria and standards regulations do not set specific limits on radionuclides in discharges. States have the authority to set criteria, standards and derived NPDES limits, and enforce them through permits. In addition, state anti-degradation policies are also designed to protect the quality of certain water bodies and source water protection efforts might restrict the levels of radionuclides in discharged waste. NRC regulations also restrict licensees from releasing effluents containing radionuclides to the general environment (10 CFR 20.1301 to 1302). The BATs and SSCTs listed in the Radionuclides Rule also remove co-occurring contaminants for which NPDES regulations set limits; this could potentially further restrict a system's options.

I-D.3.2.2 Discharge to Publicly Owned Treatment Works

Drinking water systems may be able to discharge liquid wastes to a POTW indirectly through sanitary sewers or force mains or by transporting the waste directly to the POTW. In most cases, such systems are not required to obtain a NPDES permit, but must ensure that their wastes meet the general and specific prohibitions of the Pretreatment Program and any Technically Based Local Limits (TBLLs) that may be established by the state or by the POTW itself. TBLLs should ensure that the POTW systems meet federal (40 CFR 403), state, and local pretreatment regulations, and prevent the discharge of any waste that would interfere with or pass through the POTW treatment process and cause a violation of the POTW's NPDES permit, or inhibit recycling or reuse of the POTW's biosolids. Municipalities (POTW owners) can refuse to accept waste that might trigger these events, and they generally have the legal authority to refuse any wastewater that may pose other disposal problems for the POTW. Refer to Interagency Steering Committee on Radiation Standards (ISCORS') *Assessment on Radioactivity in Sewage Sludge: Recommendations on Management of Radioactive Materials in Sewage Sludge and Ash at Publicly Owned Treatment Works* for more information on POTW legal and regulatory authority, and for guidance on identifying circumstances where discharge of liquid residuals to a POTW may interfere with sewage sludge management practices or may pose a potential worker or general public exposure concern.

Arrangements between POTWs and systems may be enforced and conditioned by a local permit issued to the system or through a contract, depending on federal, state, and local regulations. U.S. EPA regulations on the use and disposal of the sewage sludge produced by POTWs (40 CFR 257 and 503) currently do not cover radioactive material. States should encourage systems to contact the state NPDES program and potential receiving POTW, prior to choosing discharge to a POTW as a disposal option to determine whether the system is capable of meeting the applicable local limits, and to ensure that the wastes will be accepted.

Note that liquid wastes that are mixed with domestic sewage and discharged to a POTW are not regulated under RCRA, because they are subject to the Clean Water Act. This exclusion from RCRA is commonly known as the domestic sewage exclusion (§261.4(a)(1)).[16] A hazardous waste that is accumulated, managed, or transported (e.g., by truck) prior to introduction into the sewer system, however, would still be subject to regulation as a hazardous waste. Encourage systems that believe their wastes to be hazardous to contact the appropriate state agency and local POTW to ensure that wastes are properly managed.

Systems that exceed both the 'unimportant quantity' and 'small quantity' thresholds for uranium will normally be specifically licensed by NRC or Agreement State; there are strict limits set by 10 CFR 20.2003 for disposal into any sanitary sewer systems. Under these conditions: the material must be readily soluble (or readily dispersed biological material) in water; the quantity of licensed or other radioactive material that is released into the sewer in one month, divided by the average monthly volume of water released into the sewer, cannot exceed the concentration listed in Table 3 of Appendix B in 10 CFR 20; and the total quantity of licensed and other radioactive material that the licensee releases into the sanitary sewer in a year cannot exceed 5 curies (185 GBq) of hydrogen-3, 1 curie (37 GBq) of carbon-14, and 1 curie (37 GBq) of all other radioactive materials combined. Additional requirements apply if more than one radionuclide is released. If the state has adopted naturally occurring radioactive material (NORM) or TENORM regulations which apply to water treatment facilities, those regulations should be consulted to determine if there are radionuclide discharge requirements to POTWs.

I-D.3.2.3 Underground Injection

U.S. EPA developed federal regulations under SDWA that address underground injection and protect underground sources of drinking water. To determine which federal UIC regulations apply, systems will need to determine if their waste is radioactive, hazardous, or nonhazardous. Under the UIC regulations, "radioactive" refers to any waste containing radioactive concentrations that exceed those listed in 10 CFR 20, Appendix B, Table 2, Column 2. These concentrations are 60 pCi/L for radium-226, 60 pCi/L for radium-228, and 300 pCi/L for uranium.

Note that the "unity rule" applies if there is more than one radionuclide involved. The "unity rule" sets the concentration limit of each radionuclide such that the sum of the fractions contributed by each radionuclide does not exceed 1. For example, in a material with 30 pCi/L of radium-226, 30 pCi/L of radium-228, and 150 pCi/L of uranium, the fraction contributed by radium-226 is 30/60 pCi/L, or 0.5; the fraction contributed by radium-228 is 30/60 pCi/L, or 0.5; and the fraction contributed by uranium is 150/300 pCi/L, or 0.5.

The sum of these fractions is 1.5, which exceeds 1; underground injection of the material would therefore be prohibited. If, however, the concentrations of radium-226, radium-228, and uranium were 15 pCi/L, 15 pCi/L, and 150 pCi/L, respectively, the fractions would be 15/60 pCi/L, or 0.25 for radium-226, 15/60 pCi/L, or 0.25 for radium-228, and 150/300 pCi/L, or 0.5 for uranium. The sum of these fractions (0.25 + 0.25 + 0.5) is 1. Underground injection of this material would therefore be allowed.

The UIC Program does not regulate single-family residential waste disposal systems such as single-family septic systems. However, SDWA (Section 1431) gives U.S. EPA the authority to take action on a residential waste disposal system if the system introduces contaminants into an underground source of drinking water whose presence or likely presence causes an imminent and substantial endangerment to public health (Section 1431 SDWA).

Table 6 describes the five classes of wells regulated by the UIC Program, the wastes these wells can accept, and the issues systems should consider before pursuing underground injection as a disposal option. Contact the appropriate

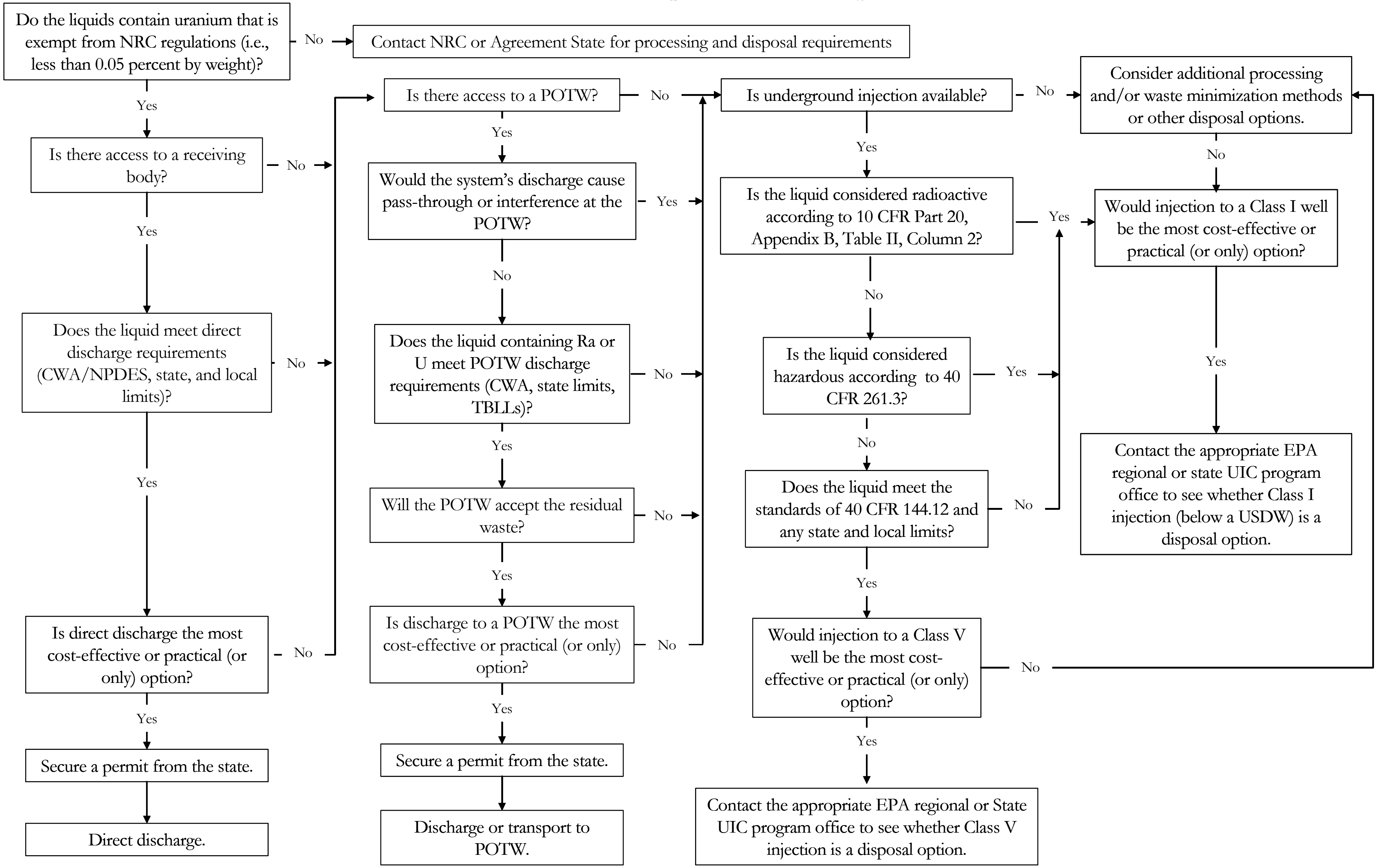
[16] Under this exclusion, these wastes are not considered to be RCRA "solid waste" and therefore cannot be classified as a hazardous waste.

U.S. EPA regional or state UIC program office for any additional state-specific UIC requirements. For additional information, systems should be referred to the appropriate U.S. EPA regional, state, or tribal UIC program listed in Appendix D.

Table 6: Underground Injection of Liquid TENORM Residuals

Class	Use	Considerations
I	Used to place radioactive, hazardous, or non-hazardous fluids (industrial and municipal wastes) into deep isolated formations beneath the lowermost USDW. There are 272 Class I injection facilities nationwide. For more information see: http://www.epa.gov/safewater/uic/classi.html	▸ Class I wells have stringent protective requirements to ensure safe injection ▸ Very few Class I facilities are commercial (able to accept hazardous or mixed waste generated off-site for injection) ▸ Disposal of slurries and solids is allowed in only limited circumstances because of the potential to fracture the receiving formation ▸ Class I wells can be expensive to construct because they are technically complex
II	Used to place produced water and other fluids in connection with oil and gas production.	Not an option
III	Used for mineral extraction.	Not an option
IV	Shallow wells used to inject hazardous or radioactive waste into or above a USDW.	▸ Class IV wells were banned in 1984. ▸ Not an option
V	Includes injection activities not described in Classes I-IV. These are generally shallow wells (e.g., large capacity septic systems and dry wells) used to place a variety of non-radioactive, non-hazardous fluids into or above USDWs.	▸ Not an option for hazardous or radioactive waste disposal ▸ Use of class V wells is prohibited if it will endanger a USDW per CFR 144.12 (cause an exceedance of any primary drinking water standard or otherwise adversely affect public health) ▸ Class V wells must also comply with state specific UIC requirements, which may be more stringent

Decision Tree 2: Liquid Residuals Disposal



I-E Worker Exposure and Safety

Because radiation is invisible, tasteless, and odorless, it is commonly overlooked as a potential hazard at water systems. Exposure to elevated levels of radiation at water treatment facilities may cause serious health effects. Systems need to determine whether a radiation problem exists and, if it does, take appropriate safety precautions to prevent or limit water system staff members' exposure to radiation. For example, if a system tested its treated water 2 years ago and found levels of 3pCi/L for radium-226 and 228, a radiation survey of the facility would be prudent.

Water system staff can be exposed to radiation during normal treatment processes for radionuclides, through handling the residual streams generated by treatment, and during media replacement or transportation. Relatively undetectable levels of radionuclides in source waters can accumulate in measurable or hazardous quantities in piping, pumps, holding tank scale or sludge, IX and granular filters, backwash, and other residual sludge. Radon gas can accumulate in closed or poorly ventilated buildings when thorium, uranium, or radium-bearing materials (including water) are present. Naturally occurring radon gas can enter through openings in the building's concrete or foundation walls. Underground connections to manholes, piping conduits, and utility tunnels provide additional pathways for radon entry. For example, elevated gamma ray levels have been found around IX columns and associated piping at some facilities. This could result in an exceedance of public dose limits.

I-E.1 Radiation Surveys

A system should contact a professional radiation protection specialist or a health physicist for assistance in conducting a radiation survey if: (1) the system has had an analytical result within the past 5 years that has approached or has exceeded an MCL for a regulated radionuclide; or, (2) if calculations derived from use of the U.S. EPA SPARRC model indicates potential concentrations of radioactivity in residuals and filters at the system.[17]

A radiation survey can be conducted by:

1. Using a radiation survey meter to identify any points at which contamination exists.

2. Using an integrating radiation measuring device to determine whether exposure could occur over time.

3. Sampling filter media, wastes, and water through further laboratory analyses. These analyses should focus on finding the principal NORM/TENORM isotopes found in surface and groundwater supplies: radium, uranium, thorium, and potassium as well as their radioactive daughter decay products.[18]

Some states require radiation protection specialists or health physicists who conduct radiation surveys (including radon surveys) to be certified or licensed. State Radiation Control contact information appears in Appendix D.

As a result of the survey, the system may need to establish a monitoring program, change existing management practices, alter methods for managing radioactively contaminated equipment and wastes, or establish worker radiation safety and education programs. The survey may also recommend methods for decontaminating buildings or facilities, if needed.

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[17]A working draft of SPARRC is available for estimating the volume and concentration of radionuclides in waste produced by water systems. The program allows the operator to select the type of treatment process, as well as input and output parameters such as water flows, doses of coagulant and polymer, and filter capacities. To view the spreadsheet, see http://www.npdespermits.com/sparrc.

[18]Decay products such as isotopes of radon, lead, polonium, and bismuth may need to be analyzed in order to calculate the concentrations of the original parent radionuclide such as radium or uranium. Characterizing the types and amounts of radionuclides present will be beneficial in identifying sources in the drinking water, understanding how, where, and why they are collecting in the treatment plant, correcting a contamination problem in the plant through selection of treatment technologies and management techniques, and aiding management in deciding where hazardous waste products should be disposed or where they might be accepted.

Although designed for post-cleanup surveys of radioactively contaminated sites, U.S. EPA's *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (EPA 402-R-97-016 Rev. 1) provides useful information on planning and conducting a survey of potentially contaminated surface soils and building surfaces. The manual and other information on radiation surveys can be obtained from U.S. EPA's Radiation Protection Division Web site at http://www.epa.gov/radiation/marssim.

Seven federal and two state agencies contributed to the development of MARLAP. MARLAP provides guidance for the planning, implementation, and assessment phases of projects that require laboratory analysis of radionuclides. This guidance is intended for project planners, managers, and laboratory personnel and provides extensive detail on the radiological sampling and analytical process, including laboratory procedures. A copy of the manual can be found at: http://www.epa.gov/radiation/marlap/manual.htm.

U.S. EPA also recommends that the system check for the presence of radon in buildings encasing system equipment. States should consult with radiation program staff to determine whether radon measurements have been taken in the county, whether a map or survey of indoor radon measurements has been developed for the county, where the system is located, and to determine the appropriate means and methods for conducting radon surveys. The state or private radon proficiency programs may be able to provide a list of licensed or certified radon contractors who could conduct the survey. Additional information on how to find qualified professionals can be found at http://www.epa.gov/iaq/radon/proficiency.html.

For U.S. EPA guidance documents on approaches to risk assessments of soil and water, see the Superfund Radiation Web sites at http://www.epa.gov/superfund/resources/radiation and http://www.epa.gov/superfund/resources/radiation/whatsnew.htm.

I-E.2 Radiation Exposure Due to Water Treatment Operations

The following discussion applies only to systems where there is the potential for accumulation of radioactivity.

Water system workers are most likely to be exposed to elevated levels of radioactive materials when coming into contact with residuals, filter backwash, and sludge; during maintenance of contaminated pumps or piping; or while moving or transporting wastes and filters for disposal. Possible sources of radiation include pumps and piping where mineral scales accumulate; lagoons, and flocculation and sedimentation tanks where residual sludges accumulate; filters, pumping stations, and storage tanks where scales and sludges accumulate; and facilities where filter backwash, brines, or other contaminated water accumulates. Facilities that are enclosed present the potential for enhanced radiation inhalation exposure, particularly from radon. Exposure to radiation can also occur at residuals processing or handling areas at the system and off-site locations such as landfills where residuals are shoveled, transported, or disposed of.

The table below shows the three primary paths of radiation exposure at a system: inhalation, ingestion, and direct exposure.

Pathway	Concern
Inhalation	Inhalation of alpha- or beta-emitting radioactive materials is a concern because radioactive material taken into the body results in radiation doses to internal organs and tissues (e.g., lining of the lungs). Workers could inhale radioactively contaminated dust or water droplets while dealing with residuals or during normal filter operations. Cleaning methods such as air scour, high pressure water sprays, and backwash operations can increase suspension of radioactively contaminated water, dusts, and particulates in respirable air, thus increasing the potential hazard of inhalation or ingestion. Workers can inhale radon and its progeny in both wet and dry conditions. Simple dust masks may not provide adequate protection from exposures via this pathway, and systems may need to implement Occupational Safety and Health Administration (OSHA) requirements for respirators.

Pathway	Concern
Ingestion	Ingestion, or the swallowing of alpha, beta, or gamma-emitting radioactive materials, is a concern for the same reasons as inhalation exposure. Workers can ingest radioactive materials if they fail to observe good sanitary practices including washing their hands before eating; failing to cover their noses and mouths by wearing approved respiratory protection and swallowing contaminated dusts and water droplets; or eating and drinking in areas (including land disposal sites), where dusts or water droplets could settle on food or drink. Simple dust masks may not provide adequate protection from exposures via this pathway.
Direct Exposure	Radioactive materials that emit gamma radiation are of concern because the gamma rays pose an external radiation exposure hazard. Because gamma rays can pass through common construction materials and most protective clothing, the distance between the radioactive material and the person, as well as the time spent in proximity to the material are factors in the amount of exposure the person receives. As gamma radiation travels through air, exposure can occur near a source of radiation as well as through direct contact. Workers most likely to be directly exposed are those who handle or work in the vicinity of resin tanks, residuals, filter backwash, and contaminated brines or waters, or participate in the maintenance of the treatment system or the replacement and transportation of filter media.

The International Commission on Radiological Protection (ICRP) and National Council on Radiation Protection and Measurements (NCRP) have recommended that facilities strive to make the levels of radiation to which the public and the environment are exposed as low as reasonably achievable (ALARA) (i.e., below regulatory limits) taking into account social and economic considerations. Steps that facilities can take include limiting the time that workers spend handling radioactive material, increasing the distance between workers and the material, and providing shielding from the radioactive material.

In addition, OSHA has developed occupational radiation standards (see 29 CFR 1910.1096) that might apply whenever an operator becomes aware of the presence of radiation at the facility. Although these standards may not apply to municipal water treatment plant workers, these workers may be covered by their state OSHA program, requiring that all controls, monitoring, record keeping, and training outlined in the OSHA standards be met.

Additional OSHA standards that may be applicable to water systems include:

- Requirements that personal protection equipment (or PPE, for the eyes, face, head, and extremities) such as protective clothing, respiratory devices, and protective shields and barriers be provided, used, and maintained whenever processes or radiological hazards capable of causing injury through absorption, inhalation, or physical contact necessitate such equipment. There are numerous other requirements related to the possession and use of PPE, including training for employees who would use the equipment. For more information, see 29 CFR 1910.132-136.

- Requirements for practices and procedures to protect employees in general industry from the hazards of entry into permit-required confined spaces. For more information, see 29 CFR 1910.146.

- Lockout/tagout requirements that require employers to establish a program and follow procedures for affixing appropriate lockout or tagout devices to energy isolating devices and disable machines or equipment. This avoids injury to employees by preventing unexpected energization, start-up, or release of stored energy. For more information, see 29 CFR 1910.147.

- Hazardous communication requirements that ensure the potential hazards of chemicals produced during or imported for treatment are evaluated and the information from this evaluation is communicated to employees through measures such as container labeling, material data safety sheets, and employee training, among others. These requirements do not apply to RCRA-defined hazardous waste or ionizing or non-ionizing radiation. For more information, see 29 CFR 1910.1200.

In circumstances where a facility may in the future be licensed by the NRC or Agreement State, worker safety precautions and radiation protection controls would take precedence (e.g., 10 CFR 20.1900, which lists radiation exposure posting requirements).

In addition to the OSHA requirements, systems should be encouraged to follow the safety practices listed below. These measures can reduce workers' risk of exposure to radioactivity and radioactive particulates:

Safety Measures

- ✓ Use an OSHA-approved respirator to avoid inhalation of biological pathogens and chemically toxic materials in residuals. Simple dust masks may not provide adequate protection.
- ✓ Limit time spent at land disposal sites to reduce inhalation of contaminated dust.
- ✓ Ventilate all buildings, especially where waste with high concentrations of radium is stored.
- ✓ Take standard OSHA measures to limit the potential ingestion of heavy metals and biological pathogens present in filters, residual sludges, and at land disposal sites to help reduce possible ingestion exposure to radioactive materials.
- ✓ Use protective gloves and frequently wash hands (particularly before eating and drinking) to reduce the potential for ingestion. Similarly, avoid eating and drinking in the vicinity of facilities or land disposal sites where air suspension of contaminated particulates or water droplets could occur.
- ✓ Avoid direct contact with any solid TENORM waste and use shovels or other remote-handling tools during extraction, transfer, and packaging.
- ✓ Locate treatment units and waste storage areas as far away from common areas (e.g., offices) as possible.
- ✓ Shower after exposure to potentially radioactive materials and launder work clothing at the system if possible. If laundering equipment is not available, workers should keep and wash work clothing separately and avoid wearing contaminated clothing into the home. Work boots or shoes should be wiped and cleaned after potential contamination. They should stay at the system or not be worn into the home.
- ✓ Use gamma survey instruments or equivalent monitors at least once annually to monitor the system's ambient radiation levels in areas where radionuclides are removed.
- ✓ Monitor levels of radiation to which staff are exposed. Systems should contact, or be referred to, state or other radiation experts for more information on how to monitor radiation levels.

Treatment plants that are licensed by the NRC or Agreement State should be referred to CFR Parts 19 and 20 for licensee reporting, notification, inspection, and safety requirements. Licensed facilities are required to post the regulations listed under Parts 19 and 20, along with numerous other documents related to the license and the activities conducted under the license. Employees likely to receive occupational doses greater than 100 mrem/year must be kept informed and instructed on various issues related to health protection, relevant regulations, and the facility's storage and transport of radioactive materials, among other things. Licensees must also keep individual employees informed of the annual radiation dose that they receive. Current and former employees can also request reports on their exposure to radiation or radioactive material.

10 CFR Part 20 outlines requirements for licensees to develop radiation protection programs (10 CFR 20.1101), sets dose limits and occupational limits for exposure to radiation (10 CFR 20.1201 to 1302), instructs licensees on how to

control access to areas where radiation levels are high or very high (10 CFR 20.1601 and 1602), and sets restrictions on the use of individual respiratory equipment (10 CFR 20.1703 and 1704), among other things.

Part 20 also sets requirements related to storage and control of licensed material, including posting, signage, and labeling requirements (10 CFR 20 Subparts I and J). These regulations stipulate that licensees' radiation protection programs be designed around the ALARA principle and require licensees to limit air emission of radioactive material (excluding radon-222 and its daughters) so that the highest total effective dose equivalent received by any member of the public is no greater than 10 mrem/year. Part 20 also sets notification requirements in the case of an incident at the licensed facility or for cases in which the facility is required to report exposures, radiation levels, or concentrations of radioactive materials exceeding constraints or limits (10 CFR 20.2201 to 2203). Consult with your NRC regional office or relevant state agency to ensure that any licensed facilities in your state are aware of these additional worker safety requirements.

I-E.3 Additional Safety Considerations

Radon is a natural decay product of radium and other radionuclides. It can vary in concentration by time of day or seasonally. It is appropriate for systems to consider radon protection measures when handling wastes containing radium. U.S. EPA recommends that action be taken to reduce radon levels in homes and schools where testing shows average concentrations of 4 pCi/L or greater. Although exposure to radon in homes or schools is evaluated differently than occupational exposure, many nations and the ICRP recommend that intervention levels for exposure to radon in homes also be used in workplaces.[19] U.S. EPA recommends that the action level used for homes and schools be used for water systems.

If radionuclides or radiation have been found in drinking water or at a system, having operators who are trained in treating for radionuclides, and handling, disposing of, and transporting TENORM waste, is highly recommended. In addition, determine whether your state requires someone specifically licensed by the state or NRC to handle these types of residuals. Operators should also be trained in how to measure radioactivity levels. Encourage systems to check with the relevant state office regarding licensing requirements and training opportunities.

Assistance and advice are available from the appropriate State Radiation Control Program (see Appendix D), the Conference of Radiation Control Program Directors at http://www.crcpd.org, and the U.S. EPA Regional Radiation Programs. For additional references on this and other topics discussed in this guide, see Appendix G.

[19] ICRP, 1993.

Section II: Treatment Technologies Overview

II-A Treatment Methods, Residuals, and Disposal Considerations

Tables 8 through 16 provide brief overviews of the uses, efficiencies, disposal considerations, and limitations of the BATs and SSCTs listed for radionuclide removal, all of which should be considered when choosing an appropriate treatment technology. In addition, the cost of installing, operating, and disposing of the residuals produced by these technologies, will be significant factors for systems choosing a new technology. As systems begin initial monitoring and treatment for, and disposal of these radionuclides, more information on costs will become available.

Note that many of the considerations for solid and liquid residual disposal are identical, regardless of the chosen treatment technology. These disposal options and considerations, introduced in the previous section, are summarized below in Table 7. Several of the technologies in Tables 8 through 16 do not have special considerations or limitations. Note that for systems licensed by the NRC or Agreement State, disposal of residuals may be further restricted.

Table 7: Common Disposal Considerations for Residuals Produced by BATs and SSCTs

Direct discharge	‣ System must have a NPDES permit ‣ Flow equalization may be required to avoid contaminant spikes ‣ Appropriate receiving bodies must be available ‣ Systems must meet state radionuclides limits
Discharge to a POTW	‣ Pretreatment may be required (e.g., flow equalization, pH adjustment, thickening, or chemical precipitation) prior to discharge to avoid interference with the POTW ‣ Systems must meet the TBLLs established by the state and/or the POTW, abide by the terms of the arrangement with the POTW, and meet state permitting requirements
Underground injection	‣ Systems must determine whether their waste is radioactive or hazardous ‣ Class I hazardous injection wells may be a disposal option for radioactive or hazardous wastes under stringent protective measures, and depending on associated constituents and the volume of waste generated ‣ Class V wells may be a disposal option for non-hazardous, non-radioactive fluids if the system can demonstrate compliance with CFR 40 part 144.12 (i.e., would not cause a violation of any primary drinking water regulation, adversely affect public health, or otherwise endanger a USDW) ‣ Single-family septic systems are exempt from federal UIC regulations ‣ Systems should check with their state to determine whether the state has more stringent UIC requirements ‣ U.S. EPA has the authority to take action on any residential waste disposal system if the system introduces contaminants into a USDW whose presence or likely presence causes an imminent and substantial endangerment to public health (SDWA Section 1431).
Landfill disposal	‣ Systems must determine whether the waste is hazardous or non-hazardous (e.g., using the TCLP) and perform the PFLT to determine whether the waste contains free liquids ‣ Systems must check with their states to determine whether landfilling is an acceptable means of disposal for hazardous and non-hazardous solid waste containing radionuclides ‣ The system must choose the appropriate type of landfill, based on the type, volume, and concentration of solid waste generated ‣ The waste must meet all other requirements for landfilling set forth under RCRA, and by the state and the disposal facility ‣ Resins require dewatering prior to disposal; the residual stream generated from dewatering may be disposed of through direct discharge, discharge to a POTW, or underground injection ‣ Regenerating the media prior to disposal may reduce its radionuclide concentration (regenerant streams will need to be disposed of through direct discharge, discharge to a POTW, or underground injection)

Table 8: IX and POU IX Overview

Use	*BAT*	IX is listed as a BAT for radium, uranium, and beta particle and photon activity removal. Anion exchange (AX) resins remove uranium; cation exchange (CX) resins remove radium and soften water. Mixed bed IX is suitable for beta particle and photon activity removal.
	SSCT	IX and POU IX are listed as SSCTs for systems serving 25-10,000 customers for radium, uranium, and beta particle and photon activity removal. POU IX units treat water from a specific tap and must be owned, controlled, and maintained by the water system or a system contractor.
Efficiency	‣ AX removes up to 95% of uranium;[20] CX removes up to 97% of radium.[21] ‣ See also Appendix E, Tables E-1, E-2, and E-3	
Residuals	*Liquid*	Backwash water, brine (volume varies according to raw water quality, unit size, regenerant concentration and media capacity), and rinse water
	Solid	Spent resins
Additional Disposal Issues*	*Direct discharge*	‣ Normally not an option due to high TDS levels and high contaminant concentrations ‣ Blending brine with backwash and rinse can significantly reduce radionuclide concentrations and TDS but usually not to levels that would allow for direct discharge
Limitations	‣ Regeneration of CX resins may not remove all radium from the resin, complicating disposal ‣ Using potassium chloride as a regenerant can increase the efficiency of CX resin regeneration ‣ Systems should conduct pilot tests of IX treatment to determine a regeneration schedule ‣ Some states do not allow systems to run IX resins to exhaustion for uranium removal ‣ Radionuclides may become so concentrated in the brine and resin that they may require special handling and disposal procedures	

*All of the common disposal considerations in Table 7 must also be taken into account.

[20] Lassovszky, P. and Hathaway, S., 1983; Hanson, S., et al, 1987; U.S. EPA, 1992.

[21] Schliekelman, R., 1976; U.S. EPA, 1992a; U.S. EPA, 1977; Brink, W.L., et al, 1978; Lassovszky, P. and Hathaway, S., 1983; U.S. EPA, 1992.

Table 9: RO and POU RO Overview

Use	*BAT*	RO is listed as a BAT for radium, uranium, gross alpha particle activity, and beta particle and photon activity and is also effective at removing other inorganic contaminants, such as heavy metals
	SSCT	RO is listed as a SSCT for radium, gross alpha, and beta particle and photon activity for systems serving 25-10,000 customers, and for uranium for systems serving 501-10,000 customers. POU RO is a SSCT for radium, uranium, gross alpha particle activity, and beta particle and photon activity for systems serving 25-10,000 customers. POU RO units treat water from a specific tap, and must be owned, controlled, and maintained by the water system or a system contractor.
Efficiency	▸ RO can remove at least 90% of these radionuclides from drinking water ▸ See also Appendix E, Tables E-1 and E-4	
Residuals	*Liquid*	Concentrated liquid waste stream
	Solid	Spent membrane
Limitations	▸ Using RO necessitates having a highly skilled operator ▸ Residuals produced can have very high concentrations of the contaminants removed from the water, including radionuclides, which may limit disposal options. The concentration depends on the efficiency of the RO unit: highly efficient units will produce low volumes of residual streams with high concentrations of contaminants while lower efficiency units will produce higher volumes of residual streams with lower concentrations of contaminants.	

Table 10: Lime Softening Overview

Use	*BAT*	Listed BAT for the removal of radium and uranium from drinking water
	SSCT	Listed SSCT for the removal of radium for systems serving 25-10,000 customers and for the removal of uranium for systems serving 501-10,000 customers
Efficiency	‣ Removal efficiency depends on the pH of the influent water ‣ Seventy-five to 90% of radium can be removed from water with pH levels above 10;[22] the pH range for radium removal is 9.5 to 11.0 ‣ Uranium removal can be as low as 16% and as high as 97%;[23] the pH should be at least 10.6 ‣ Adding magnesium carbonate during treatment can increase the efficiency of uranium removal to 99%; ferric chloride may also increase efficiency, depending on raw water uranium concentrations and pH ‣ See also Appendix E, Table E-1	
Residuals	*Liquid*	Spent filter backwash water (contains radium, uranium, particulates, and co-occurring contaminants)
	Solid	Spent filter media and lime sludge (contains high concentrations of radium, uranium, and co-occurring contaminants)
Additional Disposal Issues*	*Landfill disposal*	Because of high concentrations of radionuclides and co-occurring contaminants, sludge may require special disposal (i.e., in a LLRW or hazardous waste landfill)
Limitations	‣ Using lime softening technology necessitates having a highly skilled system operator ‣ There are many source water quality concerns that should be addressed to ensure the efficiency of radionuclide removal and the process involves complex water chemistry. This technology may be too complicated, expensive, and time-consuming for small systems to use.	

*All of the common disposal considerations in Table 7 must also be taken into account.

Table 11: Green Sand Filtration Overview

Use	*SSCT*	Listed as a SSCT for radium removal for systems serving 25-10,000 customers
Efficiency	‣ Green sand has shown removal efficiencies ranging from 19% to 63% for radium-226 removal and 23% to 82% for radium-228 removal[24] ‣ High concentrations of manganese in an oxidized state increase the efficiency of radium adsorption; high concentrations of manganese in an unoxidized state or iron in the ferric state limit the efficiency of adsorption ‣ See also Appendix E, Tables E-1, E-6, and E-7	
Residuals	*Liquid*	Spent filter backwash water (contains radium, particulates, and co-occurring contaminants)
	Solid	Spent filter media and sludge
Limitations	‣ Source water quality can greatly affect the efficiency of green sand filtration in removing radium from drinking water ‣ If the pH of the water is below 6.8, green sand may remove an inadequate level of iron and manganese; running the water through a calcite filter or adding lime or sodium hydroxide can raise the pH above 7.0	

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[22]Brink, W.L., et al, 1978; U.S. EPA, 1977; U.S. EPA, 1992.

[23]Sorg, T., 1990.

[24]Peterson, K., 2000.

Table 12: Co-precipitation with Barium Sulfate Overview

Use	*SSCT*	Listed as a SSCT for radium removal for systems serving 25-10,000 customers
Efficiency	Co-precipitation with barium sulfate (using a soluble barium salt such as barium chloride) has been shown to remove over 95% of radium from mine wastewaters, and between 40% and 90% of radium from drinking water[25]	
Residuals	*Liquid*	Spent filter backwash water (contains radium, particulates, and any co-occurring contaminants)
	Solid	Spent filter media (contains moderate concentrations of radium and any co-occurring contaminants) and high volumes of barium sulfate sludge (may contain high concentrations of radium and any co-occurring contaminants)
Limitations	‣ This technology necessitates having a highly skilled operator ‣ This technology is not widely used. It is more commonly used to remove radium from waste effluents than from drinking water and is only effective for source waters with high sulfate levels. ‣ This technology involves static mixing, detention basins, and filtration. It may not be practical for small systems that do not already have in place suitable filtration to treat high sulfate levels.	

Table 13: Electrodialysis/Electrodialysis Reversal Overview

Use	*SSCT*	Listed as a SSCT for radium removal for systems serving 25-10,000 customers; also effective at removing uranium
Efficiency	See Appendix E, Table E-1	
Residuals	*Liquid*	Concentrated waste stream
	Solid	Spent membranes
Limitations	Systems may have difficulty removing radionuclide build-up from the membrane, which could complicate disposal	

[25] Clifford, D.A., et al, 1988.

Table 14: Pre-formed Hydrous Manganese Oxide (HMO) Filtration Overview

Use	*SSCT*	Listed as a SSCT for radium removal for systems serving 25-10,000 customers
Efficiency	Radium removal efficiency depends on the levels of HMO added during the treatment process; removal efficiencies of up to 90% may be achieved[26]	
Residuals	*Liquid*	Spent filter backwash water (contains radium, particulates, and any co-occurring contaminants)
	Solid	Spent filter media (contains moderate concentrations of radium and any co-occurring contaminants) and sludge
Limitations	‣ Operators should determine the appropriate dosage of HMO, taking source water characteristics into consideration ‣ If source water iron levels are high, oxidation can enhance iron removal through filtration; if iron coatings form on the filter, radium can be desorbed ‣ HMO treatment installation may be prohibitively expensive for systems that do not already have a filtration system	

Table 15: AA Overview

Use	*SSCT*	Listed as a SSCT for uranium removal for systems serving 25-10,000 customers
Efficiency	AA may remove up to 99% of uranium in drinking water[27]	
Residuals	*Liquid*	Spent brine (volume varies according to raw water quality, unit size, regenerant concentration and media capacity), rinse water, backwash, and acid neutralization
	Solid	Spent media
Additional Disposal Issues*	*Direct discharge*	‣ Normally not an option due to high TDS levels and high contaminant concentrations ‣ Blending brine with backwash, rinse, and acid neutralization waters can significantly reduce radionuclide concentrations and TDS ‣ Additional pretreatment may be required in addition to flow equalization
Limitations	‣ AA has a higher affinity for other contaminants, such as arsenate, fluoride, and sulfate[28] ‣ The technology is very pH sensitive and the handling of chemicals required for pH adjustment (to increase uranium removal) and regeneration necessitates having a highly skilled system operator ‣ Successful operation may require monitoring effluent pH to establish accurate breakthrough curves ‣ Special disposal procedures may be required for media that can no longer be regenerated, particularly if the media has not been regenerated before removal	

*All of the common disposal considerations in Table 7 must also be taken into account.

[26] Tonka Equipment Company, date unknown.

[27] Sorg, T., 1988.

[28] AWWA, 1999.

Table 16: Coagulation/Filtration Overview

Use	*BAT*	Listed as a BAT for uranium removal
	SSCT	Listed as a SSCT for uranium removal for systems serving 25-10,000 customers
Efficiency	▸ The efficiency of uranium removal depends on water pH, the prevailing charge on the floc, and the types and amount of uranium present in the water ▸ Uranium removal efficiencies of 85% to 95% have been observed at pH levels of 6.0 and 10.0[29] ▸ See also Appendix E, Table E-1	
Residuals	*Liquid*	Spent filter backwash water and filter-to-waste (if practiced)
	Solid	Sludge and spent filter media
Additional Disposal Issues*	*Direct discharge*	Blending brine with backwash water can significantly reduce radionuclide concentrations and TDS
Limitations	▸ The use of this technology for uranium removal is only practical if the system has coagulation/filtration in place and can modify the existing processes to optimize uranium removal ▸ Choosing the most suitable coagulant for a system requires an understanding of source water characteristics, especially pH. The choice of coagulants will affect the characteristics of the residuals produced during treatment. ▸ Using this technology necessitates having a highly skilled system operator	

*All of the common disposal considerations in Table 7 must also be taken into account.

[29]U.S. EPA, 1992.

II-B Intermediate Processing

For some systems, processing residuals prior to disposal may be cost-effective. The available intermediate processing options vary in complexity and may help determine the final disposal method. Residual processing may be as simple as collecting residuals for direct disposal or as difficult as incorporating complex treatment technologies that generate additional residual streams which must also be addressed. Intermediate processing can make residual streams eligible for disposal via the sometimes otherwise limited methods available to a system and, in some cases, can reduce the volume of waste produced.

Table 17 outlines intermediate processing options, according to the type of residual produced.

Table 17: Intermediate Processing Options

	Intermediate Treatment				
Residual Stream	Flow Equalization	Chemical Precipitation/ pH Adjustment[1]	Thickening[1]	Dewatering[2]	Recycle
Brine, Backwash, Rinse, and Acid Neutralization	✓	✓	✓	✓	✓
Concentrate (i.e., membrane reject stream)		✓	✓	✓	✓
Spent Filter Backwash and Filter-to-Waste	✓	✓	✓	✓	✓
Sludge			✓	✓	✓

[1] Sludge and supernatant produced.
[2] Dewatering is preceded by thickening. Sludge of increased solids concentration and liquid from dewatering produced.

- **Flow equalization** is necessary when residual streams do not have a consistent flow and vary significantly in their physical and chemical characteristics. These may include liquid wastes from IX and AA processes, spent filter backwash, and filter-to-waste. Systems may need to collect the regeneration waste stream in a holding tank to ensure constant flow and radionuclide concentrations. If the tank is mixed, then a sludge will not be produced. If the tank is not mixed, a supernatant and sludge will be generated, and the system must decide how to dispose of these wastes.

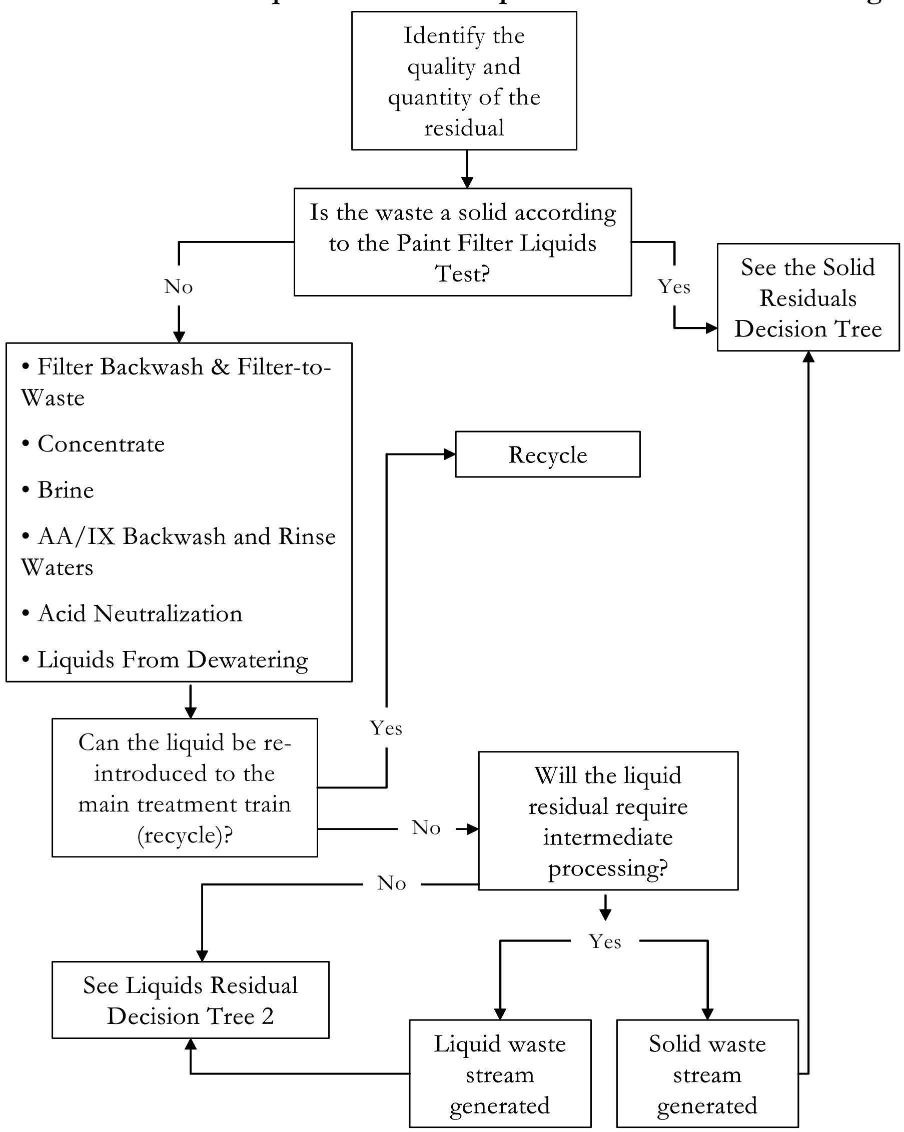
- **Chemical precipitation** involves precipitation of ions into an insoluble form in a reactor vessel followed by separation in a clarifier. (Flocculation can be used to enhance removal of suspended solids.) This procedure generates two waste streams that must be disposed of: a supernatant and the precipitated waste slurry or sludge. Systems may be able to recycle the supernatant. In addition, pH adjustment may be necessary for disposal of residuals. Compliance with specific disposal options may require that acidic or basic liquid residuals be neutralized.

- **Thickening** of liquid residuals, such as spent filter backwash, or sludge will allow the liquid and solids to separate. This produces a sludge and supernatant that may require further processing. Depending on the treatment technology used, both the sludge and the supernatant could contain radionuclides.

- **Dewatering** increases the solids concentration for final disposal, producing a sludge of increased solid concentration and a liquid. This can be done mechanically (e.g., through a centrifuge, belt filter press, or vacuum filter), or non-mechanically (e.g., through sand drying beds, freeze-thaw beds, solar drying beds, or dewatering lagoons). These non-mechanical processes may not be cost-effective; they are very land-intensive and can be climate dependent. Systems should check with their states for design guidelines, regulations, and permitting restrictions for these processes.

- **Recycle** of residuals, such as membrane concentrate and spent filter backwash, is also an option for systems. During treatment with lime softening, a portion of the sludge is recycled. Systems should avoid recycle practices that will concentrate radionuclides to levels that make disposal prohibitively expensive. In addition, the Filter Backwash Recycling Rule (FBRR) applies to those systems using surface water or groundwater under the influence of surface water, who recycle spent filter backwash, thickener supernatant, and liquids from dewatering processes from conventional or direct filtration systems.

Decision Tree 3: Liquid Residuals Disposal: Intermediate Processing



Appendix A: Glossary

Agreement State - A state under a signed agreement with the NRC (in which the NRC relinquishes authority to the Agreement state), that regulates source material, byproduct material, and small quantities of special nuclear material within the state's boundaries.

ALARA (As Low As Reasonably Achievable) - Target radiation exposure level, endorsed by the radiation protection community.[30] This requires making every reasonable effort to maintain exposures to radiation as far below the dose limits in [10 CFR 20.1003] as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest. (10 CFR 20.1003)

Alpha radiation - Positively charged, heavy (equivalent to a helium nucleus, two protons, and two neutrons) particles that are emitted from naturally-occurring and man-made radioactive material (e.g., from nuclear power or radiation used in medicine). Examples of alpha emitting radionuclides include radon, thorium, radium, and uranium.

Beta radiation - Beta particles are negatively charged subatomic particles ejected from the nucleus of some radioactive atoms. They are typically more penetrating but have less energy than alpha particles. They are equivalent to electrons, though beta particles originate in the nucleus and electrons originate outside the nucleus. Examples of beta emitting radionuclides include uranium decay products such as lead-214 and bismuth-214 and thorium decay products such as actinium-228 and lead-212.[31]

Byproduct material - Any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material (42 USC 2014 (e)(1)), and the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content (42 USC 2014 (e)(2)).

Community Water System - A public water system that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.[32]

Conditionally Exempt Small Quantity Generators - Facilities that produce less than 100 kg of hazardous waste, or less than 1 kg of acutely hazardous waste, per calendar month, which accumulate less than 1,000 kg of hazardous waste, 1 kg of acutely hazardous waste, or 100 kg of spill residue from acutely hazardous waste at any one time.[33]

Curie/picocurie - A measure of radioactivity. One Curie of radioactivity is equivalent to 3.7×10^{10} or 37,000,000,000 nuclear disintegrations per second.[34] Concentrations of radioactivity in solid materials in the environment are usually expressed as picocuries per gram (pCi/g) while radioactivity in air or liquids is expressed as picocuries per liter (pCi/L). One picocure is one trillionth of a curie.

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[30] U.S. DOE, 1997.

[31] http://www.epa.gov/radiation/understand/beta.htm

[32] U.S. EPA, 1997.

[33] U.S. EPA, January 2003.

[34] U.S. EPA, 1994a.

Direct discharge - Discharges from point sources into surface water pursuant to a CWA NPDES permit facility.[35]

Free liquids - Liquids that readily separate from the solid portion of a waste under ambient temperature and pressure (40 CFR 261.10).

Gamma (or X-ray) radiation - Also known as photon radiation, the high-energy portion of the electromagnetic spectrum. The most penetrating type of radiation, capable of passing through the human body and common construction materials. Gamma radiation is emitted during the decay of thorium and uranium.

Gross alpha particle activity - The total radioactivity due to alpha particle emission as inferred from measurements on a dry sample.[36] (Net alpha is this same measurement minus uranium activity.)

Hazardous waste - Hazardous waste is defined under 40 CFR 261.3. Waste is considered hazardous if it is a solid waste (as defined under 40 CFR 261.2) that is not excluded from regulation as hazardous waste under 40 CFR 261.4(b) and when it meets the criteria listed under 40 CFR 261.3(a)(2) and (b). The regulations most likely to be applicable to TENORM waste are the hazardous waste characteristics, especially the toxicity characteristic (40 CFR 261.24).

Industrial waste - Unwanted materials from an industrial operation in the form of liquid, sludge, solid, or hazardous waste.[37]

Ionizing radiation - Radiation that has sufficient energy to strip electrons from an atom.

Land disposal restrictions - Rules that require hazardous wastes to be treated before disposal on land to destroy or immobilize hazardous constituents that might migrate into soil and ground water.[38]

Landfill - An area of land or an excavation in which wastes are placed for permanent disposal, and that is not a land application unit, surface impoundment, or waste pile (40 CFR 257.2).

Large capacity septic systems - Septic systems that have the capacity to serve twenty or more persons per day.

Large Quantity Generators - Facilities that generate more than 1,000 kg of hazardous waste per calendar month, or more than 1 kg of acutely hazardous waste per calendar month.[39]

Low-level radioactive waste - Radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in the Atomic Energy Act section 11e.(2) (uranium or thorium mill tailings and waste).

Maximum Contaminant Level - The maximum permissible level of a contaminant in water which is delivered to any regulated user of a public water system (40 CFR 141.2).

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[35] U.S. EPA, January 2003.

[36] U.S. EPA, 1994a.

[37] U.S. EPA, 1997.

[38] U.S. EPA, 1997.

[39] U.S. EPA, January 2003.

Maximum Contaminant Level Goal - The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and which allows an adequate margin of safety. Maximum contaminant level goals are non-enforceable health goals.[40]

Mixed waste - Radioactive waste that is also a hazardous waste under RCRA. These wastes are jointly regulated by RCRA and the AEA.[41]

Municipal solid waste landfill - A discrete area of land or excavation that receives municipal solid waste.[42]

Non-ionizing radiation - Radiation that "bounces off or passes through matter without displacing electrons."[43] Its effect on human health is undetermined. Sources of non-ionizing radiation include radios, microwaves, and infrared light.

Paint Filter Liquids Test - Test to determine the presence of free liquids in a representative sample of waste, used to determine compliance with 40 CFR 264.314, 265.314, and 258.28. A predetermined amount of material is placed in a paint filter. If any portion of the material passes through and drops from the filter within the 5 minute test period, the material is deemed to contain free liquids.[44]

Publicly Owned Treatment Works - A treatment works as defined by section 212 of the CWA, which is owned by a state or municipality (as defined by section 502(4) of the CWA). Included are any devices and systems used in the storage, treatment, recycling and reclamation of municipal sewage or liquid industrial wastes. It also includes sewers, pipes and other conveyances only if they convey wastewater to a POTW. This definition also includes the municipality as defined in CWA section 502(4) that has jurisdiction over the indirect discharges to and the discharges from the POTW. (40 CFR 403.3(o))

Radiation - The emitting of energy through matter or space in the form of waves (rays or particles).[45]

Radioactive decay - The spontaneous radioactive transformation of one nuclide (or isotope) into a different nuclide or into a lower energy state of the same nuclide.[46] Radionuclides decay principally by emission of alpha particles, beta particles, and gamma rays.[47]

Radionuclide - Any man-made or natural element that emits ionizing radiation.

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[40]U.S. EPA, 1994a.

[41]U.S. EPA, January 2003.

[42]U.S. EPA, January 2003.

[43]Oak Ridge Reservation, 2000. p. G-5

[44]http://www.epa.gov/epaoswer/hazwaste/test/pdfs/9095a.pdf

[45]U.S. DOE, 1994.

[46]U.S. DOE, 1994.

[47]U.S. EPA, 1991.

Radium - A naturally occurring radioactive metal that exists as one of several isotopes (radium-223, radium-224, radium-226, and radium-228), formed when uranium and thorium decay in the environment. Radium is found at low levels in the natural environment in soil, water, rocks, coal, plants, and food.[48]

Radon - A colorless naturally occurring, radioactive, inert gas formed by radioactive decay of radium atoms in soil, rocks, or water.[49] Radon occurs as the radionuclides radon-220 and radon-222.

Small Quantity Generators - Facilities that generate between 100 kg and 1,000 kg of hazardous waste per calendar month.[50]

Solid waste - Any garbage, refuse, or sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility, and other discarded material, including solid, liquid, semisolid, or contained gaseous material, resulting from industrial, commercial, mining, and agricultural operations and from community activities. For the purposes of hazardous waste regulation, a solid waste is a material that is discarded by being either abandoned, inherently waste-like, a certain waste military munition, or recycled.[51]

Source material - Uranium or thorium, or any combination thereof, in any physical or chemical form or ores that contain 0.05 percent or more of uranium, thorium, or any combination of the two. This does not include special nuclear material (10 CFR 40.4).

Technologically Enhanced Naturally Occurring Radioactive Material - Naturally occurring materials, such as rocks, minerals, soils, and water whose radionuclide concentrations or potential for exposure to humans or the environment is enhanced as a result of human activities (e.g., water treatment).[52]

Toxicity Characteristic Leaching Procedure - A laboratory procedure that simulates landfill conditions. It is designed to predict whether a particular waste is likely to leach dangerous levels of chemicals into groundwater and is used to determine whether a waste is considered hazardous under 40 CFR 261.10.[53]

Unimportant quantity - Source material that is exempt from the licensing requirements of NRC and the Agreement States. One exemption is for any: chemical mixture, compound, solution, or alloy in which the source material is by weight less than 0.05 percent of the mixture, compound, solution or alloy. This exemption does not include byproduct material as defined in 10 CFR Part 40 (10 CFR 40.13(a)).

Universal treatment standards - The constituent-specific treatment standards found in 40 CFR 268.48. The standards must be met before hazardous waste can be land disposed.[54]

Uranium - A naturally occurring radioactive element with an atomic number of 92. The principal isotopes by weight are, in the uranium decay series, uranium-234 and uranium-238 (comprising 99.3 percent of natural uranium by mass) and, in the actinium decay series, fissionable uranium-235 (comprising 0.7 percent of natural uranium by mass).

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[48]U.S. EPA, July 2002.

[49]U.S. EPA, 1997.

[50]U.S. EPA, January 2003.

[51]U.S. EPA, January 2003.

[52]In accordance with concepts presented in NAS (1999) and IAEA (2004).

[53]U.S. EPA, January 2003.

[54]U.S. EPA, *Land Disposal Restrictions Glossary*, Date unknown.

Well - Any bored, drilled or driven shaft or dug hole whose depth is greater than the largest surface dimension; or an improved sinkhole; or a subsurface fluid distribution system used to discharge fluids underground.

Well injection - The subsurface emplacement of fluids through a well.

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Appendix C: Applicable Federal Statutes and Regulations

Atomic Energy Act (AEA)
The 1954 AEA regulates the development and use of nuclear facilities, and the creation, generation, and disposal of source, special nuclear, and byproduct material (all designated as radioactive material under the jurisdiction of the AEA). The Act enables the NRC to establish relationships with states that allow these "Agreement States" to develop and implement regulations governing the use and possession of source, special nuclear, and byproduct materials. Agreement States must establish radiation protection programs compatible with the NRC's; for a list of Agreement States, see http://www.hsrd.ornl.gov/nrc.

NRC has exempted source material from regulation under the AEA if the uranium or thorium makes up less than 0.05 percent by weight (i.e., an "unimportant quantity"). Equivalent exemptions appear in the Agreement States' regulations. For natural uranium, this is equivalent to approximately 335 pCi/g, and therefore, the uranium residuals produced by water treatment plants may, in some cases, be an "unimportant quantity of source material" and exempt from NRC's and the Agreement States' regulations. Source material may be held under a general license if it is greater than 0.05 percent by weight, but the total amount in a treatment plant's possession at any time is less than 15 pounds. This is referred to as a "small quantity" of source material. The general license to use and transfer small quantities of source material is granted under 10 CFR 40.22 and equivalent regulations of the Agreement States. Under this general license, systems may not process more than 150 pounds of source material in a calendar year. Systems that exceed the small quantity thresholds must apply for a specific license from the NRC or Agreement State.

The NRC's "Standards for Protection Against Radiation" (10 CFR Part 20), contains the basic radiation protection standards for persons licensed to receive, possess, use, transfer, and dispose of source, special nuclear, and byproduct materials as defined in the AEA. These regulations set dose limits for radiation workers and the public, and specify requirements for the monitoring and labeling of radioactive materials, the posting of radiation areas, and the reporting of theft or loss of radioactive material. Regulations for licensing of source material are contained in 10 CFR Part 40. Additional requirements for persons licensed by the NRC are contained in 10 CFR Part 19; this includes requirements for instructions and notifications to employees. The NRC's Regulations can be found at http://www.nrc.gov/reading-rm/doc-collections/cfr/.

Because the NRC's transportation duties overlap with the statutory authority of the DOT, the NRC and DOT signed a Memorandum of Understanding in 1979 covering the regulation of the transport of radioactive materials.

For more information, see http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/ml022200075-vol1.pdf#pagemode=bookmarks&page=14 and http://www.nrc.gov/who-we-are.html.

Clean Water Act (CWA)
Wastes generated by water treatment plants and discharged to a receiving body of water (direct discharge) or to a POTW are regulated under the CWA. The Act requires dischargers to have a NPDES permit in order to discharge any pollutants into waters of the United States.

When applying for a NPDES permit, systems must provide information on water temperature, pH, flow rate, and on pollutant levels in the discharge. For copies of NPDES application forms, see http://cfpub.epa.gov/npdes/doctype.cfm?sort=name&program_id=45&document_type_id=8.

See http://cfpub.epa.gov/npdes/statestats.cfm for a list of states that are authorized to administer the NPDES program.

The CWA can also require systems to pretreat waste prior to discharge to a POTW. POTWs are required to establish and enforce pretreatment programs identifying significant dischargers who are subject to pretreatment standards (40 CFR 403). If a system wants to discharge its waste to a POTW, both the system and the POTW are responsible for preventing the introduction of any pollutants that may interfere with the POTW treatment process or contaminate POTW sewage sludge. This allows POTWs to implement Technically Based Local Limits (TBLLs). TBLLs vary among states and POTWs. Systems must check with their state and local POTW before choosing discharge to a POTW as a disposal option.

In addition, if systems located near ocean or saline waters wish to discharge their wastes directly to these waters, they may be affected by the **Marine Protection, Research, and Sanctuaries Act (MPRSA)**. Permits are required for ocean disposal activities although having a NPDES permit may satisfy the requirements set forth under MPRSA.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
CERCLA is more commonly known as Superfund. It provides broad federal authority to respond to releases or threatened releases of hazardous substances that may endanger public health or the environment. Systems must consider CERCLA when selecting disposal options because they may be liable for incidents that result from disposing of wastes at a mismanaged landfill. For example, if a system disposed of sludge containing radionuclides at an improperly managed landfill and any release or threat of release occurred, the system could be partially or entirely liable for the cleanup.

Department of Transportation (DOT) Regulations
Under the Department of Transportation Act of 1966, DOT has regulatory responsibility for safety in the transportation of all hazardous materials (see 49 CFR 100-185), including radioactive material. DOT regulations govern container design, chemical compatibility, packaging, labeling, permitting, and transportation route requirements. This includes shipments by all modes of transport in interstate, intrastate, or foreign commerce (rail, highway, air, water), and by all means (truck, bus, auto, vessel, airplane, rail-car) except for postal shipments, which are under the jurisdiction of the U.S. Postal Service.

In a Final Rule (69 FR 3631) published on January 26, 2004, DOT adopted radionuclide-specific thresholds to determine when a material containing radionuclides is subject to the DOT requirements for transporting radioactive material. The exemption values consist both of activity concentrations and total consignment activities; a material containing a single radionuclide would have to be above both exemption values for that nuclide in order to be subject to those DOT requirements. If either the activity concentration or the total consignment activity is below the corresponding exemption value, that material is exempt from the DOT requirements for transporting radioactive material. The exemption values are listed in 49 CFR 173.436, and are referred to in the definition of Radioactive Material in 49 CFR 173.403. If more than one radionuclide is present, the appropriate exemption values are to be determined using a mixture rule described in 49 CFR 173.433.

In addition, in paragraph 49 CFR 173.401(b)(4), DOT exempts "natural material and ores containing naturally occurring radionuclides which are not intended to be processed for use of these radionuclides" so long as their activity concentrations and consignment activities do not exceed 10 times the levels listed in 49 CFR 173.436 or calculated using 49 CFR 173.433. For example, because the exempt activity concentration for uranium is listed in 49 CFR 173.436 as 27 pCi/g, and those for radium-226 and radium-228 are 270 pCi/g, systems transporting more than 270 pCi/g of uranium or 2,700 pCi/g of radium must comply with DOT's requirements for transporting radioactive materials (unless the consignment activities are below the consignment activity exemption values - 27 nanocuries and 270 nanocuries, respectively - in which case the material would still be exempt from those requirements). For more information, see http://hazmat.dot.gov.

Treatment plants classified as Large or Small Quantity Generators under RCRA must ensure that any waste to be transported for disposal is handled by a U.S. EPA-approved transporter.

Low-Level Radioactive Waste Policy Act (1980) and Amendments (1985)
This Act made states responsible for disposing of LLRW generated within their borders. States are permitted to form compacts with other states to develop LLRW disposal facilities serving more than one state. These facilities are

regulated by the NRC, or Agreement States (see "Nuclear Regulatory Commission (NRC) Regulations" on the previous page, and 10 CFR 61 and 62 for more detail).

Resource Conservation and Recovery Act (RCRA)
The disposal of solid wastes[55] (including sludge) is regulated under RCRA (unless it is disposed of via direct discharge or underground injection). Under RCRA, an entity or person generating a solid waste must determine whether the waste is hazardous using the method described in 40 CFR 262.11.

Solid waste exhibiting toxicity, corrosivity, reactivity, or ignitability characteristics is hazardous. Hazardous waste requires special handling and disposal, and it is subject to RCRA Subtitle C requirements.

If the system wishes to dispose non-hazardous waste in a landfill, RCRA Subtitle D requirements apply. It is recommended that water treatment plants operate in a way that will avoid any generation of hazardous waste.

Municipal Solid Waste Landfill (MSWLF) Requirements
U.S. EPA, through the MSWLF Requirements (40 CFR 258, under RCRA Subtitle D), ensures the protection of human health and the environment by setting minimum national criteria for MSWLFs. A municipal solid waste landfill is a discrete area of land or excavation that receives household waste. A MSWLF may also receive other types of RCRA Subtitle D wastes, such as commercial solid waste, nonhazardous sludge, Conditionally Exempt Small Quantity Generator (CESQG) waste, and industrial nonhazardous solid waste.

These federal requirements cover landfill location, operation, and design; ground water monitoring; corrective action; closure and post-closure, and financial assurance. States and MSWLFs may have additional requirements. For more information on municipal solid waste management, see http://www.epa.gov/msw.

Safe Drinking Water Act (SDWA) - Underground Injection Control (UIC) Program
U.S. EPA is directed by the SDWA to establish minimum federal requirements for state and UIC programs to protect underground sources of drinking water (USDWs) from contamination caused by underground injection activities. Protection includes the oversight of construction, operation, and closure of injection wells. A treatment residual generator interested in UIC as a disposal option should contact the appropriate U.S. EPA regional or state UIC program office to determine the statutory requirements in their state.

[55]Any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility, and other discarded material, including solid, liquid, semisolid, or contained gaseous material, resulting from industrial, commercial, mining, and agricultural operations and from community activities. For the purposes of hazardous waste regulation, a solid waste is a material that is discarded by being either abandoned, inherently waste-like, a certain waste military munition, or recycled.

Appendix D: State, Regional, Federal, and Tribal Contacts

Table D-1: Regional and State Drinking Water, UIC, and Radiation Control Contacts

U.S. EPA REGION 1				
Drinking Water		Drinking Water Program	www.epa.gov/region1/eco/drinkwater	(617) 918-1111
UIC		Underground Injection Control Program	www.epa.gov/region1/eco/drinkwater/pc_groundwater_discharges.html	(617) 918-1111
Radiation		Pesticides, Toxics, and Radiation Unit	www.epa.gov/region1/topics/pollutants/radioactivity.html	(617) 918-1111
State	**Area**	**Contact**	**Web/Street Address**	**Phone**
CT	Drinking Water	Department of Public Health: Drinking Water Division	www.dph.state.ct.us/BRS/water/dwd.htm	(860) 509-7333
	UIC	Connecticut Department of Environmental Protection	dep.state.ct.us/wtr	(860) 424-3018
	Radiation	Division of Radiation, Department of Environmental Protection	79 Elm Street Hartford, CT 06106-5127 dep.state.ct.us/air2/prgacti.htm#Radiation	(860) 424-3029
ME	Drinking Water	Maine Department of Human Services: Division of Health Engineering	www.state.me.us/dhs/eng/water	(207) 287-2070
	UIC	Maine Department of Environmental Protection	www.state.me.us/dep/blwq/docstand/uic/uichome.htm	(207) 287-7814
	Radiation	Radiation Control Program, Division of Health Engineering	11 State House Station Augusta, ME 04333 www.state.me.us/dhs/eng/rad	(207) 287-5677
MA	Drinking Water	Department of Environmental Protection: Drinking Water Program	www.state.ma.us/dep/brp/dws/dwshome.htm	(617) 292-5770
	UIC	Department of Environmental Protection	www.state.ma.us/dep/brp/dws/uic.htm	(617) 348-4014
	Radiation	Radiation Control Program, Department of Public Health	90 Washington Street Dorchester, MA 02121 www.state.ma.us/dph/rcp/radia.htm	(617) 427-2944
NH	Drinking Water	Department of Environmental Services: Water Supply Engineering Bureau	www.des.state.nh.us/wseb	(603) 271-2513

	UIC	Department of Environmental Services	www.des.state.nh.us/dwspp	(603) 271-2858
	Radiation	Radioactive Material Section, Bureau of Radiological Health, Department of Health and Human Services	Health and Welfare Building 6 Hazen Drive Concord, NH 03301-6527 www.dhhs.state.nh.us/DHHS/RADHEALTH/default.htm	(603) 271-4585
RI	Drinking Water	Department of Health: Office of Drinking Water Quality	www.health.ri.gov/environment/dwq/index.php	(401) 222-6867
	UIC	Rhode Island Department of Environmental Management	www.state.ri.us/dem/programs/benviron/water	(401) 222-3961
	Radiation	Division of Occupational & Radiological Health, Department of Health	3 Capitol Hill, Room 206 Providence, RI 02908-5097 www.health.ri.gov/environment/occupational/index.php	(401) 222-7755
VT	Drinking Water	Department of Environmental Conservation: Water Supply Division	www.vermontdrinkingwater.org	(802) 241-3400
	UIC	Department of Environmental Conservation	www.anr.state.vt.us/dec/ww/uic.htm	(802) 241-4455
	Radiation	Radiological Health, Department of Health	108 Cherry Street P.O. Box 70 Burlington, VT 05402 www.healthyvermonters.info/hp/hp.shtml#Anchor--Radiologic-1387	(802) 865-7743

U.S. EPA REGION 2				
Drinking Water		Division of Environmental Planning and Protection, Drinking Water Section	www.epa.gov/region02/water/drinkingwater	(212) 637-5000
UIC		Water Compliance Branch	www.epa.gov/region02/capp	(212) 637-3766
Radiation		Division of Environmental Planning and Protection, Radiation and Indoor Air Branch	www.epa.gov/region02/org/depp.htm	(212) 637-4010
NJ	Drinking Water	Department of Environmental Protection: Bureau of Safe Drinking Water	www.state.nj.us/dep/watersupply/safedrnk.htm	(609) 292-5550

	UIC	Department of Environmental Protection, Department of Water Quality	www.state.nj.us/dep/dwq/nonpoint.htm	(609) 633-7021
	Radiation	Radiation Protection Programs, Division of Environmental Safety, Health & Analytical Programs, Department of Environmental Protection	P.O. Box 415 Trenton, NJ 08625-0415 www.state.nj.us/dep/rpp	(609) 984-5636
NY	Drinking Water	Department of Health: Bureau of Public Water Supply Protection	www.health.state.ny.us/nysdoh/water/main.htm	(518) 402-7650
	UIC	U.S. EPA Region 2	www.epa.gov/Region2/water/grndtop.htm	(212) 637-4226
	Radiation	Radiological Health Unit, Division of Safety and Health, New York State Dept. of Labor	NYS Office Campus, Building 12, Room 169 Albany, NY 12240	(518)457-1202
		Radioactive Waste Policy and Nuclear Coordination, New York State Energy Research & Development Authority	17 Columbia Circle Albany, NY 12203-6399	(518) 862-1090
		Radiation Section, Division of Hazardous Waste and Radiation Management, New York State Department of Environmental Conservation	625 Broadway, 8th Floor Albany, NY 12233-7255 www.dec.state.ny.us/website/dshm/hazrad/rad.htm	(518) 402-8579
		Bureau of Radiological Health, New York City Department of Health	Two Lafayette Street, 11th Floor New York, NY 10007	(212) 676-1556
		Bureau of Environmental Radiation Protection, New York State Department of Health	547 River Street Troy, NY 12180-2216	(518) 402-7550
PR	Drinking Water	Department of Health: Public Water Supply Supervision Program	www.epa.gov/region02/cepd/prlink.htm	(787) 977-5870
	UIC	Puerto Rico Environmental Quality Board	www.sso.org/ecos/states/delegations/pr.htm	(787) 767-8073
	Radiation	Radiological Health Division, Department of Health	P.O. Box 70184 San Juan, PR 00936-8184	(787) 274-7815
VI	Drinking Water	Department of Planning & Natural Resources: Division of Environmental Protection	www.dpnr.gov.vi/dep/home.htm	(340) 773-1082
	UIC	U.S. EPA Region 2	www.epa.gov/Region2/water/grndtop.htm	(212) 637-4232

	Radiation	N/A		
U.S. EPA REGION 3				
Drinking Water		Water Protection Division	www.epa.gov/reg3wapd	(215) 814-2300
UIC		Water Protection Division	www.epa.gov/reg3wapd/drinkingwater/uic	(215) 814-2300
Radiation		Radiation Program	www.epa.gov/reg3artd/radiation/radiation.htm	(215) 814-2089
DE	Drinking Water	Delaware Health & Social Services: Division of Public Health, Office of Drinking Water	www.state.de.us/dhss/dph	(302) 741-8630
	UIC	Department of Natural Resources and Environmental Control	www.dnrec.state.de.us/water2000/Sections/GroundWat/DWRGrndWat.htm	(302) 739-4762
	Radiation	Office of Radiation Control, Division of Public Health	P.O. Box 637 Dover, DE 19903 www.state.de.us/dhss/dph	(302) 744-4546
DC	Drinking Water	U.S. EPA Region 3	www.epa.gov/reg3wapd/drinkingwater	(202) 535-2190
	UIC	U.S. EPA Region 3	www.epa.gov/reg3wapd/drinkingwater/uic	(215) 814-5445
	Radiation	Department of Health, Environmental Health Administration, Bureau of Food, Drug, and Radiation Protection	51 N Street NE, Room 6025 Washington, DC 20002	(202) 535-2188
MD	Drinking Water	Department of the Environment: Public Water Supply Program	www.mde.state.md.us/Programs/WaterPrograms/Water_Supply/index.asp	(410) 537-3000
	UIC	Department of the Environment	www.mde.state.md.us/Water	(410) 631-3323
	Radiation	Radiological Health Program, Air and Radiation Management Administration, Maryland Department of the Environment	1800 Washington Blvd Suite 750 Baltimore, MD 21230-1724 www.mde.state.md.us/Programs/AirPrograms/Radiological_Health	(410) 537-3300
PA	Drinking Water	Department of Environmental Protection: Bureau of Water Supply Management	www.dep.state.pa.us/dep/deputate/watermgt/wsm/wsm.htm	(717) 787-5017

	UIC	U.S. EPA Region 3	www.epa.gov/reg3wapd/drinkingwater/uic	(215) 814-5445
	Radiation	Bureau of Radiation Protection, Department of Environmental Protection	P.O. Box 8469 Harrisburg, PA 17105-8469 www.dep.state.pa.us/dep/deputate/airwaste/rp/rp.htm	(717) 787-2480
VA	Drinking Water	Department of Health: Division of Water Supply Engineering, Office of Drinking Water	www.vdh.state.va.us/dw	(804) 864-7500
	UIC	U.S. EPA Region 3	www.epa.gov/reg3wapd/drinkingwater/uic	(215) 814-5445
	Radiation	Radiological Health Program, Division of Health Hazards Control, Department of Health	Main Street Station 1500 East Main, Room 240 Richmond, VA 23219 www.vdh.state.va.us/rad	(804) 786-5932
WV	Drinking Water	Bureau for Public Health: Environmental Engineering Division	www.wvdhhr.org/oehs/eed	(304) 558-2981
	UIC	Division of Environmental Protection	www.wvdep.org/item.cfm?ssid=11&ss1id=165	(304) 558-6075
	Radiation	Radiation, Toxics, & Indoor Air Division, Department of Health and Human Resources	815 Quarrier Street - Suite 418 Charleston, WV 25301 www.wvdhhr.org/rtia/	(304) 558-6772

U.S. EPA REGION 4				
Drinking Water		Water Management Division	www.epa.gov/region4/water	(404) 562-9345
UIC		Water Management Division	www.epa.gov/region4/water/uic	(404) 562-9345
Radiation		Air, Pesticides, and Toxic Management Division	www.epa.gov/region4/air/radon	(404) 562-9135
AL	Drinking Water	Department of Environmental Management: Water Supply Branch	www.adem.state.al.us/WaterDivision/WaterDivisionPP.htm	(334) 271-7773
	UIC	Department of Environmental Management	www.adem.state.al.us/WaterDivision/Ground/UIC%20GW/GWUICInfo.htm	(334) 271-7844

	Radiation	Office of Radiation Control, Alabama Department of Public Health	201 Monroe Street, P.O. Box 303017 Montgomery, AL 36130-3017 www.adph.org/radiation	(334) 206-5391
FL	Drinking Water	Department of Environmental Protection: Drinking Water Section	www.dep.state.fl.us/water/drinkingwater	(850) 245-8624
	UIC	Department of Environmental Protection	www.dep.state.fl.us/water/uic/index.htm	(850) 921-9417
	Radiation	Bureau of Radiation Control, Florida Department of Health	4052 Bald Cypress Way, SE, Bin C21 Tallahassee, FL 32399-1741 www.doh.state.fl.us/environment/radiation	(850) 245-4266
GA	Drinking Water	Department of Natural Resources: Drinking Water Program	www.dnr.state.ga.us/dnr/environ	(404) 656-4087
	UIC	Environmental Protection Division	www.dnr.state.ga.us/dnr/environ	(404) 656-3229
	Radiation	Radioactive Materials Program, Environmental Protection Division, Department of Natural Resources	4244 International Parkway, Suite 114 Atlanta, GA 30354 www.ganet.org/dnr/environ/aboutepd_files/branches_files/rmprogram/default.htm	(404) 362-2675
KY	Drinking Water	Department for Environmental Protection: Drinking Water Branch	www.water.ky.gov/dw	(502) 564-3410
	UIC	U.S. EPA Region 4	www.epa.gov/region4/water/uic	(404) 562-9452
	Radiation	Radiation Health & Toxic Agents Branch, Cabinet for Health Services, Department of Public Health	275 East Main Street Mail Stop HS 2E-D Frankfort, KY 40621-0001 chs.ky.gov/publichealth/radiation.htm	(502) 564-7818
MS	Drinking Water	Department of Health: Division of Water Supply	www.msdh.state.ms.us/msdhsite	(601) 576-7518
	UIC	Department of Environmental Quality	www.deq.state.ms.us/MDEQ.nsf/page/Main_Home?OpenDocument	(601) 961-5640
	Radiation	Division of Radiological Health, State Department of Health	3150 Lawson Street, P.O. Box 1700 Jackson, MS 39215-1700 www.msdh.state.ms.us/radiological	(601) 987-6893

NC	Drinking Water	Department of Environment and Natural Resources: Public Water Supply Section	www.deh.enr.state.nc.us/pws	(919) 733-2321
	UIC	Department of Environment and Natural Resources	gw.ehnr.state.nc.us/uic.htm	(919) 715-6165
	Radiation	Division of Radiation Protection, Division of Environmental Health, Department of Environment & Natural Resources	3825 Barrett Drive Raleigh, NC 27609-7221 www.drp.enr.state.nc.us	(919) 571-4141
SC	Drinking Water	Department of Health & Environmental Control: Bureau of Water	www.scdhec.net/water/html/dwater.html	(803) 898-4300
	UIC	Department of Health and Environmental Control	www.scdhec.net/eqc/water/html/uic.html	(803) 898-3549
	Radiation	Bureau of Radiological Health, Department of Health & Environmental Control	2600 Bull Street Columbia, SC 29201	(803)545-4403
		Division of Waste Management, Bureau of Land and Waste Management, Department of Health & Environmental Control	2600 Bull Street Columbia, SC 29201 www.scdhec.net/lwm/html/radio.html	(803) 896-4245
TN	Drinking Water	Department of Environment & Conservation: Division of Water Supply	www.state.tn.us/environment/dws	(615) 532-0191
	UIC	U.S. EPA Region 4	www.epa.gov/region4/water/uic	(404) 562-9452
	Radiation	Division of Radiological Health, Tennessee Department of Environment and Conservation	L&C Annex, Third Floor 401 Church Street Nashville, TN 37243-1532 www.state.tn.us/environment/rad	(615) 532-0364

U.S. EPA REGION 5				
Drinking Water		Water Division, Ground Water and Drinking Water Branch	www.epa.gov/region5/water	(312) 886-6107
UIC		Water Division, UIC Branch	www.epa.gov/region5/water/uic/uic.htm	(312) 886-1492
Radiation		Air and Radiation Division	www.epa.gov/region5/air	(312) 353-2212
IL	Drinking Water	Illinois Environmental Protection Agency: Division of Public Water Supplies	www.epa.state.il.us/water/index-pws.html	(217) 785-8653

	UIC	Illinois Environmental Protection Agency	www.epa.state.il.us/land/regulatory-programs/underground-injection-control.html	(217) 782-6070
	Radiation	Division of Nuclear Safety, Illinois Emergency Management Agency	1035 Outer Park Drive Springfield, IL 62704 www.state.il.us/idns	(217) 785-9868
IN	Drinking Water	Department of Environmental Management: Drinking Water Branch	www.ai.org/idem/owm/dwb	(317) 232-8603
	UIC	U.S. EPA Region 5	www.epa.gov/region5/water/uic/uic.htm	(312) 353-4543
	Radiation	Indoor & Radiologic Health Division, State Department of Health	2 N. Meridian Street, 5F Indianapolis, IN 46204-3003 www.state.in.us/isdh/regsvcs/radhealth/welcome.htm	(317) 233-7146
MI	Drinking Water	Department of Environmental Quality: Drinking Water & Radiological Protection Division	www.michigan.gov/deq	(517) 335-4716
	UIC	U.S. EPA Region 5	www.epa.gov/region5/water/uic/uic.htm	(312) 353-4543
	Radiation	Hazardous Waste and Radiological Protection Section, Waste and Hazardous Materials Division, Michigan Department of Environmental Quality	525 West Allegan Street PO Box 30241 Lansing, MI 48909-7741 www.michigan.gov/deq/0,1607,7-135-3312_4120_4244---,00.html	(517) 373-0530
MN	Drinking Water	Department of Health: Drinking Water Protection Section	www.health.state.mn.us/divs/eh/water	(651) 215-0770
	UIC	U.S. EPA Region 5	www.epa.gov/region5/water/uic/uic.htm	(312) 353-4543
	Radiation	Section of Asbestos, Indoor Air, Lead and Radiation, Division of Environmental Health, Department of Health	121 E. Seventh Place, Suite 220 P.O. Box 64975 St. Paul, MN 55164-0975 www.health.state.mn.us/divs/eh/radiation	(651) 215-0945
OH	Drinking Water	Ohio Environmental Protection Agency: Division of Drinking & Ground Water	www.epa.state.oh.us/ddagw	(614) 644-2752
	UIC	Ohio Environmental Protection Agency	www.epa.state.oh.us/ddagw/uic.html	(614) 644-2771

	Radiation	Bureau of Radiation Protection, Ohio Department of Health	P.O. Box 118 Columbus, OH 43266-0118	(614) 644-7860
WI	Drinking Water	Department of Natural Resources: Bureau of Water Supply	www.dnr.state.wi.us/org/water/dwg	(608) 266-0821
	UIC	Department of Natural Resources	dnr.wi.gov/org/water/dwg/Uiw/index.htm	(608) 266-2438
	Radiation	Radiation Protection Section, Division of Public Health, Department of Health and Family Services	P.O. Box 2659 Madison, WI 53701-2659 www.dhfs.state.wi.us/dph_beh/RadiatioP/	(608) 267-4792

U.S. EPA REGION 6				
Drinking Water		Water Quality Protection Division, Drinking Water Section	www.epa.gov/earth1r6/6wq/swp/drinkingwater/aboutq&a.htm	(214) 665-7155
UIC		Water Quality Protection Division, Source Water Protection	www.epa.gov/earth1r6/6wq/swp/uic	(214) 665-7165
Radiation		Multimedia Planning and Permitting Division	www.epa.gov/earth1r6/6pd/6pd.htm	(214) 665-8124
AR	Drinking Water	Department of Health: Division of Engineering	www.healthyarkansas.com/eng	(501) 661-2623
	UIC	Department of Environmental Quality	www.adeq.state.ar.us/water/branch_permits/default.htm	(501) 682-0646
	Radiation	Division of Radiation Control & Emergency Management, Radioactive Materials Program, Department of Health	4815 West Markham Street, Slot #30 Little Rock, AR 72205-3867	(501) 661-2173
LA	Drinking Water	Office of Public Health: Division of Environmental & Health Services	www.oph.dhh.state.la.us/engineerservice/safewater	(225) 765-5038
	UIC	Department of Natural Resources	www.dnr.state.la.us	(225) 342-5561
	Radiation	Permit Division, Office of Environmental Services	P.O. Box 4313 Baton Rouge, LA 70821-4313 www.deq.state.la.us/permits	(225) 219-3005
NM	Drinking Water	Environment Department: Drinking Water Bureau	www.nmenv.state.nm.us/dwb/dwbtop.html	(505) 827-7545

	UIC	Environment Department	www.nmenv.state.nm.us/gwb/New%20Pages/UIC.htm	(505) 827-2936
	Radiation	Radiation Control Bureau, Environment Department	1190 St. Francis Drive, Rm S2100 P.O. Box 26110 Santa Fe, NM 87502-0110 www.nmenv.state.nm.us/nmrcb/home.html	(505) 476-3236
OK	Drinking Water	Department of Environmental Quality: Water Quality Division	www.deq.state.ok.us/WQDnew	(405) 702-8100
	UIC	Department of Environmental Quality	www.deq.state.ok.us/LPDnew/uicindex.html	(405) 702-5142
	Radiation	Radiation Management Section, Oklahoma Department of Environmental Quality	P.O. Box 1677 Oklahoma City, OK 73101-1677	(405) 702-5155
TX	Drinking Water	Texas Commission on Environmental Quality: Water Supply Division	www.tnrcc.state.tx.us/permitting/waterperm/pdw/pdw000.html	(512) 239-4671
	UIC	Texas Commission on Environmental Quality	www.tceq.state.tx.us	(512) 239-6633
	Radiation	Bureau of Radiation Control, Texas Department of Health	1100 West 49th Street Austin, TX 78756-3189 www.tdh.state.tx.us/radiation/default.htm	(512) 834-6679
		Office of Permitting, Remediation & Registration, Texas Commission on Environmental Quality	P.O. Box 13087, MC 122 Austin, TX 78711-3087 www.tceq.state.tx.us/AC/about/organization/oprr.html	(512) 239-6731

U.S. EPA REGION 7				
Drinking Water		Water Division	www.epa.gov/region07/water/dwgw.htm	(913) 551-7003
UIC		Water Division	www.epa.gov/region07/water	(913) 551-7003
Radiation		Radiation, Asbestos, Lead, and Indoor Programs Branch	www.epa.gov/region7/topics.htm	(913) 551-7003
IA	Drinking Water	Department of Natural Resources: Water Supply Section	www.state.ia.us/epd/wtrsuply/wtrsup.htm	(515) 725-0275
	UIC	U.S. EPA Region 7	www.epa.gov/Region7/water/contact.htm	(913) 551-7413

	Radiation	Bureau of Radiological Health, Iowa Department of Public Health	401 SW 7th Street, Suite D Des Moines, IA 50309 www.idph.state.ia.us/eh/radiological_health.asp	(515) 281-3478
KS	Drinking Water	Department of Health and Environment: Public Water Supply Section	www.kdhe.state.ks.us/pws	(785) 296-5514
	UIC	Department of Health and Environment	www.kdhe.state.ks.us/uic	(785) 296-5509
	Radiation	Radiation and Asbestos Control, Kansas Department of Health & Environment	1000 SW Jackson, Suite 320 Topeka, KS 66612-1366 www.kdhe.state.ks.us/radiation	(785) 296-1565
MO	Drinking Water	Department of Natural Resources: Public Drinking Water Program	www.dnr.state.mo.us/wpscd/wpcp	(573) 751-5331
	UIC	Department of Natural Resources	www.dnr.state.mo.us/homednr.htm	(573) 368-2170
	Radiation	Division of Environmental Health, Department of Health and Senior Services	930 Wildwood Drive, P.O. Box 570 Jefferson City, MO 65102-0570 www.dhss.state.mo.us/RadProtection/	(573) 751-6112
NE	Drinking Water	Department of HHS Regulation & Licensure	www.hhs.state.ne.us/enh/pwsindex.htm	(402) 471-2541
	UIC	Department of Environmental Quality	www.deq.state.ne.us	(402) 471-2186
	Radiation	Radiation Control Programs	P.O. Box 95007 Lincoln, NE 68509-5007 www.hhs.state.ne.us/rad/radindex.htm	(402) 471-2079

U.S. EPA REGION 8			
Drinking Water	Drinking Water Program	www.epa.gov/region08/water/dwhome/dwhome.html	(303) 312-6812
UIC	UIC Program	www.epa.gov/region08/water/uic	(303) 312-6312
Radiation	Radiation Protection Program	www.epa.gov/Region8/search/alpha.html#R	(303) 312-6312

CO	Drinking Water	Department of Public Health & Environment: Drinking Water Program	www.cdphe.state.co.us/wq/wqhom.asp	(303) 692-3500
	UIC	U.S. EPA Region 8	www.epa.gov/Region8/water/uic	(303) 312-6125
	Radiation	Radiation Management Program, HMWMD-B2, Hazardous Materials & Waste Management Division, Department of Public Health & Environment	4300 Cherry Creek Drive South Denver, CO 80246-1530 www.cdphe.state.co.us/hm/rad/radiationservices.asp	(303) 692-3428
MT	Drinking Water	Department of Environmental Quality: Public Water Supply Section	www.deq.state.mt.us/wqinfo	(406) 444-3080
	UIC	U.S. EPA Region 8	www.epa.gov/Region8/water/uic	(303) 312-6125
	Radiation	Radiological Health Program, Department of Public Health & Human Services, Licensure Bureau	2401 Colonial Drive P.O. Box 202953 Helena, MT 59620-2953	(406) 444-1510
ND	Drinking Water	Department of Health: Division of Municipal Facilities	www.ehs.health.state.nd.us/ndhd/environ/mf	(701) 328-5211
	UIC	Department of Health	www.health.state.nd.us/wq/gw/uic.htm	(701) 328-5233
	Radiation	Division of Air Quality, North Dakota Department of Health	1200 Missouri Avenue, Rm 304 P.O. Box 5520 Bismarck, ND 58506-5520 www.health.state.nd.us/ndhd/environ/ee/rad/rad.htm	(701) 328-5188
SD	Drinking Water	Department of Environment & Natural Resources: Drinking Water Program	www.state.sd.us/denr/des/drinking/dwprg.htm	(605) 773-3754
	UIC	U.S. EPA Region 8	www.epa.gov/Region8/water/uic	(303) 312-6125
	Radiation	Office of Health Care Facilities, Licensure & Certification, Systems Development and Regulations	615 East 4th Street Pierre, SD 57501-1700	(605) 773-3356
UT	Drinking Water	Department of Environmental Quality: Division of Drinking Water	www.drinkingwater.utah.gov	(801) 536-4200
	UIC	Department of Environmental Quality	waterquality.utah.gov	(801) 538-6023

	Radiation	Division of Radiation Control, Department of Environmental Quality	168 North 1950 West P.O. Box 144850 Salt Lake City, UT 84114-4850 www.eq.state.ut.us/EQRAD/drc_hmpg.htm	(801) 536-4250
WY	Drinking Water	U.S. EPA Region 8: Wyoming Drinking Water Program	www.epa.gov/region08/water/dwhome/wycon/wycon.html	(307) 777-7781
	UIC	Department of Environmental Quality	deq.state.wy.us/wqd/index.asp?pageid=56	(307) 777-7095
	Radiation	Solid & Hazardous Waste Division, Department of Environmental Quality	Herschler Building, 4E Cheyenne, WY 82002 deq.state.wy.us/shwd	(307) 777-7753

U.S. EPA REGION 9				
Drinking Water		Water Division	www.epa.gov/region09/water	(415) 947-8707
UIC		Water Division	www.epa.gov/region09/water	(415) 947-8707
Radiation		Radiation Protection Program	www.epa.gov/region09/air/radiation	(415) 947-4197
AS	Drinking Water	Environmental Protection Agency: American Samoa	www.epa.gov/Region9/cross_pr/islands/samoa.html	(415) 972-3767
	UIC	U.S. EPA Region 9	www.epa.gov/region09/water/underground/notes	(415) 972-3767
	Radiation	N/A		
AZ	Drinking Water	Department of Environmental Quality: Drinking Water Monitoring & Assessment Section	www.adeq.state.az.us/environ/water/dw	(602) 771-2303
	UIC	U.S. EPA Region 9	www.epa.gov/region09/water/underground/notes	(415) 972-3767
	Radiation	Arizona Radiation Regulatory Agency	4814 South 40th Street Phoenix, AZ 85040 www.arra.state.az.us	(602) 255-4845
CA	Drinking Water	Department of Health Services: Division of Drinking Water & Environmental Management	www.dhs.ca.gov	(916) 449-5577

	UIC	U.S. EPA Region 9	www.epa.gov/region09/water/underground/notes	(415) 972-3767
	Radiation	Radiologic Health Branch, Division of Food, Drugs, and Radiation Safety, California Department of Health Services	15 Capitol P.O. Box 997414, MS 7610 Sacramento, CA 95899-7414 www.dhs.ca.gov/RHB/default.htm	(916) 440-7899
GU	Drinking Water	Guam Environmental Protection Agency	www.epa.gov/region09/cross_pr/islands/guam.html	(671) 972-3770
	UIC	U.S. EPA Region 9	www.epa.gov/region09/water/underground/notes	(415) 972-3767
	Radiation	N/A		
HI	Drinking Water	Department of Health: Environmental Management Division	www.hawaii.gov/health/eh/sdwb	(808) 586-4258
	UIC	U.S. EPA Region 9	www.epa.gov/region09/water/underground/notes	(415) 972-3767
	Radiation	Noise, Radiation & IAQ Branch, Department of Health	591 Ala Moana Boulevard Honolulu, HI 96813-4921 www.hawaii.gov/health/environmental/noise/index.html	(808) 586-4700
NV	Drinking Water	Department of Human Resources: Bureau of Health Protection Services	health2k.state.nv.us/bhps/phe/sdwp.htm	(775) 687-6615
	UIC	Department of Environmental Protection	ndep.state.nv.us/bwpc/uic01.htm	(775) 687-4670
	Radiation	Radiological Health Program, Bureau of Health Protection Services, Nevada State Health Division	1179 Fairview Drive, Suite 102 Carson City, NV 89701-5405 health2k.state.nv.us/BHPS/rhs	(775) 687-5394

U.S. EPA REGION 10			
Drinking Water	Drinking Water Unit	yosemite.epa.gov/R10/WATER.NSF/Drinking+Water/About+DWU	(206) 553-8515
UIC	Underground Injection Control Program	yosemite.epa.gov/R10/WATER.NSF/UIC/UIC+Program	(206) 553-1673
Radiation	Radiation Program	yosemite.epa.gov/R10/Airpage.nsf/webpage/Radiation	(206) 553-7660

AK	Drinking Water	Department of Environmental Conservation: Drinking Water & Wastewater Program	www.state.ak.us/dec/eh/dw	(907) 269-7647
	UIC	U.S. EPA Region 10 Ground Water Protection Unit	www.epa.gov/region10	(206) 553-1900
	Radiation	Radiological Health Program, Section of Laboratories, State of Alaska/DH&SS	4500 Boniface Parkway Anchorage, AK 99507-1270 www.hss.state.ak.us/dph/labs/radiological/radiological_health.htm	(907) 334-2107
ID	Drinking Water	Department of Environmental Quality: Water Quality Division	www.deq.state.id.us/water/prog_issues.cfm	(208) 373-0502
	UIC	Department of Water Resources	www.idwr.state.id.us	(208) 327-7956
	Radiation	Department of Environmental Quality	900 N. Skyline, Suite C Idaho Falls, ID 83402 www.deq.state.id.us	(208) 528-2617
OR	Drinking Water	Department of Human Resources: Drinking Water Program	www.ohd.hr.state.or.us/dwp	(503) 731-4317
	UIC	Department of Environmental Quality	www.deq.state.or.us/wq/groundwa/uichome.htm	(503) 229-5945
	Radiation	Radiation Protection Services, Oregon Health Services, Department of Human Services	800 NE Oregon Street, Suite 260 Portland, OR 97232-2162 www.ohd.hr.state.or.us/rps	(503) 731-4014
WA	Drinking Water	Department of Health: Drinking Water Division	www.doh.wa.gov/ehp/dw	(360) 236-3100
	UIC	Department of Ecology	www.ecy.wa.gov/programs/wq/grndwtr/uic	(360) 407-6143
	Radiation	Office of Radiation Protection, Division of Environmental Health, Department of Health	7171 Cleanwater Lane, Bldg #5 P.O. Box 47827 Olympia, WA 98504-7827 www.doh.wa.gov/ehp/rp	(360) 236-3210

Table D-2: Tribal Drinking Water Contacts

U.S. EPA Headquarters		
American Indian Environmental Office	www.epa.gov/indian	(202) 564-0303

U.S. EPA Regional Tribal Capacity Development Coordinators		
U.S. EPA Region 1	www.epa.gov/region01/topics/government/tribal.html	(888) 372-7341
U.S. EPA Region 2	www.epa.gov/region02/nations	(212) 637-3600
U.S. EPA Region 4	www.epa.gov/region04/ead/indian	(404) 562-6939
U.S. EPA Region 5	www.epa.gov/region5/water/stpb	(312) 353-2123
U.S. EPA Region 6	www.epa.gov/region06/6xa/tribal.htm	(800) 887-6063
U.S. EPA Region 7	www.epa.gov/region07/government_tribal	(913) 551-7030
U.S. EPA Region 8	www.epa.gov/region08/tribes	(303) 312-6116
U.S. EPA Region 9	www.epa.gov/region09/cross_pr/indian	(415) 744-1500
U.S. EPA Region 10	yosemite.epa.gov/r10/tribal.NSF	(206) 553-4011

Other Contacts		
Administration for Native Americans	www.acf.dhhs.gov/programs/ana	(877) 922-9262
Bureau of Indian Affairs	www.doi.gov/bureau-indian-affairs.html	(202) 208-3710
Indian Health Service	www.ihs.gov	(301) 443-3024
Native American Water Association	www.nawainc.org	(775) 782-6636

Table D-3: Tribal UIC Contacts

Office	Web site	Phone
Tribal Contacts		
Arizona - Class V Wells (U.S. EPA Region 9)	http://www.epa.gov/region09/water/underground/notes	(415) 972-3544
California (U.S. EPA Region 9)	http://www.epa.gov/region09/water/underground/notes	(415) 972-3544
Michigan, Mille Lacs, Department of Natural Resources and Environment	http://www.millelacsojibwe.org	(320) 532-7721
Navajo (U.S. EPA Region 9)	http://www.epa.gov/region09/water/underground/notes	(505) 599-6317
Osage (U.S. EPA Region 6)	http://www.epa.gov/region6/water/swp/uic	(918) 287-4041

Table D-4: Regional NRC Contacts for Non-Agreement States

Region	Address	Web site	Phone
NRC Region I			
Connecticut, Delaware, New Jersey, Pennsylvania, Vermont, Washington, D.C.	475 Allentown Road King of Prussia, PA 19406-1415	www.nrc.gov/who-we-are/organization/rifuncdesc.html	(610) 337-5000; 1-800-432-1156
NRC Region II			
Virginia, West Virginia, Puerto Rico, Virgin Islands	Sam Nunn Atlanta Federal Center 61 Forsyth Street, Suite 23T85 Atlanta, GA 30303-8931	www.nrc.gov/who-we-are/organization/riifuncdesc.html	(404)-562-4400; 1-800-577-8510
NRC Region III			
Indiana, Michigan, Minnesota, Missouri	2443 Warrenville Road, Suite 210 Lisle, IL 60532-4352	www.nrc.gov/who-we-are/organization/riiifuncdesc.html#funcdesc	(630) 829-9500; 1-800-522-3025
NRC Region IV			
Alaska, Guam, Hawaii, Montana, Idaho, South Dakota, Wyoming	611 Ryan Plaza Drive, Suite 400 Arlington, TX 76011-4005	www.nrc.gov/who-we-are/organization/rivfuncdesc.html	(817) 860-8100; 1-800-952-9677

Appendix E: Radionuclide Levels at Selected Water Treatment Plants

A variety of studies between 1982 and 1995 found that commonly used filtering methods and media for radionuclides at water treatment plants may concentrate uranium and radium at highly different levels of radioactivity. Depending on the radiation level of the water to be treated, as well as the treatment process, residuals and filters can accumulate radionuclides in the range of less than 10 pCi/g or per liter, to thousands of pCi/g or per liter. The method chosen for filtering water may have a significant impact on the radiation protection program that may need to be instituted at the treatment facility and available waste disposal options. Table E-1 summarizes the ranges of radium and uranium concentrations found nationwide in different filter media and backwash. Additional findings from water treatment plants follow in Tables E-2 to E-7.

Table E-1: Summary of Treatment Technologies for Removal of Naturally Occurring Radionuclides in Water[56]

Treatment Technology	Contaminant Removed	Removal Efficiency	Wastes Produced	Waste Concentrations
Cation exchange	Radium	85-97%	Rinse & backwash water Regenerant brine	8 to 94 pCi/L-Ra[1] 50 to 3,500 pCi/L-Ra[1] 22 to 94 pCi/L[2]
Anion exchange	Uranium	95%	Rinse & backwash water Brine regenerant solution	2 to 6e+06 pCi/L[1]-U 35 to 4.5e+06 pCi/L[1]-U 1.3 to 11 pCi/L
Lime softening	Radium Uranium	90% 85-90%[3]	Sludge (at clarifier Sludge (dry) Filter backwash	76 to 4,577 pCi/L-Ra 1 to 21.6 pCi/g-Ra 1 to 10 pCi/g-U 6.3 to 21.9 pCi/L-Ra
Reverse osmosis	Radium Uranium	90+% ---	Reject water	7 to 43 pCi/L-Ra 200 to 750 pCi/L-U
Electrodialysis	Radium Uranium	90% ---	Reject water	No data
Iron removal -Oxidation -Greensand	Radium	0 to 70%[4]	Solids & supernatant from filtration backwash Green sand Media	12 to 1,980 pCi/L-Ra 28 to 250 pCi/g-Ra
Selective sorbents	Radium Uranium	90+%	Selective sorbents (radium selective and activated alumina)	up to 3.6 pCi/g-Ra
Coagulation/ Filtration	Uranium	50 to 85%	Sludge	10,000 to 30,000 pCi/L-U

[1] Peak values
[2] Average for given waste forms
[3] May be increased to 99% by the presence or addition of magnesium carbonate to the water
[4] May be increased to 90% by passing the water through a detention tank after the addition of potassium permanganate prior to filtration

[56] Data extracted from U.S. EPA 1982, 1986, 1994b, 1995; Wade Miller Associates 1991; and Reid 1985.

Table E-2: Radium-226 Concentrations in Ion Exchange Treatment Plant Wastes[57]

Location (Ra-226 in raw water)	Average Ra-226 Concentration (pCi/L)			Peak Ra-226 Concentration in Wastes (pCi/L)
	Brine + Rinse	*Brine + Rinse + Backwash*	*Peak 1/4-1/3 of Regeneration Cycle*	
Eldon, IA (46 pCi/L)	530	420	2,000	3,500
Estherville, IA (5 pCi/L)	N/A	52	114	320
Grinnell, IA (6 pCi/L)	110	N/A	260	320
Holstein, IA (13 pCi/L)	175	N/A	576	1,100
Quail Creek, TX (7.3 pCi/L)	NA	93	190	200

Table E-3: Uranium Removal with Anion Exchange[58]

Location	Concentration of Uranium (μg/L)		Gallons Treated	Bed Capacity (lbs U/ft^3)
	Raw Water	*Treated Water*[1]		
Cove, AZ	64	63	31,400	0.017
Fort Lupton, CO	35	35	22,310	0.007
Brighton, CO	23	23	45,460	0.009
Marshdale, CO	28	<0.1	40,610	[2]
Church Rock, NM	52	0.1	20,360	[2]

[1] Uranium concentration of treated water measured after indicated number of gallons treated

[2] Bed capacity not exhausted

[57] Schliekelman, R., 1976; U.S. EPA, 1992.

[58] Lassovszky, P. and Hathaway, S., 1983.

Table E-4: Radium Removal with Reverse Osmosis – Sarasota, FL[59]

System (capacity – Kgpd)	Raw Water TDS (mg/L)	Ra-226 (pCi/L)			Ra-226 Removal Efficiency	Percent Recovery
		Raw Water	*Treated Water*	*Reject Water*		
Bay Lakes Estates MHP (40)	2,532	3.2	0.1	--	97%	--
Venice (1,000)	2,412	3.4	0.3	7.8	91%	64%
Sorrento Shores (200)	3,373	4.6	0.2	7.9	96%	39%
Spanish Lakes MHP (70)	1,327	10.4	1.2	20.5	88%	31%
Nokomis School (0.8)	1,442	11.1	0.5	11.9	95%	--
Bayfront TP (1.6)	895	12.1	0.6	19.4	95%	28%
Kings Gate TP (30)	1,620	15.7	2.0	--	87%	--
Sarasota Bay MHP (5)	2,430	20.5	0.3	37.9	98%	50%
AVERAGE					*93%*	

Table E-5: Radium Concentrations in Lime Softening Sludges and Backwash Waters[60]

Location and Type of Sludge (Ra in raw water)	Percent Solids	Wet Basis (pCi/L)		Dry Basis (pCi/g)	
		Ra-226	*Ra-228*	*Ra-226*	*Ra-228*
West Des Moines, IA (9.3 pCi/L)					
Lagoon Sludge	37.6%	5,159	596	10.8	1.3
Clarifier Sludge	1.6%	< 20	< 40	< 0.02	< 0.04
Lagoon Sludge	N/A	2,300	N/A	N/A	N/A
Backwash Water	N/A	6.3	N/A	N/A	N/A
Bushnell, IL					
Clarifier Sludge	19%	4,577	< 45	21.6	< 0.21

[59]Sorg, T., 1980.

[60]Snoeyink, V., et al, 1984.

Table E-5, Continued

Location and Type of Sludge (Ra in raw water)	Percent Solids	Wet Basis (pCi/L)		Dry Basis (pCi/g)	
		Ra-226	***Ra-228***	***Ra-226***	***Ra-228***
Clarifier Sludge	12.6%	2,038	236	15.0	1.7
Backwash Water	0.23%	< 20	< 39	N/A	N/A
Webster City, IA (6.1 pCi/L)					
Sludge	N/A	980	N/A	N/A	N/A
Backwash	N/A	50	N/A	N/A	N/A
Peru, IL (5.8 pCi/L)					
Backwash Water	N/A	36.9	N/A	N/A	N/A
Elgin, IL (5.6 pCi/L)					
Lagoon Sludge	57.3%	9,642	9,939	11.3	11.7
Clarifier Sludge	10.3%	948	873	8.6	8.0
Backwash Water	0.05%	< 20	< 40	< 0.02	< 0.04
Sludge	NA	18.3	N/A	N/A	N/A

Table E-6: Concentration of Radionuclides in the Spent Filter Backwash from Green Sand Filtration and Other Iron/Manganese Filtration Processes[61]

Plant	Raw Water			Spent Filter Backwash Water		
	Ra-226 (pCi/L)	Ra-228 (pCi/L)	Uranium (pCi/L)	Ra-226 (pCi/L)	Ra-228 (pCi/L)	Uranium (pCi/L)
Sandstone [1]	9.2	5.2	0.13	40.6	27.4	1.1
Hinckley [2]	7.6	4.5	0.14	270	304	2.3
Madelia [3]	2.1	3.9	< 0.14	108	170	< 0.20
Inver Grove Heights [1]	5.3	1.1	0.62	145	5.9	0.31
Savage [2]	7.5	8.1	0.4	69.9	54.4	0.98

[1] Treatment scheme consists of chlorination, potassium permanganate, and anthracite/sand filter

[2] Treatment scheme consists of aeration, chlorination, potassium permanganate, and anthracite/green sand filter

[3] Treatment scheme consists of aeration, chlorination, detention, potassium permanganate, and anthracite/sand filter

[61] Peterson, K. 1999.

Table E-7: Concentration of Radionuclides on Water Treatment Process Media and Materials[62]

Location	Treatment Process	Process Media/Material	Radionuclide Concentration (pCi/g)	
			Ra-226	**Ra-228**
Herscher, IL	Iron removal	Filter media	111.6	38.9
Dwight Correctional Institute, IL	Natural green sand	Green sand	29-46	
Peru, IL	Lime softening	Filter media	4.6	3.6
Elgin, IL	Lime softening	Filter media	16.0	8.3
Elkhorn, WI	Iron removal	Filter media (sand)	1.47	0.48

[62]Bennett, D.L., 1978; Brink, W.L., et al, 1978.

Appendix F: Thorium and Uranium Decay Series

Figure F-1: Thorium Decay Series

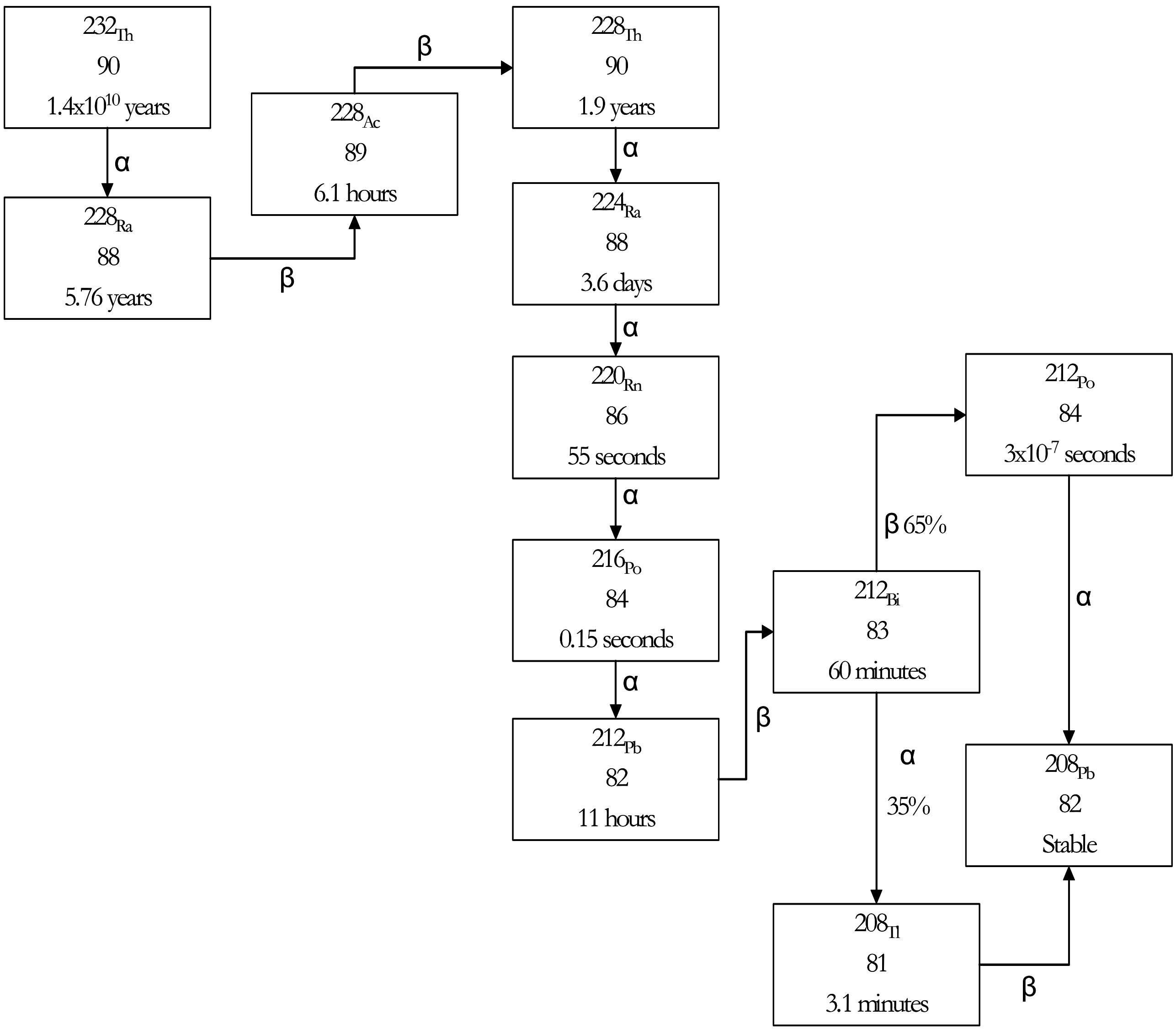
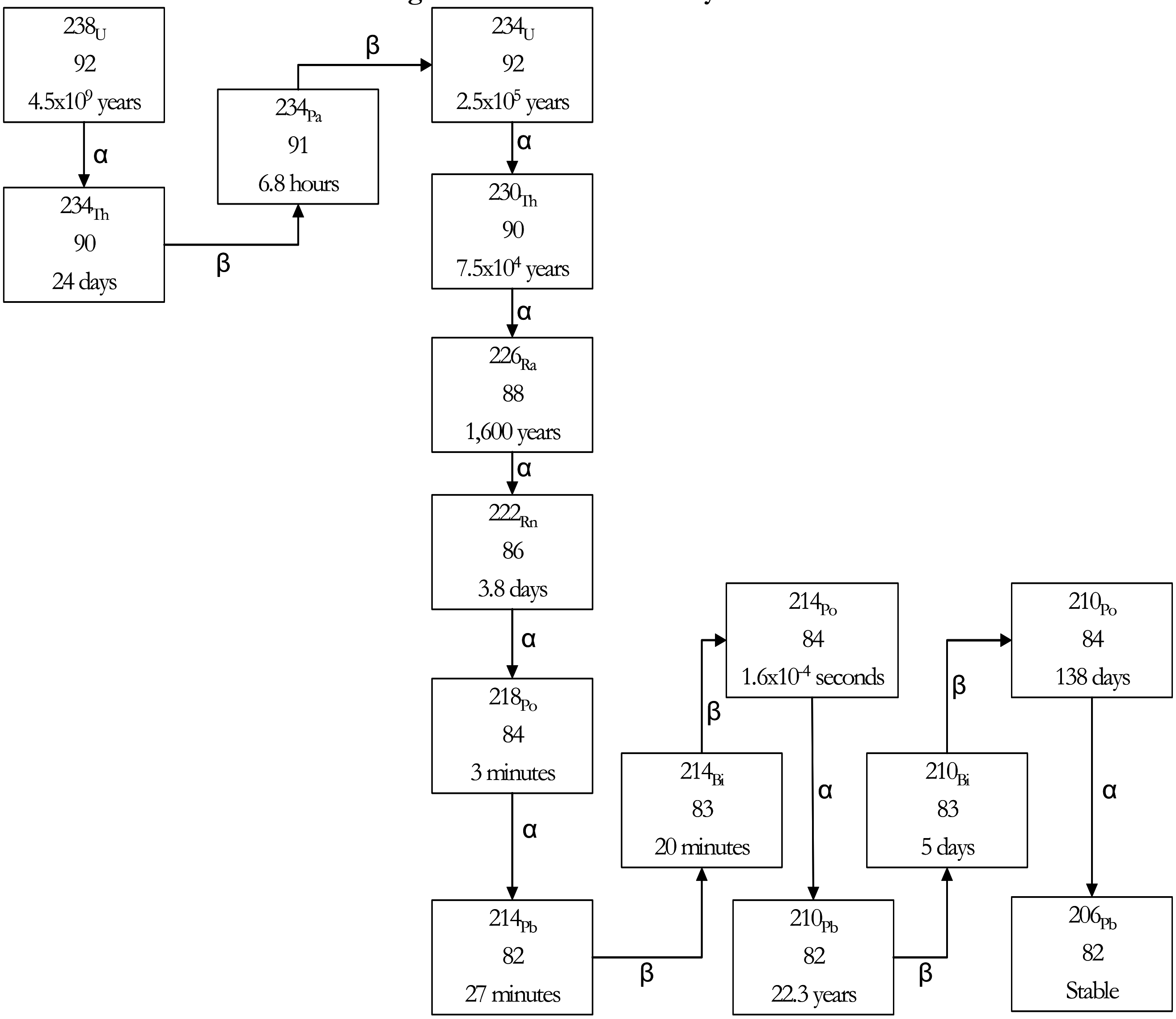


Figure F-2: Uranium Decay Series



Appendix G: Additional Reference Materials

The following resources provide more information on the Radionuclides Rule, and the treatment, handling, and disposal of radionuclides:

Documents

Evaluation of EPA's Guidelines for Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM), Report to Congress, EPA 402-R-00-01, June 2000
(http://www.epa.gov/radiation/tenorm/docs/nas_resp.pdf)

Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials, Committee on Evaluation of EPA Guidelines for Exposure to Naturally Occurring Radioactive Materials, National Academy of Sciences, 1999
(http://www.nap.edu/books/0309062977/html/index.html)

Final Report: ISCORS Assessment of Radioactivity in Sewage Sludge: Radiological Survey Results and Analysis, NUREG-1775, EPA 832-R-03-002/DOE/EH-0669, November 2003
(http://www.iscors.org/FinalSurvey.pdf)

Implementation Guidance for Radionuclides, EPA 816-F-00-002, March 2002
(http://www.epa.gov/safewater/rads/final_rads_implementation_guidance.pdf)

Radioactive Material Regulations Overview, U.S. Department of Transportation, Research and Special Programs Administration
(http://hazmat.dot.gov/pubtrain/ramreview.pdf)

Radionuclides Rule (Final), Federal Register, Vol. 65, No. 36, December 7, 2000
(http://www.epa.gov/safewater/rads/radfr.pdf)

Radionuclides Rule: A Quick Reference Guide, EPA 816-F-01-003, June 2001
(http://www.epa.gov/safewater/rads/quickguide.pdf)

Radionuclides in Drinking Water: A Small Entity Compliance Guide, EPA 815-R-02-001, February 2002
(http://www.epa.gov/safewater/rads/pdfs/rads-smallsyscompguide.pdf)

Radionuclides Notice of Data Availability, Technical Support Document, EPA, March 2000
(http://www.epa.gov/safewater/rads/tsd.pdf)

RCRA Orientation Manual, EPA 530-R-02-016, January 2003
(http://www.epa.gov/epaoswer/general/orientat/r02016.pdf)

Web sites

Conference of Radiation Control Program Directors, Inc. - http://www.crcpd.org

U.S. EPA Office of Air and Radiation:
Radiation Protection - http://www.epa.gov/radiation/index.html
Managing Radioactive Materials and Waste - http://www.gov/radiation/tenorm/index.html

TENORM - http://www.epa.gov/radiation/tenorm/index.html

U.S. EPA Office of Ground Water and Drinking Water
Radionuclides in Drinking Water - http://www.epa.gov/safewater/radionuc.html
Underground Injection Control Program - http://www.epa.gov/safewater/uic.html

U.S. EPA Office of Solid Waste and Emergency Response
Hazardous Waste Identification - http://www.epa.gov/epaoswer/hazwaste/id/index.htm
Key Radiation Guidances and Reports - http://www.epa.gov/oerrpage/superfund/resources/radiation/index.htm
Non-Hazardous Waste (RCRA Subtitle D) - http://www.epa.gov/osw/
Paint Filter Liquids Test - http://www.epa.gov/epaoswer/hazwaste/test/pdfs/9095a.pdf

U.S. EPA Office of Wastewater Management
NPDES - http://cfpub.epa.gov/npdes/

The TENORM Page - http://www.tenorm.com/