United States Environmental Protection Agency
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Guidance on Radioactive Materials in Sewage Sludge and Ash at Publicly Owned Treatment Works

Interagency Steering Committee on Radiation Standards
Sewage Sludge Subcommittee

Revised Draft
June 2000

This document resulted from interagency discussions. The Interagency Steering Committee on Radiation Standards, Sewage Sludge Subcommittee, is composed of representatives from the Environmental Protection Agency (EPA), Nuclear Regulatory Commission (NRC), Department of Energy, Department of Defense, State of New Jersey, the city of Cleveland and the county of Middlesex, New Jersey. This document has not been approved by the respective agencies and does not represent the official position of any participating agency at this time.

This document is a draft, available for review and comment. Comments should be provided to the EPA or NRC contact listed in Chapter 7. The Subcommittee prefers that comments be provided by October 13, 2000. The final version of this document will be produced after the survey of radioactivity in sewage sludge is complete. The subcommittee currently plans to produce the final version in Fall 2001.

Cover photo courtesy of Water Environment Federation, Alexandria, VA

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1 INTRODUCTION

Authorities that operate Publicly Owned Treatment Plants (POTWs) have many considerations to address in the monitoring and daily operation of the treatment plants. One of these considerations is the potential for radioactive materials to become concentrated in the treatment plant. Radioactive materials are typically not a major concern at POTWs; however, they are a component of the waste stream that is less understood.

There are more than 16,000 POTWs in the United States. The Nuclear Regulatory Commission (NRC) estimated that of the more than 24,000 regulated users of Atomic Energy Act (AEA) radioactive materials, about 9,000 users have a potential to release radioactive materials to the sewer (GAO, 1994). Naturally occurring radioactive material may also enter sewer systems. Considering the many means for deposition and concentration of material in sewer systems, radioactive materials may concentrate in the wastewater systems and in sewage sludge and ash.

In the United States there have been no identified cases in which radioactive materials in sewage systems have been a threat to the health and safety of POTW workers or the public. There have been a small number of facilities where elevated levels of contamination have been detected. Based upon past experience, there is the potential for radioactive material to concentrate in sewage sludge and ash, but such material is not likely to pose a threat to the health and safety of workers or the public.

The Sewage Sludge Subcommittee of the Interagency Steering Committee on Radiation Standards (ISCORS) is comprised of representatives from several federal agencies (see Section 4.4 for more information about ISCORS). The subcommittee is assisting NRC and the Environmental Protection Agency (EPA) in developing this guidance for POTWs and in performing a survey of radioactive material in sewage sludge and ash. One purpose of this document is to inform POTW authorities of the possibility for radioactive materials to concentrate in sewage sludge and incinerator ash. A second purpose is to help the POTW authorities determine what they may want to do about any radioactive materials present in their sewage sludge or ash.

Recent Example of Radioactive Material Concentrating in Sewage Sludge

There are certain geographical areas of the U.S. where relatively high radium concentrations occur in ground water and a number of public drinking water supplies depend upon ground water as their source of water. Some of these supplies have radium levels that exceed the drinking water standard for radioactive material. In treating the drinking water to remove the radium, a wastewater is created, which may contain much of the removed radium. When this wastewater is discharged to the sanitary sewer, the radium can be reconcentrated in sewage sludge produced by the sewage treatment plant. In some cases, the sludge is treated by composting and used as a soil conditioner or organic fertilizer by farmers and the general public. Several States are aware of this problem and are in the process of evaluating the radium levels in these materials.

Elevated Levels of Radioactive Material

The term "elevated levels of radioactive material," as used throughout this document, refers to measured or detected levels of radioactive material that would, in the opinion of the ISCORS member agencies, alert the POTW that some appropriate actions may be warranted. The various appropriate actions, which are described in this document, are suggested as best or prudent management practices that could be taken to ensure that worker safety, and public health and environmental protection have not been compromised. The presence of such "elevated levels" in a particular sewage sludge or ash sample does not imply that a dangerous or hazardous condition exists, but rather that the POTW may want to consider taking some appropriate action.

At the time this draft guidance was prepared, the "elevated levels" term had not been quantified. The use of this term, therefore, does not imply some quantified incremental exceedance of an existing benchmark or standard. Determining whether there is any concern for worker safety or general public health at any measured level of radioactive materials in a particular sludge sample is dependent upon a number of factors, and should be considered on a case by case basis.

As efforts by the ISCORS Sewage Sludge Subcommittee to conduct a survey and to perform dose modeling are completed, the term "elevated levels" could be further refined to include quantified ranges of radioactive material concentrations in various types of sewage sludge and ash products that correspond to suggested best management practices.

1.1 Reported Incidences of Radioactive Contamination

In their 1994 report, *Nuclear Regulation: Action Needed to Control Radioactive Contamination at Sewage Treatment Plants,* the General Accounting Office (GAO) described nine cases where contamination was found in sewage sludge or ash or the wastewater collection system, which have resulted in considerable cleanup expense to the POTW authority or specific industrial dischargers of the wastewater (see Table 1). There have also been a few additional cases identified that are still under evaluation.

TABLE 1. Sewage Treatment Plants Where Elevated Levels of Radioactive Material Were Found			
Location	**Year Found**	**Radionuclides**	**Actions Taken**
Tonawanda, New York	1983	Americium-241	State spent over $2 million cleaning up treatment plant. No final decision has been made regarding radioactive material found in the landfill.
Grand Island, New York	1984	Americium-241 Hydrogen-3 Polonium-210	No plant cleanup was warranted.
Oak Ridge, Tennessee	1984	Cobalt-60 Cesium-134 Cesium-137 Manganese-54	Soil around sewer line cleaned up, and some special sludge disposal occurred.
Royersford, Pennsylvania	1985	Manganese-54 Cobalt-58 Cobalt-60 Strontium-89 Zinc-65 & others	No plant cleanup was warranted.
Erwin, Tennessee	1986	Americium-241 Plutonium-239 Thorium-232 Uranium	Sludge digester cleaned up.
Washington, D.C.	1986	Carbon-14 Hydrogen-3 Phosphorous-32&33 Sodium-22 Sulfur-35 & others	No plant cleanup was warranted.
Portland, Oregon	1989	Thorium-232	Sewage lines cleaned up and pretreatment system added.
Ann Arbor, Michigan	1991	Cobalt-60 Manganese-54 Silver-108m, 110m Zinc-65	No plant cleanup was warranted.
Cleveland, Ohio	1991	Cobalt-60	Treatment plant cleanup and related activities have cost over $1 million.
Source: GAO, 1994.			

The U.S. Nuclear Regulatory Commission (NRC) conducted a limited survey in the mid-1980s to determine if radioactive material discharged to sewage systems was concentrated in sludge.

This took place at the facilities of 15 radioactive material users (licensees) and associated sewage treatment plants. The sampling revealed no reconcentration problems (GAO 1994).

In 1986, the EPA published a literature review titled *Radioactivity of Municipal Sludge* (EPA 1986). The literature search and follow-up telephone survey identified nine references containing data on radioactivity concentrations in sewage sludges. These references included the results of one-time surveys and ongoing monitoring programs by local authorities and state agencies, results for individual facilities and facilities from as many as 10 cities, and reports of incidents of sludge contamination reported by NRC. The data obtained varied widely with respect to the purpose of data collection, type of material sampled, number of samples, and radionuclides analyzed. The available data identified four radionuclides as most frequently reported: iodine-131, radium-226, americium-241, and cesium-137.

The NRC and EPA efforts to characterize radioactive materials in sewage sludge and ash are discussed in Section 1.3 and Chapter 4.

1.2 Selected Examples of Contamination

Despite efforts to identify POTWs with radioactive contamination through surveys, most of the cases involving elevated levels of radioactive materials at POTWs have been discovered through measurements obtained for other purposes. As shown in Table 1, at least five of these instances warranted some mitigative action. A brief discussion of three of these cases illustrate the need for the POTW authority to be aware of the possibilities of radioactive contamination and the potential consequences.

Oak Ridge, Tennessee, Sanitary Sewage Treatment Facility

In March of 1984, staff from the Oak Ridge weapons complex was performing a survey to identify if any material contaminated with mercury or uranium from the complex had been used as fill in the surrounding community. Elevated radiation readings were detected along Emory Valley Road. Soil samples revealed contamination from radioactive cesium-137 and cobalt-60. During this time, the Quadrex Corporation notified the Tennessee Division of Radiological Health that contaminated sediment was detected in Quadrex' drain sump. The Quadrex facility was involved in the decontamination of large pieces of radioactively contaminated equipment, such as duct work and piping. The process produced large volumes of water with low levels of contamination. Subsequent examination of the sewage collection system confirmed the soil and sediment contaminations were related and that the Quadrex plant was probably responsible for the releases. Cracks in the sewer line apparently resulted in the radioactive material contaminating the soil.

Further examination showed that contamination had also occurred at the Oak Ridge Waste Treatment Plant (ORWTP). Surveys at the ORWTP showed contamination of both sewage sludge in a digester storage tank, as well as sludge placed on drying beds in November 1983.

Quadrex agreed to assist in decontaminating the exposed contaminated sludge and to assist the city in conducting measurements when portions of the old sewer line were to be excavated. The contaminated sludge was subsequently disposed in a sanitary landfill.

In the late 1980s, it was discovered that, in addition, routine, licensed discharges of several different radionuclides (e.g., Co-60, Cs-137, and uranium) from multiple facilities resulted in reconcentration of radioactive materials in sewage sludges. This occurred even though the discharge levels were reportedly only small fractions of regulatory limits. (Since then, NRC's regulatory discharge limits have been changed, which has reduced the concentrations of radioactive materials in sewage sludge.) These routine discharges to the sewer led to the expenditure of considerable resources over the past ten years.

The most significant concern related to radioactive material discharges faced by the Oak Ridge POTW managers was the possibility that radionuclides, even at low levels, may have inhibited their ability to continue land applying the sludge, the practice of land application of the Oak Ridge sludge was frequently called into question. In response, Oak Ridge developed a site-specific, risk-based methodology for establishing radionuclide limits for its sewage sludge (see Appendix F).

Portland, Oregon Contaminated Wastewater Collection Lines

Thorium-232 was detected in wastewater collection lines in Portland, Oregon, in 1989. While contamination did not reach the treatment facility, the collection lines were contaminated and sewer workers took special precautions. The generator of the wastewater containing the Th-232 was identified, remediated the contamination, and installed a pretreatment system to reduce discharges.

The Cleveland, Ohio Southerly Sewage Treatment Plant

The Southerly plant is operated by the Northeast Ohio Regional Sewer District (NEORSD). It is an activated sludge facility that produced 103,000 wet tons of filter cake and incinerated 97,000 tons of the filter cake in 1992. During an aerial survey conducted in April 1991 of licensees in the area, NRC inspectors noted elevated readings of radiation at the sewage treatment plant. Subsequent ground level measurements indicated radioactive cobalt-60 was present, primarily in areas where ash had accumulated in fill areas and storage lagoons. Additional surveys were conducted in September 1991 and March 1992 to determine the extent of the contamination. These measurements of ash deposits indicated no new contamination had occurred since 1991. The highest direct radiation readings were found when a probe was lowered into animal burrows made in the residue deposits.

This suggested that the concentration of material was higher below the surface. From the records of the areas where the ash was placed, it appeared that the contamination occurred in the late 1970s, and perhaps in the early 1980s.

In 1992, NEORSD developed a remediation plan to remove ash from three storage lagoons which were filled to near capacity. Remediation was completed in 1993, resulting in 174,000 cubic yards of contaminated ash stabilized on site in two areas that are fenced (total of about 25 acres) and capped with six inches of dirt. Radiation measurement devices were placed at the periphery of the area and seven monitoring wells were installed. Some contamination still exists in other areas of the site and the NEORSD is working with the NRC to assess its extent and degree. In 1994, NEORSD terminated sewer service to the wastewater generator.

As of February 2000, the remediation costs incurred by NEORSD included about $1,800,000 for the on-site remediation and related activities and $120,000 to erect the fence around the fill and holding pond areas. The NRC spent about $370,000 on radiation exposure assessment, soil sampling and analyses, and other surveys. The POTW authority engaged in a series of legal actions to recover the costs from the waste generator; about $1,200,000 was recovered. To date, the generator has failed to meet the NEORSD criteria for restoration of sewer service.

Based on the cases identified thus far, though rare, the contamination of a POTW with radioactive material can have serious financial consequences.

1.3 Congressional Interest

A joint House and Senate hearing was held in May 1994 to officially release and address questions raised in a General Accounting Office (GAO) report, *Actions Needed to Control Radioactive Contamination of Sewage Treatment Plants* (GAO 1994). The hearing and GAO report were stimulated by concerns associated with the elevated levels of radioactive materials in sewage sludge incinerator ash at the NEORSD's Southerly plant described in Section 1.2. Testimony presented by both NRC and EPA during the hearing noted that there was no indication of a widespread problem in this area and that the NEORSD incident appeared to be an isolated incident. However, at the hearing NRC and EPA committed to jointly develop guidance for POTWs and to collect more data on the concentration of radioactive materials in samples of sewage sludge and ash from POTWs across the country.

Since the hearing and GAO report, the NRC and EPA, with the assistance of other federal agencies participating on the ISCORS Sewage Sludge Subcommittee, have been addressing questions regarding radioactive materials in sewage sludge and ash from POTWs. The Subcommittee, formed by ISCORS in 1996, developed an initial draft of this joint NRC/EPA guidance document for POTWs, which was issued in May 1997 for public comment. The Subcommittee is also in the process of conducting a comprehensive survey of radioactive materials in sewage sludge and ash from 300 POTWs nationwide. The survey will focus on POTWs in regions where the potential for elevated levels of radioactive materials in wastewaters may exist. The results of this survey will be published in a survey report and summarized in the final version of this guidance document.

2 PURPOSE

One purpose of this document is to inform POTW authorities of the possibility for radioactive materials to concentrate in sewage sludge and incinerator ash. A second purpose is to help the POTW authorities determine what they may want to do about the radioactive materials present in their sewage sludge or ash. This guidance is not intended to serve as a comprehensive reference regarding radioactivity. However, it provides information on important issues related to the control of radioactive materials that may enter POTWs.

This guidance document poses the following questions; answers to these questions are found in various sections of the report, as cited below:

Is There Radioactive Material in My Treatment Plant?

One of the first things a POTW authority needs to realize is that there is radioactive material in the wastewater their system treats. Chapter 3 discusses why there is radioactive material in sewage sludge and when the presence of these materials may be of concern. Chapter 5 discusses how to determine if there are elevated levels of radioactivity and who can help in the unlikely event that there are elevated levels.

Who Are the Other Players in My Specific Case?

The Federal and State regulatory authority over radioactive materials, sewage sludge, and industries which may discharge into sewage systems is complex. Further information on regulatory authorities is available in Chapter 4.

What Should the POTW Authority Consider Doing to Determine if There Is a Problem With Levels of Radioactive Materials?

There are several steps to consider in evaluating whether a POTW may have a problem regarding radioactive contamination. Chapter 5 describes what a POTW can do to determine if there is radioactive contamination at their facility, and who can help. Appendix A is a primer on radioactivity and radioactive materials. The information provided in Appendix A should be helpful in understanding the nomenclature and some of the basics about the health risks of radioactivity.

What Can the POTW Authority Do if Contamination is Found?

There are several options for consideration if contamination is found. There are a number of options that a POTW may want to consider. Chapter 6 presents the options, as well as their legal and technical aspects.

3 WHY IS THERE RADIOACTIVE MATERIAL IN SEWAGE SLUDGE AND ASH? WHAT IS THE CONCERN?

Radioactive materials are an ever-present component of the natural environment and are also produced through some human activities. Generally, the presence of radioactive materials is a concern only when concentrations become sufficiently elevated above background levels to potentially pose a health risk or in cases where the ability of a POTW to use or dispose of the sludge or ash is inhibited. There have not been many known occurrences of such elevated concentrations since the 1980s. This section explores sources of radioactive materials that may reach a POTW and why they may become a concern to POTW personnel and the public.

3.1 Types of Sources

There are three general sources of radionuclides in the environment: natural sources, natural sources concentrated or enhanced by human activity, and man-made sources. Radioactive material from all of these types of sources have the potential to enter sewage systems.

Sources of Radioactivity

Natural Sources. Geologic formations, water, and soils that contain small amounts of radioactive elements, typically known as naturally-occurring radioactive materials (NORM).

Natural Sources Concentrated or Enhanced by Human Activity. Naturally-occurring radioactive materials, technologically enhanced by human activity, known as TENORM.

Man-made Sources. Radioactive materials generated by human activities such as accelerator material (often referred to as NARM); nuclear byproduct material, source material, or special nuclear material; and fallout from nuclear weapons testing.

3.1.1 Natural Sources

Natural sources of radiation include geologic formations and soils that contain uranium, radium, radon, and other nuclides that are radioactive. Water originating in or moving through the formations and soil may transport the radioactive materials either dissolved in the water itself or attached to dissolved and suspended solids in the water. Radon is also released to the atmosphere from soil and water.

The amount of naturally-occurring radioactive materials in the ground varies widely. Some areas with elevated levels of naturally-occurring radioactive materials include locations such as those underlain by phosphate ore and uranium ore deposits. The lowest levels are generally found in sandy soils of the Atlantic and Gulf Coasts. Figure 1 shows average indoor screening-level radon concentrations by county in the U.S. These average concentrations may roughly correspond to the general levels of uranium and radium in soils in the area.

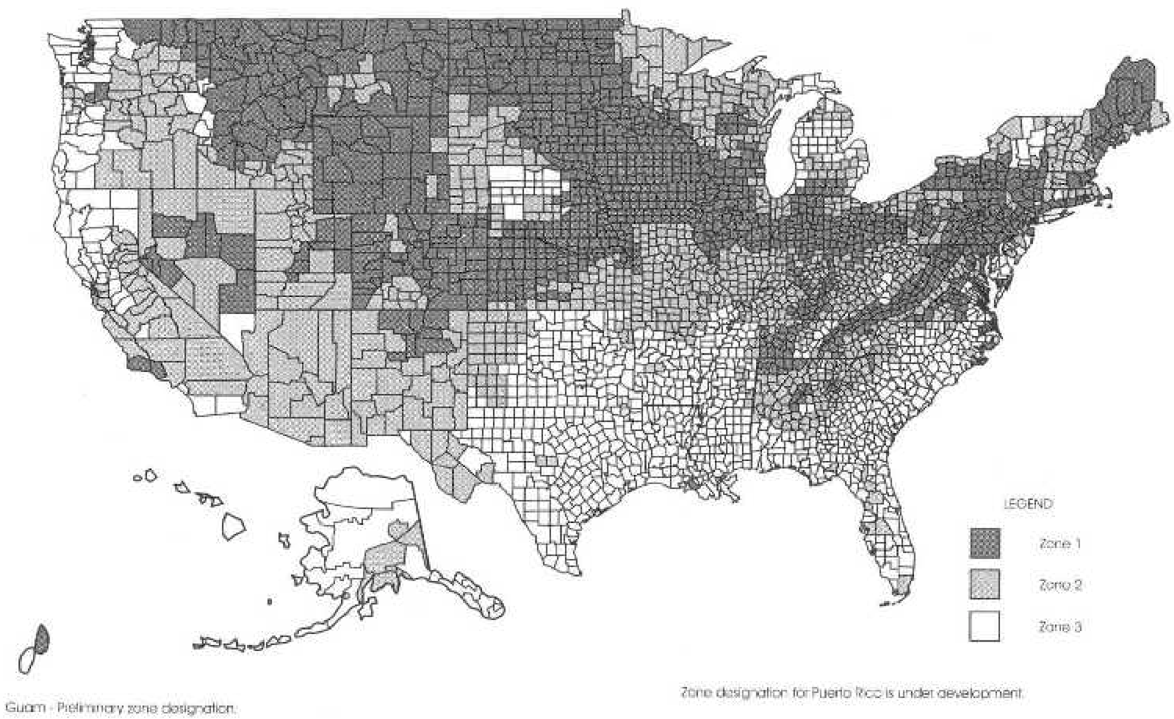

Figure 1. Average indoor-air, screening-level concentrations of radon in the U.S. From EPA (1993a). Zone 1 counties have a predicted average indoor screening level greater than 4 pCi/L. Zone 2 counties have a predicted average between 2 and 4 pCi/L, and Zone 3 counties have a predicted average less than 2 pCi/L.

3.1.2 Natural Sources Concentrated or Enhanced by Human Activity

Levels of naturally-occurring radioactive materials can be enhanced by human activity and by technologies associated with extraction processes. These materials, when enhanced by human activity, are known as Technologically-Enhanced Naturally Occurring Radioactive Materials (TENORM). Examples of TENORM include articles made from or coated with naturally-occurring radioactive materials and wastes from mineral and petroleum production, burning coal, and geothermal energy production.

TENORM may be introduced to the sewage system from ground and surface water, plants and food, as well as from potential discharges from industries (e.g., water treatment plants, mining and petroleum industries, fertilizers, electronics, ceramics, foundries and paper/pulp mills). EPA is in the process of studying this potential radiation hazard. Additional information on TENORM may be found in EPA (1993b), NAS (1999), and Eisenbud and Gesell (1997).

3.1.3 Man-Made Sources

Radioactive materials are also generated by human activities. Man-made sources include radioactive material produced for and as a result of the operation of nuclear reactors (i.e., source material, special nuclear material, and byproduct material). Other man-made sources are produced from the operation of accelerators, and from global fallout from testing of nuclear weapons and from nuclear accidents (e.g., the Chernobyl accident).

NRC and Agreement States have licensed about 24,000 facilities to use radioactive materials and about 9000 of these have the potential to release radioactivity to sewers. Licensees include utilities, nuclear fuel fabricators, universities, medical institutions, radioactive source manufacturers, and industrial users of radioactive materials. Laboratories and universities use man-made radioactive materials (e.g., carbon-14) in research, including in genetic research, the study of human and animal organ systems, and in the development of new drugs. Radioactive materials are also found in consumer products such as smoke detectors, luminous watches, and tobacco products (NRC, 1978). Radioactive materials are prescribed to medical patients for the diagnosis and treatment of illnesses (Cember, 1987).

Nuclear power plants are not considered significant sources of radioactive materials in sewage treatment systems. Such plants currently do not dispose of radioactive materials through release to sewers. Wastes containing radioactive materials are collected, treated, and packaged for disposal in licensed radioactive waste disposal facilities. Thus, any radioactive materials released into sewage systems are incidental quantities, from sanitary waste systems (i.e., restrooms). In addition, most nuclear power plants maintain their own sewage treatment systems, not connected to public systems, and any sewage sludges shipped offsite are monitored to ensure that no detectable radioactive material is present. Thus, potential quantities of radioactive materials released by nuclear power plants into sewage treatment systems are generally quite small compared to the average broad scope licensee.

3.2 How Radioactive Materials Reach POTWs

Radioactive materials reach POTWs primarily via wastewater discharges. Chemicals and other materials (e.g., lime, fly ash, waste pickle liquor, or wood ash) used by the POTWs may also contain radioactive materials. In addition, infiltration and inflow into sanitary sewers may contain radioactive materials. Table 2 summarizes the sources and pathways by which radioactive materials may reach POTWs.

Table 2. Sources and Potential Pathways for Radioactive Materials to Reach POTWs		
Discharges to POTWs	**Treatment Process**	**Infiltration and Inflow**
• Drinking water and drinking water residuals that contain NORM • Sewage with radioactive materials from food and medical procedures • Wastewater from NRC or Agreement State licensees handling radioactive materials in unsealed form • Wastewater from industries handling or processing materials containing NORM • Exempt or unlicensed radioactive materials	• Process chemicals with radioactive materials (e.g., lime, fly ash, waste pickle liquor, or wood ash)	• Infiltrating ground water containing NORM • Surface waters runoff containing NORM or fallout, via combined sewers

The local drinking water supply may contain NORM found in the soil or geologic media from which the water is removed. The local drinking water treatment facility may remove some of the radioactive materials from the raw water by ion exchange, precipitation, coagulation, or filtering of dissolved or suspended solids. The resulting residuals are sometimes disposed of by discharge to the wastewater collection system. Any radioactive materials remaining in the finished water supply would eventually be transported to the POTW along with waste waters.

Two other domestic sources of radioactive materials in sewage are food and medical procedures. Radioactive materials in food are digested and discharged to the POTW when excreted. Bananas and brazil nuts are examples of food containing radioactive materials (e.g., potassium-40) (Eisenbud and Gesell 1997). Similarly, radioactive materials (e.g., iodine-131, technetium-99m, and thallium-201) used in the diagnosis and treatment of medical conditions are also discharged to the POTW when excreted.

Other potential sources of radioactive materials include facilities with NRC and Agreement State licenses. All licensees are authorized by the regulations (see section 4.1 for details about the regulations) to discharge radioactive materials to the sewers; however, it is estimated that only about

20 percent of NRC licensees actually do so. The main reason most licensees do not discharge radioactive material to the sewers is that they possess only sealed sources, which are extremely unlikely to be released into sewers. Other licensees may have unsealed sources, but not in liquid form, and hence there is no radioactivity released to wastewater.

Many licensees which use radioactive materials in liquid form do not need to discharge to the sewers because: 1) the materials used are very short-lived and can decay in short-term storage and then be discharged as non-radioactive, or 2) the material may contain wastes that cannot be disposed of into sanitary sewers, if the material is non-dispersible or due to the presence of other non-radioactive pollutants. These pollutants may be prohibited from discharge into sewers by regulations other than NRC's regulations, such as the Clean Water Act.

Radioactive material is handled in "unsealed" forms in the nuclear fuel fabrication industry, in the production of radiopharmaceutical medicines, and in research. Limits in quantities and concentrations that the NRC and Agreement States allow to be discharged to the sanitary sewer are based on a fraction of the dose limit that can be received by an individual member of the public (see section 4.1 for the dose limits).

Table 3 lists types of NRC licensees that could dispose radioactive materials into the sewer system and radionuclides previously found in POTW sewage or those that could be present. It should be noted that a broad scope licensee is usually authorized to possess and use any radionuclide with an atomic number from 1 to 83. This means that many more radionuclides than those listed in Table 3 could be disposed into the sanitary sewer. The half lives and types of radiation emitted by these radionuclides are listed in Appendix A, Table A-1.

Licenses may be issued for specific applications, such as for industrial radiography, irradiators, well logging or specific medical uses. In such cases, the application, the physical and chemical states and the radioactivity of the materials are well defined. In other cases, the application is not as well defined, such as medicine and research. The physical and chemical form and activity will depend on the nature of the medical treatment, diagnosis or research being conducted. To accommodate undefined or changing applications, broad scope licenses are issued (e.g., to hospitals, universities, and research facilities).

For POTWs that serve large medical institutions, a major portion of the radioactive discharges to the sewer comes from patients. POTWs serving large medical centers and universities in which extensive research is conducted may receive discharges from both the research activities and from patients. A complicating factor is that some patients reside far away from the medical centers. Wastes from these patients will probably be discharged to the POTW serving the patients' residences. Refer to Table 3 for radionuclides commonly used in the medical facilities.

<table>
<tr><th colspan="3">Table 3. Types of NRC and Agreement State Licensees and Typical Radionuclides</th></tr>
<tr><th>Academic
(broad scope)</th><th>Medical
(broad scope, nuclear pharmacies)</th><th>Manufacturing and Distribution (broad scope, nuclear laundries, decontamination services)</th></tr>
<tr><td>Carbon-14
Cobalt-60
Cesium-137
Hydrogen-3
Iodine-125/131
Iron-59
Manganese-54
Phosphorus-32
Phosphorus-33
Sulphur-35</td><td>Carbon-14
Chromium-51
Cobalt-57
Gallium-67
Indium-111
Iodine-125/131
Iron-59
Phosphorus-32/33
Strontium-89/90
Sulphur-35
Technetium-99m
Thallium-201</td><td rowspan="3">Americium-241
Antimony-125
Cobalt-60
Cesium-134/137
Hydrogen-3
Iodine-125/131
Manganese-54
Niobium-95
Phosphorus-32
Plutonium-238/239/240
Polonium-210
Strontium-89/90
Sulphur-35
Uranium-233/234/235/238
Zirconium-95</td></tr>
<tr><th>Research and Development
(broad scope)</th><th>Others (e.g., ore processing mills, uranium enrichment plants)</th></tr>
<tr><td>Carbon-14
Cesium-134
Hydrogen-3
Iodine-125/131
Phosphorus-32
Sulphur-35</td><td>Plutonium-238/239/240
Radium-226
Thorium-228/232
Uranium-233/234/235/238</td></tr>
</table>

Radioactive material can also enter a POTW in chemicals used in wastewater treatment. In addition, infiltrating ground water may contain radioactive materials from natural sources that were either dissolved or attached to suspended solids as the water flows through soils and geologic formations. Similarly, surface water and sediment in runoff containing NORM or fallout may enter the POTW via combined sewers. The amount of radioactive materials entering POTWs by infiltration and inflow will vary depending upon the degree of infiltration and inflow, and the amount of natural sources and fallout in the service area.

3.3 Why Radioactive Materials May Be of Concern at a POTW

Although it is unlikely that radionuclide levels in sewage sludges and ash at most POTWs across the country pose a concern for treatment plant workers or the general public, it is possible that low concentrations of radioactive material from natural and man-made sources could become concentrated in sewage sludge and ash at some POTWs. However, there are low amounts of radioactive materials that are legally authorized, under federal and state laws and regulations, to be disposed into the sanitary sewer system. This section addresses POTW operations that have potential to cause concerns due to exposure to radiation. (For more information regarding radioactivity, see Appendix A.)

3.3.1 Reconcentration of Radioactive Materials at POTWs

The purpose of wastewater treatment facilities is to reduce or remove pollutants from wastewater in order to ensure adequate water quality before the treated effluent is reused or discharged to surface waters. The removal of radionuclide contaminants by various wastewater treatment processes and the usual association of these contaminants with solids can cause the concentration of the contaminants to increase, or reconcentrate, in sewage sludge and ash. Radioactive materials disposed of into the sanitary sewer in dilute form may become reconcentrated in the sludge solids during different stages of wastewater treatment and sludge processing, in a manner similar to some heavy metals.

Reconcentration may occur during physical, biological, or chemical processes. Sludge treatment and processing may result in increasing the concentration of the radioactive contaminant by decreasing the concentration of other components. Final concentration will depend on the characteristics of the processes used at the treatment facility, the efficiencies of those processes, as well as the chemical form of the radionuclides and their half-lives.

Radioactive materials found in sewage are partitioned between the liquid and solid phases of the influent. During treatment, the concentrations of radionuclides change as the solids are removed and the treatment processes remove radionuclides from the wastewater. Because radionuclide concentrations in wastewater influents are very dilute, there is generally no concern unless the radionuclide concentrations are increased, or reconcentrated, during the treatment process.

A study by Ainsworth et al. reported that reconcentration of dissolved radionuclides (those not associated with the suspended solids) is unlikely to occur during primary treatment (Ainsworth et al., 1994). Reconcentration is possible during secondary treatment, but neither the mechanism(s) or unit process(es) involved are understood in a quantitative manner.

Reconcentration can also occur during sludge treatment (Ainsworth et al., 1994). It can potentially result from the physical, chemical, and biological removal of radionuclides from the sewage and sewage sludge produced during wastewater treatment. Physical processes that increase the solids content of the sludge without loss of radioactive materials may lead to reconcentration. Sludge handling techniques that may contribute to reconcentration include digestion, dewatering, and incineration. Incineration may be the most significant process, because the total mass of the sludge is greatly reduced by water removal and combustion of organic material.

Although there is a potential for a reconcentration of radioactive materials in the sludges or ash at POTWs, there have only been limited surveys of radiation levels in sewage sludge or sludge products. A recent study by the Association of Metropolitan Sewerage Agencies (AMSA) revealed the presence of both man-made radioactive material and NORM at low levels in sewage sludges and sludge products (NBP 1999). AMSA coordinated an extensive sampling effort as part of their national survey conducted in 1995. While this was a voluntary survey and was not structured to ensure a statistically representative result, samples from 55 POTWs in 17 states do provide a significant database. Studies by NRC and EPA to determine the presence and levels of radioactive materials at POTWs and in the sludges or ash are ongoing (NRC and EPA 1999). Table 4 summarizes results from the AMSA study and the pilot study (preliminary phase) of the NRC and EPA project.

3.3.2 Radiation Exposure Due to POTW Operations

Based on what is known about the potential for reconcentration at POTWs, possible sources of radiation exposure would be at sludge processing or handling areas at the POTW and at off-site locations where the sewage sludge or ash is disposed or used. People most likely to be exposed to elevated levels of radioactive materials would be sewage sludge or ash handling personnel at the POTW or members of the public near disposal or land application sites. Three primary ways for these people to be exposed to radiation associated with POTW operations are inhalation, ingestion, and direct exposure (see Figure 2).

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). POTW workers could inhale radioactively contaminated dust during ash or sludge handling operations. The drier the material, the more likely it could be resuspended into the air when it is handled. Measures taken by POTW workers to avoid inhalation of biological pathogens and chemically toxic materials in sludge and ash dust may effectively reduce the possible exposure to radioactive materials. Members of the public could also inhale contaminated dust blown from disposal or land application sites or dust from handling sewage sludge products made available for public use.

Ingestion of alpha- or beta-emitting radioactive materials is a concern for the same reason as inhalation. It may occur when food crops are grown on areas where sludge or ash have been applied to the land as fertilizer or soil conditioner. Ingestion could also occur when the materials migrate into the ground water or surface waters used as drinking water sources. POTW workers could ingest radioactive materials if they fail to observe good sanitary practices, such as washing their hands before eating after handling sewage sludge or ash.

Table 4. Summary of Concentrations of Radioactivity in Sludge and Ash from AMSA Survey and NRC/EPA Pilot Survey (pCi/g) [1]											
Radio-nuclide	AMSA			NRC/EPA Pilot		Radio-nuclide	AMSA			NRC/EPA Pilot	
	min	median	max	min	max		min	median	max	min	max
gross alpha	nd	7.4	80.1			Bi-207	nd	nd	nd		
gross beta	nd	15.0	61.5			Tl-201				nd	24
H-3				nd	30.4	Tl-208	nd	0.16	2.08	nd	0.6
Be-7	nd	1.54	50.03	nd	22	Bi-212	nd	0.47	11.48	nd	2.0
C-14				nd	nd	Bi-214	0.12	0.66	39.1	nd	16
Na-22	nd	nd	0.031			Pb-212	0.08	0.48	7.3	0.2	2.0
K-40	nd	4.5	60.8	2.0	16	Pb-214	0.14	0.71	46.48	nd	17
Cr-51				nd	4.0	Ra-223				nd	0.06
Mn-54	nd	nd	0.06			Ra-224				nd	4.0
Co-57	nd	nd	0.09			Ra-226	nd	1.74	118.12	1.0	29
Co-60	nd	nd	0.05	nd	6.0	Ra-228				nd	9.0
Zn-65	nd	nd	nd			Ac-227	nd	nd	3.86		
Sr-89				nd	7.0	Ac-228	nd	1.30	51.08		
Sr-90				nd	0.7	Th-227				nd	0.1
Nb-94	nd	nd	nd			Th-228				nd	2.0
Ru-106	nd	nd	0.23			Th-229	nd	nd	nd		
Ag-108m	nd	nd	1.08			Th-230				nd	2.0
Ag-110m	nd	nd	nd			Th-232				0.01	1.0
Cd-109	nd	nd	6.28			Th-234				nd	12
Sb-125	nd	nd	nd			Pa-231	nd	nd	1.34		
I-125				nd	1.0	Pa-234m				nd	15
I-131	nd	2.6	174.6	nd	70	U-234				0.2	44
Cs-134	nd	nd	0.08			U-235	nd	nd	0.93	nd	3.0
Cs-137	nd	nd	0.37	nd	1.0	U-238				0.2	12
Ba-140				nd	nd	Np-237	nd	nd	1.97		
Ce-144	nd	nd	nd			Pu-238				nd	0.03
Eu-152	nd	nd	0.1			Pu-239				nd	0.08
Eu-154	nd	nd	0.13			Am-241	nd	nd	0.58	nd	nd
Eu-155	nd	nd	2.82			Am-243	nd	nd	1.27		
Gd-153	nd	nd	2.24			Cm-243	nd	nd	1.41		

[1] nd = not detected

Sources: AMSA data, for 55 POTWs, from NBP (1999); NRC/EPA pilot study data, for 9 POTWs, from NRC and EPA (1999).

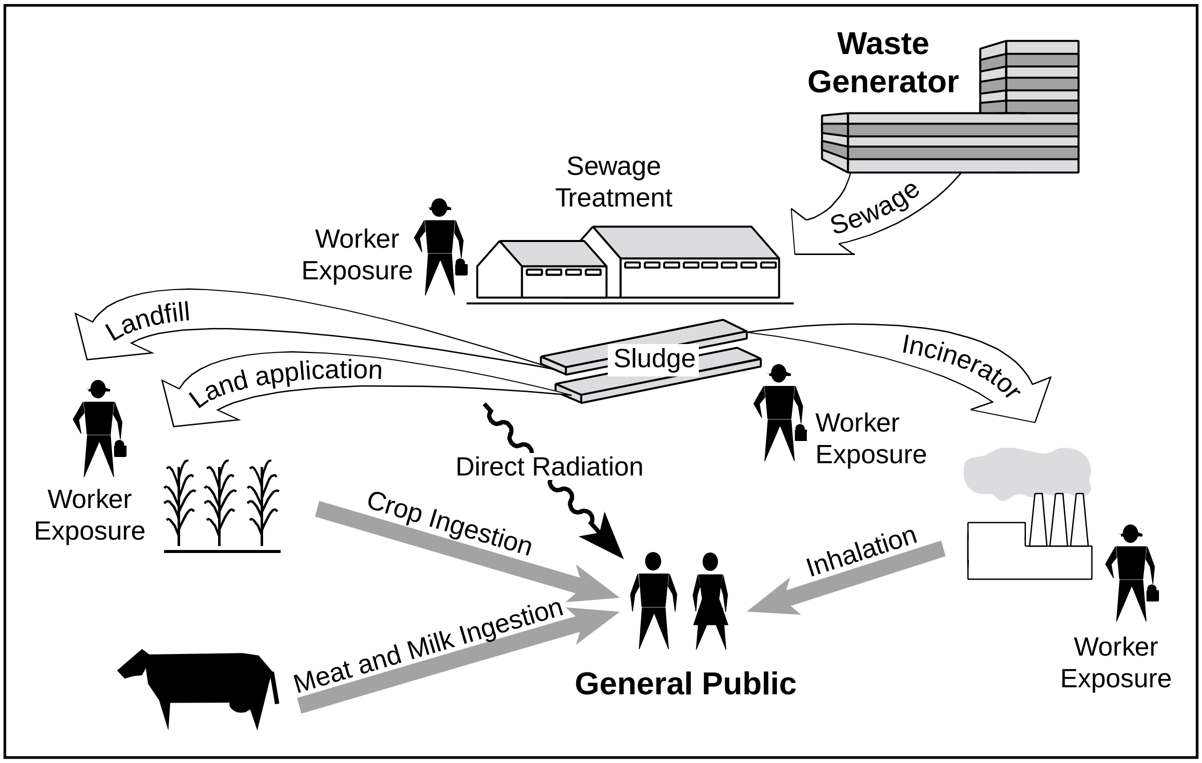

Figure 2. Primary Pathways for Radiation Exposure Due to POTW Operations

Measures taken to limit the potential ingestion of heavy metals at land application sites would help to reduce possible exposure to radioactive materials. Similarly, measures taken by POTW workers to avoid ingestion of pathogen-containing materials would serve to prevent ingestion of radioactive materials.

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, the distance between the radioactive material and the person is a factor in the amount of exposure the person receives.

POTW workers most likely to receive direct exposure are workers that handle sludge and ash. Farmers and other members of the public who use sewage sludge products or ash as fertilizer or soil conditioners could receive direct exposure to gamma radiation if these materials are present.

3.3.3 How Radiation Doses from Sewage Sludge and Ash Compare to Average Radiation Doses from All Sources

Almost everything, including people, contains some radioactive material. Naturally-occurring radioactive materials are found in the earth, in the materials used to build our homes, and in the food and water we ingest. Even the air we breathe contains some radioactive gases and particles. People are exposed to radiation on a daily basis from both natural and man-made origin.

Human exposure to radiation sources is derived primarily from background natural radiation; however, a person's occupation, geographic location, time spent outdoors, need for diagnostic medical treatments and testing, time spent traveling in airplanes, and other activities can determine the relative contributions of natural, man-made, and global fallout sources. On the average, 80 percent of human exposure to radiation comes from natural sources: radon gas, the human body, outer space, rocks, and soil. The remaining twenty percent comes from man-made radiation sources, primarily x-rays. Diagnostic medical and dental x-rays, radiation treatment and other applications of nuclear medicine contribute approximately 10 to 15 percent of the average annual human dose. Certain consumer products (television sets and other electrical appliances, smoke detectors, building materials and tobacco products) and to a lesser extent, airport and other types of inspection equipment, contribute approximately three to five percent of the average radiation dose.

It is estimated that less than one percent of the average annual dose to humans from background radiation is a result of global fallout. Global fallout results from nuclear accidents (e.g., Chernobyl) and from nuclear weapons testing during the 1940s to 1960s. Although above-ground testing ceased in the United States in 1963, radiation remaining in the atmosphere continues to account for a residual level of background human exposure.

The average radiation dose to an individual in the U.S. is about 360 mrem/yr. (The term "dose" and other background information on radioactivity are described in Appendix A.) Typical values for annual exposure to radiation within the U.S. are summarized in Table 5.

Terrestrial radiation comes from radioactive material that is naturally occurring in the environment. Radon occurs in the environment and is listed separately in Table 5 because of radon's significant contribution to radiation exposure (see also Figure 1). Cosmic radiation comes from outer space and some of it penetrates through the atmosphere covering the earth. The amount of cosmic radiation will vary depending on the altitude and latitude where one lives. Internal radiation comes primarily from ingested natural radioactive substances, such as potassium-40.

As demonstrated by the ranges shown in Table 5, radiation exposure can vary greatly, as the various factors that contribute to total exposure are not constant from location to location, and an individual's lifestyle and daily activities vary this amount. For example, the atmosphere serves as a shield against cosmic radiation; therefore, dose increases with altitude. The dose at an altitude of one mile at Denver (60 mrem/yr) is about double that at sea level (30 mrem/yr). Also, a flight on a commercial airliner increases an individual's dose from cosmic gamma rays about 1 mrem for each cross-country flight.

Table 5. Average Annual Exposure to Radiation		
Source of Radiation	Average Exposure (mrem/yr)	Typical Range of Variability (mrem/yr)
Natural Sources		
Terrestrial	30	10-80
Radon	200	30-500
Cosmic	30	30-80
Internal	40	20-100
Man-Made Sources		
Medical	50	
Consumer products	10	
Other (Nuclear fuel cycle and occupational)	1	
TOTAL	**360**	**90-760**
Sources: NCRP 1987a, for average exposure values; Huffert et al. 1994 for ranges of variability.		

Dose rates from terrestrial sources vary from about 10 to 80 mrem/yr across the U.S. The major sources in the ground are potassium, thorium, uranium, and uranium progeny. The higher doses are associated with uranium deposits in the Colorado Plateau (Figure 3), granitic deposits in New England, and phosphate deposits in Florida (Figure 4). The lowest rates are the sandy soils of the Atlantic and Gulf coastal plains. Annual doses for individuals living in brick homes may increase up to 10 mrem/yr due to naturally-occurring thorium, uranium, and radium found in clays often used to make bricks.

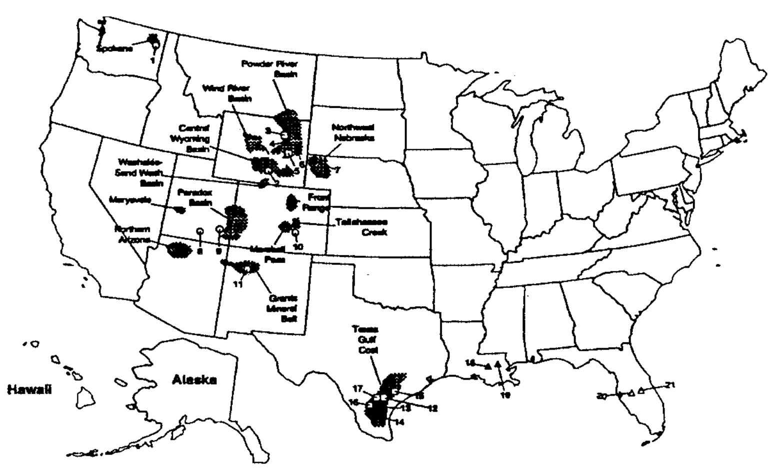

Figure 3. Uranium deposits in the U.S. Reference DOE (1997).

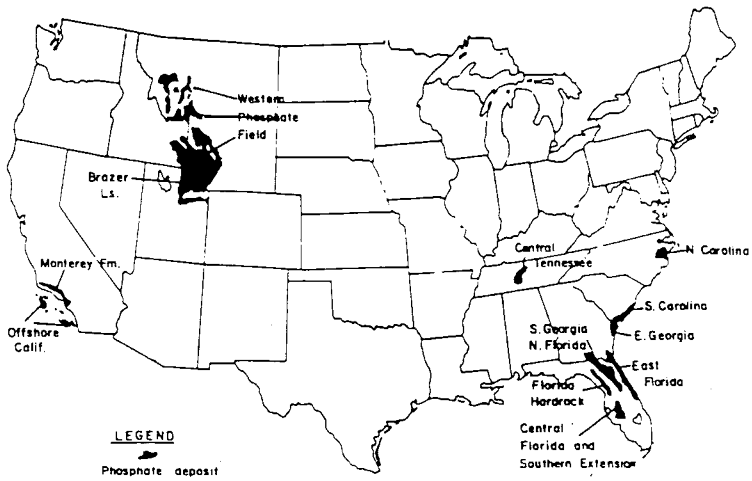

Figure 4. Major phosphate deposits in the U.S. with significant uranium content. Reference EPA (1993b).

The principal naturally-occurring radionuclides in food are potassium-40 (a common example is bananas) and radium-226 (e.g., in brazil nuts). Radium in water, particularly ground water, varies across the U.S. Radium is present in higher concentrations in some states, such as Georgia, Illinois, Minnesota, Missouri, Kansas and Wisconsin.

Table 6 lists some radionuclides present in background that may be present in POTW sewage sludge and ash. All of these radionuclides are from terrestrial sources, except strontium-90 and cesium-137, which are due to radioactive fallout from atmospheric testing of nuclear weapons. A more comprehensive list of radionuclides may be found in Table A-1.

Table 6. Some Background Radionuclides that May be Present in POTW Sewage Sludge and Ash

Radionuclide	Type of Radiation	Half-Life
Potassium-40	gamma	1.3 billion yrs
Rubidium-87	beta	47 billion yrs
Strontium-90	beta	28.6 yrs
Cesium-137	beta, gamma	30 yrs
Radium-226	alpha, gamma	1600 yrs
Radium-228	beta	5.7 yrs
Thorium-232	alpha	14 billion yrs
Uranium-238	alpha	4.5 billion yrs

Half-life values from DOE/EH-0070 (DOE, 1988)

Radiation doses at POTWs are generally insignificant compared to background radiation under most conditions. However, under conditions at POTWs where elevated levels of radionuclides have been detected, there is the possibility that doses to POTW workers and to the general public could be of concern. Studies attempting to quantify these doses, however, have failed to identify actual exposures that would indicate a potential health risk.

The NRC conducted a study to estimate maximum radiation exposures to POTW workers and others who could be affected by low levels of radioactivity in wastewater (Kennedy et al. 1992). The study used scenarios, assumptions, and parameter values generally selected in a manner to produce prudently conservative estimates of individual radiation doses. However, the quantities of radionuclides released into the sewer systems were assumed to be the maximum allowed under NRC regulations. Thus, the calculations were intended to be based on realistic or prudently conservative conditions at POTWs, but based on maximized releases to sewer systems. The estimates of these hypothetical exposures to workers range from zero to a dose roughly equal to natural background levels (Kennedy et al. 1992). Table 7 summarizes the results for some of the scenarios considered.

Table 7. Hypothetical Maximum Doses Associated With POTW Operations (mrem/yr)

Individual	Exposure Source	Primary Exposure Pathway	Hypothetical Maximum Doses (mrem/yr)
POTW sludge process operator	Sludge in processing equipment	External	360
POTW incinerator operator	Incinerator ash	Inhalation of dust	340
POTW heavy equipment operator	Sludge or ash in truck	External	210
Farmers or commercial operators	Land applied sludge	Ingestion via local crops, external	17
Landfill equipment operator	Ash disposed in landfill	External	64
Resident on former landfill site	Ash disposed in former landfill	Inhalation via resuspension of dust, ingestion via garden vegetables	170

Source: Kennedy et al. 1992.

3.4 Summary

Radioactive materials are a natural part of the environment and a byproduct of human activity. These materials may enter POTWs by water infiltration or inflow, domestic discharges, and permitted or accidental discharges.

Processes at POTWs can reconcentrate radioactive materials in sewage sludge and ash. People working with or near the sludge at the POTW, those working at disposal sites, and users of sludge products could be exposed to any radionuclides that reach the POTW. Exposure could occur from inhalation of dust, ingestion of contaminated food, or direct exposure. Estimates of hypothetical maximum doses indicate that doses from these exposures could range from 0 to 340 mrem/year in addition to the average dose of 360 mrem/year from all other sources. POTW workers at facilities where radionuclides have been found are estimated to have received minimal to non-detectable additional doses.

4 WHAT ARE THE RELEVANT REGULATORY AGENCIES AND WHAT ARE THEY DOING?

The regulatory framework for radioactive materials in wastewater is somewhat complex; there are many levels of authority and types of requirements. Federal Guidance on radiation exposure to workers and the public is prepared under the authority of the EPA as approved by the President. Regulations are issued and enforced by various agencies at different levels of government, depending upon the type of radioactive material and the agreements arranged. Information provided in this section includes only those aspects most germane to the types of materials that may enter wastewater and therefore affect POTW operations.

The primary division of the regulatory framework is based on the origin of radioactive material. In general, man-made radioactive materials are regulated differently than NORM.

Radioactive materials consisting of source, byproduct, and special nuclear material are subject to the provisions of the Atomic Energy Act (AEA). In addition, when these materials are in the commercial-private sector, they are subject to the rules of the NRC. When these materials are in the defense sector in weapons development operations, they are under the control of the Department of Energy (DOE). This guidance focuses on the NRC regulations, rather than the DOE requirements, primarily because POTWs are more likely to be concerned with waste generators in the commercial sector.

The AEA allows the NRC to establish formal agreements with states, granting the states with authority to develop and oversee the implementation of specific regulations regarding use and possession of source, byproduct and special nuclear materials generated or used at these facilities.

States with such an agreement, i.e., Agreement States, are required to maintain a radiation protection program that is adequate to protect public health and safety and is compatible with that of the NRC. A current list of Agreement States is provided in Appendix B and the relevant state agencies that are designated with the authority to develop and oversee the regulations are listed in Appendix E.

The lead federal agency in the regulation of NORM and TENORM is EPA. The DOE also regulates TENORM at DOE facilities. In addition, some state and local authorities also regulate various aspects of the materials discussed above. Other radioactive materials are generally regulated by the States. More detailed information on the role and regulations of the NRC, Agreement States, EPA, state agencies, and local authorities, as well as ISCORS, is provided in the following sections.

4.1 NRC and Agreement States

The NRC and Agreement States regulate the possession, use, and disposal of certain radioactive materials, and also develop and implement guidance and requirements governing licensed activities, inspection and enforcement activities to ensure compliance with the requirements. The primary radiation protection regulations for AEA materials regulated by the NRC are contained in the Code of Federal Regulations (CFR), Title 10, Part 20. Section 20.1301 of these regulations contains the dose limit for members of the public, which is 100 mrem/year from operations of an NRC-licensed facility. Section 20.2003 describes the limits on sewer disposal for radioactive materials. This regulation sets limits on the quantity of radioactive material that may be discharged to the sewer in one month and the total annual discharge. In 1991, the NRC revised the regulatory provisions that limit releases to the sewer, due to the discovery of problems with metallic radioactive materials disposed of as finely dispersed materials. The NRC regulations now require that all radioactive materials disposed to the sewer be readily soluble (or be readily dispersible biological material) in water.

With some specified exceptions, any activity involving source, byproduct, and special nuclear material must be conducted under a license issued by the NRC or an Agreement State. The exempt activities are described in NRC's 10 CFR Part 30, Part 40, and other Parts. For example, exemptions from specific licensing include some consumer products, such as smoke detectors and luminous watches.

Licenses are issued to licensees only after NRC or the Agreement State is satisfied that the licensee has the qualified staff, equipment, procedures, instrumentation, training programs, and management oversight deemed necessary to operate the proposed program in a safe manner and within the restrictions specified in the license. Both NRC and Agreement States monitor their licensees by means of periodic inspections. The frequency of inspections depends on the type of license issued to the licensee, and will vary from annual inspections for the larger licensees, such as hospitals, radiopharmaceutical companies, and other large users of byproduct materials, to inspections once every 3-5 years for small licensees who may use only one small radioactive source in a routine and well-established application. The license may be suspended or revoked if NRC or the Agreement State finds that the licensee's operation does not meet minimum safety standards. Additional information about NRC and Agreement State licensing and enforcement is provided in Appendix I.

The NRC has evaluated the possible pathways that humans may be exposed to radioactive materials in sewage and the behavior of radioactive materials in the POTW environment (Kennedy et al. 1992, Ainsworth et al. 1994).

4.2 U.S. Department of Energy (DOE)

Under the Atomic Energy Act, the Department of Energy Organization Act (DOA), and other related federal statutes, DOE has been assigned broad responsibility for protection of the public, the environment, and real or personal property from radiological hazards associated with its research, development, weapons production, and other activities. Operators of DOE facilities are responsible for compliance with internal directives which contain specific requirements for managing radioactive materials. For a summary of these directives, consult "The Long-term Control of Property: Overview of Requirements in Orders DOE 5400.1 and 5400.5," which can be obtained from DOE's Office of Environment, Safety and Health website (http//:tis.eh.doe.gov/oepa/) under the section entitled "Policy and Guidance - Radiation Protection."

DOE internal directives restrict the release of radioactive material to the environment by setting an annual general public dose limit based on all pathways of potential exposure. Controls are in place at each DOE nuclear facility to ensure that releases of radioactivity from all sources are monitored so that general public exposures are well below the general public dose limit. Any release of liquid waste that contains radionuclides that meets the protective levels established in DOE internal directives is considered a "federally permitted release," and as such, is subject to treatment by a process selected through the Best Available Treatment procedure, and is also subject to the As Low As Reasonably Achievable standard. Although federally permitted releases to sewage systems are not subject to prior notice or approval by the POTW operator, DOE internal directives do require that radioactivity levels be controlled so that a local POTW's wastewater treatment and sludge management processes are not disrupted.

4.3 EPA

Under the Atomic Energy Act (AEA) of 1954 as amended and the Reorganization Plan 3 of 1970, EPA has authority to establish generally applicable environmental standards for the protection of the general environment from radioactive materials. In addition, the AEA directs EPA to promulgate the Federal Guidance on radiation exposure to workers and the public. EPA also establishes regulations addressing what industries may discharge to POTWs, as well as regulations concerning the POTWs effluent and sludge solids. This section describes EPA's role and regulations for each of these types of facilities. TENORM in sewage sludge and ash from a POTW could also be regulated by EPA.

4.3.1 Role in Regulating Facilities That May Discharge to POTWs

EPA regulates the discharge of contaminants in wastewater effluents through the National Pollution Discharge Elimination System (NPDES). Industries with processes that may discharge TENORM include those that process certain mineral substances, such as titanium and zircon.

EPA also regulates the discharges of waste material from contaminated facilities cleaned up under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). If such facilities discharge to a sanitary sewer, EPA has the authority to regulate the limits for both man-made radioactive materials and TENORM. EPA may also grant authority to a state to serve as the regulator of CERCLA cleanups.

EPA also establishes radiation-related standards in other areas that may indirectly affect the consideration of both man-made radioactive materials and TENORM at a POTW. For example, under the Clean Air Act (CAA) EPA may limit radionuclide releases to the air from facilities (e.g., elemental phosphorous plants). These facilities may generate waste products containing radioactive materials that could enter the sanitary sewer system.

Another radiation-related standard that may indirectly affect POTWs, includes EPA's standards for radionuclides in drinking water. These regulations, encompassing both man-made radioactive materials and TENORM, have caused many municipalities to incorporate water treatment that removes radioactive materials from the influent water before releasing it to the service connections. EPA has prepared draft guidelines ("Suggested Guidelines for Disposal of Drinking Water Treatment Wastes Containing Radioactivity," June 1994) that specifically recommend landfill disposal of all drinking water treatment plant residuals, rather than discharge to the sanitary sewer system. At the present time, these guidelines have not been issued as official Agency guidance. It has been noted in several instances that a municipal water treatment facility discharged residue with elevated radioactive material content from this process to the sanitary sewer system.

4.3.2 Role in Regulating POTWs

EPA regulates POTWs in several ways. EPA regulates the discharge of wastewater from POTWs. The Clean Water Act (CWA), as amended, is implemented by the EPA and is designed to protect the waters of the United States (e.g., rivers, lakes, and wetlands) from pollution. The CWA is implemented through the National Pollutant Discharge Elimination System (NPDES). This system requires all pollutant discharges to the waters of the U.S. to comply with certain pollutant discharge criteria. Permits are issued to dischargers (including both industries and POTWs), specifying the discharge conditions and monitoring requirements to ensure these conditions are met. This permitting function may be delegated by EPA to individual states.

EPA implements the CWA National Pretreatment Program. Under this program, facilities discharging a significant amount of wastewater to the POTW must limit their discharges of specific pollutants to the sanitary sewers. By limiting the discharge of these pollutants, the sewage treatment plants receiving the discharges are better able to meet their NPDES permit conditions, to protect the treatment plant workers from these pollutants and to keep pollutants in the sewage sludge produced by these plants below specified limits.

The Supreme Court determined that three types of radioactive materials — source material, special nuclear material, and byproduct material — are not "pollutants" within the meaning of the CWA. Therefore, the EPA has no authority under the CWA to regulate these materials. However, EPA has authority to regulate radioactive materials that are not source, special nuclear, or byproduct material regulated under the AEA (e.g., TENORM).

EPA also regulates the use and disposal of sewage sludge produced by POTWs. The relevant regulations are found in the Code of Federal Regulations in Chapter 40 Parts 257, 403, and 503, but do not address radioactive material in sewage sludge at this time. Under the Resource Conservation and Recovery Act (RCRA), EPA cannot directly regulate as hazardous waste radioactive material in sewage sludge that is subject to the AEA. However, EPA could regulate the non-AEA components of the sludge under RCRA.

When sewage sludge is incinerated, some radioactive material may be emitted. Under the Clean Air Act (CAA), EPA has no direct authority to regulate the concentration of radioactive materials in sewage sludge/ash at POTWs. However, radionuclides were expressly included in the initial list of hazardous air pollutants in Part 112(b) of the CAA, and EPA has authority to establish National Emission Standards for Hazardous Air Pollutants (NESHAPs) under Part 112 of the CAA for facilities that emit radionuclides to the ambient air. Although EPA does not regulate the concentration of radionuclides in sewage sludge/ash directly under the CAA, the measures required to control emissions of hazardous air pollutants from POTWs may indirectly affect the concentration of radionuclides in sewage sludge.

Under the CWA, EPA determines the pollutants for which it will establish sewage sludge use and disposal standards (i.e., 40 CFR Part 503) based on current information about the potential for adverse consequences to human health and the environment. Part 405(d) of the CWA requires EPA, based on available information, to establish numerical pollutant limits for pollutants present in sewage sludge in concentrations that may adversely affect public health and the environment. These standards must be adequate to protect public health and the environment from reasonably anticipated adverse effects. This authority, in combination with the Agency's authority under AEA to establish generally applicable environmental standards for the protection of the general environment from radioactive material and to establish NESHAPs for hazardous air pollutants (including radionuclides) under part 112 of the CAA for facilities which emit radionuclides to the ambient air, would appear to provide adequate authority to establish numerical limits for any radionuclides in sewage sludge/ash for most end use and disposal practices if deemed necessary to protect public health and the environment. While the definition of "pollutant" in the NPDES Regulations (40 CFR 122.2) specifically exempts radioactive materials that are regulated under the AEA as amended (42 U.S.C. 2011 et seq.), the Pretreatment Regulations (40 CFR Part 403) do not separately define "pollutant," but do prohibit "interference," which includes a discharge which "inhibits or disrupts the POTW, its treatment processes or operations, or its sludge processes, use or disposal" [40 CFR 403.3(i)]. The sewage sludge standards (40 CFR Part 503) separately define "pollutant" without reference to the AEA, and as discussed above could use EPA's authority under AEA to establish generally applicable environmental standards for the protection of the general environment from radioactive material in sewage sludge/ash.

These standards could then trigger action on the part of POTWs through their contracts or permits with licensees to dispose of waste into the treatment works to avoid pass through and interference for the POTW. However, the nature of the arrangement between the POTW and its customers will depend upon state and local law as well as any applicable requirements in EPA's pretreatment program (40 CFR Part 403). In some cases, there are local permits issued to POTW users that would govern the circumstances of discharges to the POTWs. In other cases, the arrangements are purely contractual and the relationship between the POTW and its users (including whether the users must notify the POTW before the discharging of radioactive material) would be a matter of negotiation between the parties.

4.4 ISCORS

NRC and EPA formed the Interagency Steering Committee on Radiation Standards (ISCORS) in 1995 to expedite the resolution and coordination of regulatory issues associated with radiation standards. The objectives of the committee include the following: (1) facilitate a consensus on acceptable levels of radiation risk to the public and workers, (2) promote consistent risk assessment and risk management approaches by setting and implementing standards for occupational and public protection from ionizing radiation, (3) promote completeness and coherence of federal standards for radiation protection, and (4) identify interagency issues and coordinate their resolution. In addition to NRC and EPA, ISCORS membership also includes senior managers from the Department of Defense, the Department of Energy, the Department of Labor's Occupational Safety and Health Administration, the Department of Transportation, and the Department of Health and Human Services. Representatives of the Office of Management and Budget, Office of Science and Technology Policy, and the States are observers at meetings.

ISCORS formed a Sewage Sludge Subcommittee. This subcommittee is assisting NRC and EPA in conducting the NRC/EPA sewage survey and in developing this POTW guidance document. The member agencies of ISCORS agree there is not yet enough information on occurrence and levels of radioactive materials in sewage sludge and ash to develop any conclusive regulatory decisions. Most of the information available is due to unusual circumstances that triggered discovery of incidents in the course of other business. These incidents also generally resulted from practices prior to the recent changes in NRC regulations for the restricted licensees releases to the sewer. The Sewage Sludge Subcommittee is evaluating the occurrence of radioactive materials in sewage sludge, including the sampling of sewage sludge and ash from POTWs across the country and is conducting modeling to evaluate the dose associated with radioactive material in sewage sludge and ash. These activities are being conducted to support consideration of the need for future regulatory actions. Some of the regulatory actions that may be considered include the following:

- NRC regulations that would further limit the sanitary sewer discharge of man-made radioactive materials.
- EPA regulations that would further limit the discharge of NORM through NPDES permits.
- EPA regulations that would include requirements for radioactive materials in sewage sludge/ash use and disposal practices.

4.5 State Agencies

In addition to the role of state agencies as NRC Agreement States, states have been active regarding the issue of potential radioactive contamination at POTWs. Many states (both Agreement and non-Agreement States) have legislative authority and have promulgated regulations regarding TENORM, in a manner similar to the regulations regarding man-made radioactive materials. For example, some states have established licensing and inspection requirements for users of TENORM. Other states require users of TENORM to register with the state, rather than being issued a license. To date, nine states have approved regulations for TENORM, and several states have TENORM-related guidance, as it applies primarily to the oil and gas industries and the mining industry. State radiation control programs may also address the following areas:

1. X-ray machines,
2. Licensing of radiological technologies,
3. Accelerator-produced radioactive materials,
4. Source, by-product, or special nuclear materials (if Agreement State),

5. Radon awareness,
6. Certification programs for radon tester or mitigators,
7. Non-ionizing sources of radiation, such as radio frequency sources, lasers and others,
8. Drinking water standards for radium, radon and others,
9. Cleanup of radioactively contaminated sites,
10. Monitoring around nuclear power plants,
11. Emergency response to nuclear power plants and radioactive materials incidents,
12. Low-level radioactive waste siting, and
13. Laboratory services.

Examples of state involvement in addressing radioactive contamination at POTWs include the case studies presented in Chapter 1 (i.e., Tennessee and Oregon). State radiation control programs are good contacts for the POTW operator for information about radiation control. State radiation control programs are composed of individuals who have studied radiation and have experience with that particular states' problems.

4.6 Local Authorities

The role and authority of local jurisdictions, especially POTW authorities, is one of the more complex of the relationships related to POTWs and radioactive material. In general, POTWs have the same authority concerning radioactive material as they do for any other material in influents to the POTW. However, the U.S. Supreme Court has held that for radioactive materials covered by the AEA, Federal authority preempts other regulatory authorities when the issue is radiation protection (Pacific Gas & Electric Co. v. State Energy Conservation Comm., 461 U.S. 190, 1983). However, the resolution of particular preemption issues is often highly fact dependent. Therefore, if the basis for the state or local government action is something other than the protection of workers and the public from the health and safety hazards of regulated materials, it may be that the action is not preempted. Thus, if a POTW has sound reasons other than radiation protection to impose certain pretreatment requirements or certain prohibitions on receipt of such waste, it may be possible to do so. However, as this is an unsettled area of the law with little case law upon which to rely, it is difficult to predict whether unusual cost by the POTW would be a sufficient reason that would avoid a successful preemption challenge.

The nature of the arrangement between the POTW and its customers will depend upon state and local law as well as any applicable requirements in EPA's pretreatment program (40 CFR Part 403). In some cases, there are local permits issued to POTW users that would govern the circumstances of discharges to the POTWs. In other cases, the arrangements are purely contractual and the relationship between the POTW and its users (including whether the users must notify the POTW before the discharging of radioactive material) would be a contract condition.

Two relatively recent court cases have addressed issues of local authority on radiation matters, but do not provide definitive answers. In Cleveland, Ohio, a discharger of radioactive materials was unable to obtain a restraining order to prevent local authorities from terminating sewer service based on the radioactive materials in its wastewater. The POTW's actions were supported by restraining orders from both state and federal courts, but a settlement of the overall case precluded either state or federal court from reaching a final opinion. Therefore, there remains some uncertainty in this case.

In Sante Fe, New Mexico, a discharger has obtained a summary judgement in Federal Court, which appears to prevent local authorities from regulating environmental matters generally, including radioactive discharges. However, this decision was based on interpretation of New Mexico statues. The Court held that while state law authorizes local governments to construct and operate sewage treatment plants, the regulation of environmental matters generally has not been delegated to local authorities and may only be exercised at the state level. However, because the Court's decision was based entirely on New Mexico laws, the case has little precedential value in interpreting federal law or laws of other states.

5 WHAT CAN A POTW OPERATOR DO TO DETERMINE IF THERE IS RADIOACTIVE CONTAMINATION AND WHO CAN HELP?

Although POTWs may not be the primary regulatory authority, there are several steps, listed below, that a POTW may consider if they have concerns regarding radioactivity. Depending on the outcome of the preceding step(s), it is possible that not every step is necessary. It is also likely that the cost for each succeeding step will be more than the cost of the preceding step. The steps include the following:

1. Determine what radioactive materials may be discharged into or otherwise enter the wastewater collection and treatment system.

2. Determine if screening surveys or sampling for radioactive material at the POTW should be performed and if necessary how to perform them.

3. Evaluate any external radiation exposure of collection system workers or POTW personnel through screening surveys or sampling.

4. Evaluate any potential radiation exposure of workers or the general public related to the use or disposal of sewage sludge or ash through screening surveys or sampling.

Prior to taking the steps described in this chapter, the POTW authority may want to consider employing a consultant when evaluating the potential for a radioactive contamination problem. Part of the POTW's consideration will depend upon available resources and experience of the authority's own personnel, as well as the initial findings regarding the number and complexity of the sources of radioactive material in the service area. Assistance and advice are available to the POTW authority from the appropriate State Radiation Control Program, the NRC Regional Office, and the EPA Regional Radiation Program. Information regarding these programs and offices, including contact information, is provided in Appendices B, C, D, and E.

5.1 Determine What Radioactive Materials May be Discharged into or Otherwise Enter the Wastewater Collection and Treatment System

The POTW operator should identify the source(s) of radioactive materials that enter the wastewater system. As described in Chapter 3, the sources of potential contamination may be from man-made and/or naturally occurring materials. To determine potential sources of man-made radioactive materials, the POTW operator should identify facilities in the service area that are licensed to use radioactive materials. A list of licensees, obtained from the appropriate regulatory agency, should be used to determine likely sources.

If the POTW is in an Agreement State, the state can provide a list of the licensees and the material(s) they are licensed to use. If the POTW is not in an Agreement State, the POTW must check with the NRC (e.g., the NRC Regional Office) to identify the licensees that are located in their service area. If the POTW services any federal government facilities, it will also be necessary to contact the NRC Regional Office, even in an Agreement State. These facilities cannot be licensed by the State and are always under NRC purview. For example, Army, Navy, and Air Force facilities are licensed by the NRC.[1] In all States, the POTW should contact the State radiation control program office for information regarding non-AEA man-made radioactive materials (i.e., accelerator produced material, NARM). If there is a DOE facility in the service area, the POTW should contact the DOE facility directly to determine if there may be a potential for the discharge of radioactive materials to the sanitary sewer. Contacts at specific DOE facilities may be obtained from the DOE Office of Environment, Safety and Health website (http://www.eh.doe.gov/portal) under "DOE and the Community," "Contact Us."

To determine if information is available regarding the potential presence of TENORM in the service area, the POTW operator should contact the State Radiation Control Agency (see Appendix E). EPA regional radiation program managers (see Appendix D) may also be able to assist in this question.

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[1] Additional information for Navy and Air Force facilities may be obtained from the corresponding Service Coordinating Committee. The Navy Committee can be contacted directly at 703/602-2582 and the Air Force Committee can be contacted directly at 210/536-3331.

Information on what radioactive material is authorized for use is as important as identifying the user. For instance, if a wastewater discharger only uses a "sealed source," it is unlikely the facility would discharge radioactive material in the sewer system. This information can be requested from the licensee or from the NRC or Agreement State. After the likely sources of radioactive materials have been identified, the discharger should be contacted to determine if any continuous or accidental releases may have occurred.

5.2 Determine if Screening Surveys or Sampling for Radioactive Material at the POTW Should Be Performed and if Necessary How to Perform Them

In Section 5.1 above, a number of suggested steps were provided for a POTW to follow in learning what available information may exist on radioactive materials entering into or being discharged into the sanitary sewer system. Following are some criteria which may be useful in determining if it is appropriate to sample the POTW facility sludge or ash for radionuclide content:

1. Is the facility located in an area with elevated levels of uranium and radium occurrence in soils or bedrock (see Figure 1, Figure 3, or Figure 4)?

2. Have water treatment plants which may discharge residuals into the sewer system reported exceedances of EPA drinking water MCLs for radium, or for alpha and beta emitting radionuclides? The current standards are: combined radium-226/228, 5 pCi/L; a combined standard of 4 mrem/yr for beta emitters; and a gross alpha standard of 15 pCi/L, not including radon and uranium (see 40 CFR Part 141).

3. Are there industrial facilities in the POTW service area for the following industries which discharge significant quantities of untreated process waste water into the sewer system: ceramics, electronics, minerals or metal fabrication (any one of aluminum, copper, gold, silver, phosphate, potassium, vanadium, zinc, zirconium, tin, rare earths, molybdenum, titanium, depleted uranium, radium), paper and pulp, metal foundry and engine manufacture, luminous watch and clock manufacture, cement or concrete, optics, electric lighting, gypsum board manufacture, welding, paint and pigment, or fertilizer manufacture? What percentage of total discharge to the system is provided by these facilities? All of these industries have been associated with the use of TENORM materials or production of TENORM wastes.

4. Are there NRC or Agreement State licensees, DOE facilities, Department of Defense facilities in the service area that discharge to the sewer system in the following categories: medical, medical laboratory, research & development college or university, nuclear laundries, decommissioning facilities for byproduct material facilities, UF_6 production plants, hot cell operations, uranium enrichment plants, or uranium fuel fabrication plants. Are there State

licensed accelerators which may discharge to the sewer system? Are there facilities which discharge landfill leachate or Superfund site discharges in the service area? How many licensees are there in the system and how much do they discharge annually? What percentage of total discharge to the system is provided by these facilities?

While there have been few studies conducted to evaluate the volumes and movement of radionuclides throughout the sewage system and their accumulation and occurrence in sewage sludge or ash, a POTW can make some qualitative judgements about whether sampling or surveying is prudent based on an informed analysis of dischargers to the system.

- If there are no occurrences of any of the items listed above in the system, the likelihood of finding contamination by radioactive materials in the sewage sludge and ash is unlikely, but still remotely possible. Sampling would not likely be warranted.

- If both criteria 1 and 2 are true, the possibility does exist that NORM could be elevated in the sludge and ash and would merit testing.

- If either (or both) criteria 1 and 2 are true, and industries listed in criteria 3 are present in the service area, the possibility exists that NORM or TENORM could occur in the sludge and ash, and merit testing of the POTW sludge and ash.

- If criteria 4 is true, and there are either multiple licensees in the service area, or the licensees may discharge a significant fraction of wastewater in the sewer system (more than a few percent), it may be appropriate to periodically sample and test the sludge and ash for the presence of radionuclides, particularly those that are man-made. Since the volume of wastewater discharged from a licensee may not be indicative of the amount of radionuclides discharged during the year, reviewing licensee discharge records may be a better indicator of what, and how much, is entering the system.

- If any of criteria 1, 2, or 3 are true and criteria 4 is true, the likelihood exists for occurrence of NORM, TENORM, and man-made radionuclides in the sewage sludge or ash, and it may be appropriate to sample the sewage sludge or ash.

Further information on identifying and dealing with new industrial sources, radioactive contaminants, and individual facilities is provided in a guidance document developed by the National Biosolids Partnership (NBP 1999).

The results of the ongoing, joint NRC and EPA survey and associated dose modeling being conducted by the ISCORS Sewage Sludge Subcommittee (see Section 4.4) may be helpful to POTWs when deciding whether they should sample.

5.3 Evaluate Any Potential External Radiation Exposure of Collection System Workers or POTW Personnel Through Screening Surveys or Sampling

There may be a potential for external radiation exposure (i.e., from outside the body, rather than from ingestion or inhalation) to collection system workers and POTW personnel if gamma radiation emitting radionuclides are discharged into the wastewater system (more information regarding the various types of radionuclides is provided in Appendix A). If the potential for such discharges is determined, the POTW should initiate an evaluation. This evaluation may be conducted using two methods: (1) use a radiation survey meter to identify any points at which such contamination exists, and (2) use an integrating radiation measuring device to determine if any exposures could occur over time. It may be advisable to hire a health physics consultant to assist in the selection of appropriate survey methods and instruments.

A source of useful information on such surveys is a federal consensus document, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*. This manual may provide useful information on planning and conducting a survey involving potential contamination of surface soils and building surfaces. This document, prepared specifically for site surveys involving radiological contaminants, contains useful information on sampling procedures, field measurement methods and instrumentation, quality assurance and quality control procedures and interpretation of results. This information was developed as a consensus approach by four federal agencies (EPA, DOE, NRC and DOD) to determine whether dose or risk-based release criteria for buildings and soils have been met. In the context of a POTW survey for radiological contaminants, the methods and procedures contained in this manual should be generally applicable. The MARSSIM document and related informational tools can be obtained from the EPA's Office of Radiation website (http://www.epa.gov/radiation/marssim/).

Direct measurement can be conducted with an instrument using a sodium iodide detector tube or a very sensitive Geiger Muller detection device. The instrument should be able to detect gamma radiation in the micro-roentgen per hour range.

In taking measurements along the collection system, it is best to focus on system junctions and bends that are immediately downstream from the wastewater generator of concern. These are points that allow the accumulation of radioactive material. Prior to taking collection system measurements, it is important to create a baseline of the background radiation levels; a background measurement should be taken in the general vicinity of the system before taking measurements in the collection system itself. If possible, these background measurements should be taken upstream of the discharger over grassy areas. Table 8 provides typical ranges of radioactive material concentrations found in U.S. soils and common items such as fertilizers and building materials, as well as the range of radioactive material concentrations detected during the pilot survey of sludges and ash from nine POTWs. This table is taken from Appendix B of the pilot survey report (NRC and EPA 1999).

Table 8. Concentration Ranges from Pilot Survey and for Typical U.S. Background in Soil, Fertilizer, and Building Materials (pCi/g-dry weight)

	Common materials			Pilot study results	
Radio-nuclide	Soil [1]	Phosphate Fertilizer [2]	Building Materials [1]	Sludge	Ash
Am-241	NDA[3]	NDA	NDA	ND[4]	ND
Ba-140	NDA	NDA	NDA	ND	ND
Be-7 *	NDA	NDA	NDA	ND - 22	4.0 - 13
Bi-212	0.1 - 3.5	0.1 - 4.6	0.1 - 3.7	ND - 2.0	ND - 2.0
Bi-214	0.1 - 3.8	4.0 - 140	2.5 - 5.05	ND - 2.0	.02 - 16
C-14 *	NDA	NDA	NDA	ND	ND
Co-60	NDA	NDA	NDA	ND - 6.0	ND
Cr-51	NDA	NDA	NDA	ND - 4.0	ND
Cs-137	0.1 - 0.2[6]	NDA	NDA	ND - 1.0	0.03 - 0.08
H-3 *	NDA	NDA	NDA	ND - 30.4	ND
I-125	NDA	NDA	NDA	ND - 1.0	ND - 0.3
I-131	NDA	NDA	NDA	ND - 70	ND - 4.0
K-40 *	2.7-19	32 - 160 [7]	0.8 - 30	2.0 - 8.0	14 - 16
Pa-234m *	0.1 - 3.8	4.0 - 140	0.2 - 5.0[5]	ND - 15	ND - 9.0
Pb-212 *	0.1 - 3.5	<0.1 - 4.6	0.1 - 3.7	0.2 - 2.0	1.0 - 2.0
Pb-214 *	0.1 - 3.8	4.0 - 140	0.2 - 5.0	ND - 2.0	2.0 - 17
Pu-238	NDA	NDA	NDA	ND - 0.03	ND - 0.01
Pu-239	NDA	NDA	NDA	ND - 0.08	ND - 0.01
Ra-223 *	<0.1 - 0.2	0.2 - 6.6	<0.1 - 0.2[5]	ND - 0.06	ND
Ra-224 *	0.1 - 3.5	<0.1 - 4.6	0.1 - 3.7[1]	ND - 1.0	0.5 - 4.0
Ra-226 *	0.1 - 3.8	0.1 - 24	0.1 - 3.5	1.0 - 29	3.0 - 25
Ra-228 *	0.1 - 3.5	<0.1- 4.6	0.1 - 3.7	ND - 2.0	2.0 - 9.0
Sr-89	NDA	NDA	NDA	ND - 7.0	ND - 0.8
Sr-90	NDA	NDA	NDA	ND - 0.7	ND
Th-227 *	<0.1 - 0.2	0.2 - 6.6	<0.1 - 0.2	ND - 0.1	ND
Th-228 *	0.1 - 3.5	<0.1 - 4.6	0.1 - 3.7	ND - 1.0	ND - 2.0
Th-230 *	0.1 - 3.8	4.0 - 140	0.2 - 5.0	ND - 1.0	0.5 - 2.0
Th-232 *	0.1 - 3.5	<0.1 - 4.6	0.1 - 3.7	0.01 - 0.9	0.4 - 1.0
Th-234 *	0.1 - 3.8	4.0 - 140	0.2 - 5.0	ND - 12	2.0 - 5.0
Tl-201	NDA	NDA	NDA	ND - 24	ND
Tl-208 *	0.1 - 3.5	<0.1 - 4.6	0.1 - 3.7	ND - 0.5	ND - 0.6
U-234 *	0.1 - 3.8	4.0 - 140	0.2 - 5.0	0.2 - 44	5.0 - 8.0
U-235 * [8]	<0.1 - 0.2	0.2 - 6.6	<0.1 - 0.2	ND - 3.0	ND - 1.4
U-238 *	0.1 - 3.8	4.0 - 140	0.2 - 5.0[5]	0.2 - 12	2.0 - 5.0

See next page for footnotes.

Table 8. Concentration Ranges from Pilot Survey and for Typical U.S. Background in Soil, Fertilizer, and Building Materials (pCi/g-dry weight): Footnotes

1 Reference: Tykva and Sabol 1995. This reference is the source of data for concentrations of radionuclides in soil and building materials except for the concentrations of U-238, U-235, and Cs-137 which came from references 5 and 6, respectively. The concentrations of the daughters or decay products of U-238, such as Th-234, Ra-226, etc., those of U-235, such as Th-227 and Ra-223, and those of Th-232 are set equal to those of their respective parent radionuclides by assuming that the daughters are in secular radioactive equilibrium with the parent radionuclides.

2 Source for data on fertilizers: NCRP (1987b), pp. 24-32. This is the source of data for the concentrations of radionuclides in fertilizers except for the concentration of K-40 in soil which came from the reference in note 7.

3 NDA - No data available

4 ND - Not detected. The radionuclide was not detected in some of the samples during the pilot study.

5 Reference: Eisenbud and Gesell (1997).

6 Cs-137 concentration range in soil obtained from Figure 4-4, p. 94 of NCRP (1976).

7 Source for data on K-40 in fertilizer: (EPA 1993b).

8 Values for U-235 in soil, fertilizer and building materials were based on the concentrations of U-238 in the same materials and the natural ratio of U-235 to U-238.

9 The symbol "<" which appears throughout the table is an abbreviation for the words "less than."

10 * = naturally occurring radionuclide

If there is reason to believe that there is an exposure problem to collection system workers then appropriate monitoring of the collection system may be necessary. Monitoring down manholes in the collection system may result in highly variable measurements. These variations may be a few times the background levels and may result from the construction materials used in the manhole. Marked variations may be observed between concrete and brick, or even among different concrete or brick materials. These variations are largely due to the natural radioactive materials in the construction materials. If elevated values are found, further investigation may be warranted. Consultation with the radiation regulatory authority is recommended. More detailed information on this issue may be found in the National Biosolids Partnership guidance (NBP 1999).

At the POTW, direct radiation measurements should be taken at locations where solid materials accumulate, including grit chambers and points of sludge collection. If incineration of sludge is performed, the residual ash should also be measured. Background measurements should be made away from the sludge collection point. Some variability in measurements can be expected. These measurements are necessary to compare levels in sewage sludge and ash samples.

To identify changes over time, POTW operators may also want to employ an integrating measurement device that accumulates radiation exposure over time. It is also possible to periodically conduct follow-up surveys using direct radiation measurements; however, integrating measurement devices are more effective for time analyses.

Although there are expensive self-recording types of devices available, it may be more cost effective to use some thermoluminescent dosimeters (TLD). These devices are crystal structures that store the energy imparted by incident radiation so that it can be subsequently measured to evaluate the exposure received. The selection of the particular TLD to use should be made after consultation with the vendor, including a discussion of the particular use intended.

The locations selected for placing the TLDs should be determined carefully, in a manner similar to the location selection process for the direct radiation measurements. Several of the TLDs should be placed in an area removed from sludge processing (e.g., an office desk, cabinet) to serve as a background measurement. The TLD devices used for system measurements can be hung down manholes or over areas where sludge is collected, or over conveyer belts where sludge is transported. The TLDs should be left in place for a period of a few weeks to a month and then returned to the vendor for evaluation.

5.4 Evaluate Any Potential Radiation Exposure of Workers or the General Public Related to the Use or Disposal of Sewage Sludge and Ash Through Screening Surveys or Sampling

In addition to evaluating the potential for exposures to POTW workers from radioactive materials in sewage sludge and ash, POTWs may also need to evaluate potential exposures to other workers who handle or manage sludge and ash or to members of the public.

5.4.1 How to Evaluate if There Are Any Potential External Radiation Exposure Problems with the Disposal or Reuse of Sewage Sludge and Ash

If a thorough survey of sludge accumulation points indicates there is no problem with elevated readings, there is a reduced probability that land application sites or landfills will have radioactive contamination. However, materials placed in these sites in the past may have caused contamination. Also, there may be areas where repeated applications have occurred, causing a buildup of material that would not have been detected otherwise.

A survey of land application sites or landfills where sludge has been disposed is a prudent step if there is reason to believe that elevated levels of radioactive materials may have been discharged to the system. Measurement of radiation levels in these areas can be made with the same instrument used for the collection and treatment systems. Background levels should be measured in areas without sludge or ash for comparison purposes. Some variation in background levels should be expected due to local soil conditions. If levels significantly above background are found, it is suggested that the appropriate radiation control authority be consulted.

In cases where the POTW uses or disposes of sewage sludge/ash or contracts it out, the following factors may be considered to decide whether to perform measurements at the use or disposal sites:

- Indications that there has been radioactive contamination in the POTW.
- The liability arrangements between the POTW and the contractor.
- The adequacy of available records on past sewage sludge/ash applications.
- The frequency and amount of sewage sludge/ash applications to each site.

Based on these factors, the POTW may want to collect samples at the sludge or ash disposal site.

5.4.2 How to Evaluate if There are any Potential Internal Radiation Exposure Problems with the Disposal or Reuse of Sewage Sludge/Ash

Following the steps described above, any significant occurrence of radioactive contamination at a collection system or POTW should have been detected. If there is a determination of potential contamination from the direct radiation measurements, a determination of what radioactive material caused the problem should be made. Such a determination would also be necessary to identify the possibility of ingestion or inhalation of radioactive material during wastewater collection and treatment, or sewage sludge and ash use or disposal practices. In these cases, it may be necessary to take physical samples of the sewage sludge, ash, or other residual material and have this material analyzed at a laboratory with the capability for such an assessment. Other cases where sampling and analysis may be required are circumstances where the possible radioactive contamination is not detectable by the methods previously described. These would be instances where the radiation emitted was only alpha or weak beta radiation. Such radioactive materials include some man-made elements that are heavier than uranium, and more common radioactive materials, such as hydrogen-3 (tritium) and carbon-14.

If it is found that the sampling of sewage sludge and ash should be conducted (either because of detected contamination or undetected radioactive materials are believed to be present), a carefully planned program should be executed. Analysis of sewage sludge and ash samples may become expensive. An initial gamma scan and gross alpha and gross beta determination may be useful as an inexpensive screening tool for further analysis. Further assessments may require analyses for specific radioactive materials.

A gamma spectrometer is used to estimate gamma-emitting radionuclide concentrations. Gamma spectrometry can discriminate among various radionuclides on the basis of characteristic gamma and x-ray energies to provide a nuclide-specific measurement. Gross alpha or gross beta activity analyses are used to screen samples to determine the need for nuclide-specific analyses.

The EPA guidance, *POTW Sludge Sampling and Analysis Guidance Document* (1989), provides information on conducting sampling and analysis of sludge.[2] Information on how to collect samples, what containers to put them in, how to preserve them, and other sampling steps, should be worked out in consultation with the selected analysis vendor. Also, some analyses require specific time periods for counting radionuclide decay emissions or collecting radon or other decay products. These time periods may vary with the radionuclides being tested and can take several days or weeks to complete.

A radiochemical laboratory should be selected before sampling so that the laboratory may be consulted on the analytical methodology and sampling protocol. A list is maintained by the Conference of Radiation Control Program Directors (CRCPD) of laboratories that provide radiological analysis of diverse materials, have quality assurance and quality control programs, and will perform work for government and private firms. Appendix J lists those laboratories from the January 2000 CRCPD list that have indicated they perform analyses of sludge samples. To evaluate the laboratory, the following considerations should be made:

- Does the laboratory possess the appropriate well-documented procedures, instrumentation, and trained personnel to perform the necessary analyses?
- Is the laboratory experienced in performing the same or similar analyses?
- Does the laboratory have satisfactory performance evaluation results from formal monitoring or accreditation programs? The laboratory should have a formal quality assurance (QA) program in place. The laboratory should be able to provide a summary of QA audits and proof of participation in inter-laboratory cross-check programs. Equipment calibrations should be performed using National Institute of Standards and Technology (NIST) traceable reference radionuclide standards whenever possible.
- Is there an adequate capacity to perform all analyses within the desired time frame?
- Does the laboratory provide an internal quality control review of all generated data that is independent of the data generators?
- Are there adequate protocols for method performance documentation and sample security?

[2] The EPA guidance document can be obtained from the Education Resource Information Center (ERIC number W134) by calling (800) 276-0462 or the National Technical Information Center (NTIS number PB93-227957) at (800) 553-NTIS.

Typical Analysis Costs

Costs for analysis will depend on the type of analyses that are requested. The more detailed or complicated the analysis, the more expensive and time demanding the analysis becomes. Gamma spectroscopy analysis for one sample could cost a few hundred dollars, gross alpha/beta analysis may cost a few hundred dollars and costs for radiochemical analysis for alpha and beta emitters may range from several hundred to over one thousand dollars, depending on the radionuclides analyzed.

If there is any concern by the POTW operator regarding potential radiological contamination of buildings or facilities where sewage sludge or ash is land applied or disposed in a landfill, there may be a need to conduct an appropriate radiological survey. As discussed in Section 5.3, a source of useful information on such surveys is the MARSSIM.

6 WHAT TO DO IF ELEVATED LEVELS OF RADIOACTIVE MATERIALS ARE FOUND

Elevated levels of radioactivity at a POTW do not necessarily mean that workers or the public are in danger. POTW operators should evaluate the risks and determine the appropriate course of action through consultation with radiation regulatory authorities and health specialists. Actions may also be needed to prevent interference with use or disposal of sewage sludge and ash, to prevent a reoccurrence, or to clean up contaminated areas.

6.1 Contact Regulatory Agencies for Assistance

If elevated levels of radioactive materials are suspected or detected, the POTW should first consult with their state radiation regulatory agency (see Appendix E). Based on the initial contact with the state, the POTW may also need to contact the NRC regional office or the EPA regional Radiation Program Manager (see Appendices C and D, respectively). These regulatory agencies are valuable sources of information on radiation and radiation protection and may assist the POTW in addressing the situation and in communicating with the public. They can also help identify possible sources of the radionuclides, assist in establishing an appropriate course of action, and take enforcement actions if needed to correct the problem.

The regulatory agency may determine that the levels are not sufficiently elevated to cause concern for worker or public health and safety. In that case, no additional action by the POTW would be needed to protect workers. However, the POTW should convey the regulator’s findings to the POTW workers so that they know there is no cause for concern. A letter or other documentation from the regulator would be useful in communicating with workers that the levels do not pose a concern.

6.2 Protect Workers

When there are elevated levels of radioactivity, the most important concern for the POTW should be the protection of the workers and the public. If consultations with the regulatory agency indicate there may be a concern regarding exposure to the POTW workers, the POTW may need to obtain the services of a qualified consultant, such as a health physicist, to evaluate the radiation levels at the plant and disposal sites. The consultant can recommend appropriate protective measures that are commensurate with the radiation hazards to keep exposure levels as low as reasonably achievable. These measures may include: limiting the amount of time workers spend near units with elevated levels of radioactivity; increasing the distance between workers and the radiation source(s); and increasing the shielding between the source(s) and the workers.

Many of the measures that protect workers from radiation hazards are the same as those used at POTWs to protect against pathogens. Personal hygiene practices such as washing hands before eating prevents ingestion of radionuclides as well as pathogens. Similarly, the use of dust masks in sludge and ash handling areas reduces the potential for health risks from inhaling dust and the radionuclides in the dust.

If elevated levels of radioactivity have been identified, the POTW employees should be informed. The POTW employees should also be provided with factual information on the risks associated with the level of radiation exposure. Regulatory agencies or health physicists may have literature available to assist in communicating with POTW personnel.

6.3 Prevent Reoccurrence or Reduce Radiation Levels

POTWs, in consultation with the regulatory agencies, should determine what can be done to prevent reoccurrences, reduce radiation levels, and prevent interference with use or disposal of sewage sludge and ash. Each situation will be unique and the appropriate actions will vary from no additional action to regulatory enforcement. The approach taken will be affected by the answers to several questions that the POTW and the regulator may explore.

1. Where did the radionuclides come from? Consultation with the regulatory agency could identify whether the radionuclides are naturally-occurring, TENORM, or man-made. See Section 3.1 for a description of these types of sources. For man-made sources, the presence of specific radionuclides could help regulators determine if a licensee is the source.

2. How did the radionuclides get to the POTW? As discussed in Section 3.2, radionuclides may reach the sewers and POTW in several ways. For example, radionuclides may enter the POTW via discharges, POTW treatment processes, or infiltration and inflow. To determine the location of discharges that may cause contamination, the POTW may need to take samples from the sewers leading from the sources. The necessity of sampling should be discussed with the NRC

or state contact prior to initiation. Based on this information, the POTW should be able to determine the source(s) of any radioactive materials that may enter the POTW.

3. How often are radionuclides expected to reach the POTW? Knowing the timing of releases enables POTW operators to plan for their arrival. For example, some users of radioactive materials are allowed to continuously or intermittently release small amounts of radionuclides to the sewer system. Accidental discharges may only occur once or infrequently. Naturally occurring radionuclides may reach the POTW continuously or periodically following precipitation events that increase infiltration and inflow.

4. Who is responsible for controlling the sources of the radionuclides to prevent reoccurrences and interference with use and disposal of sewage sludge and ash? Regulatory agencies are responsible for setting license conditions and limits to protect human health. Licensees are responsible for operating or handling their materials in accordance with regulations and their license conditions. Land owners may be responsible for controlling erosion that carries natural sources into the sewer system through inflow. POTW operators are responsible for maintaining an effective infiltration and inflow program, which could reduce the potential for natural sources to reach the POTW.

5. Are the appropriate controls in place to minimize releases of radionuclides to the POTW? The POTW may want to evaluate the effectiveness of the controls used by the discharger to minimize releases of radionuclides. The POTW may need to consult with the regulatory agency to review the regulations and license conditions imposed on a discharger, or their implementation by the discharger. The POTW should review infiltration and inflow controls if that is the source.

The POTW can work with the regulator to decide on appropriate actions to prevent reoccurrences. Examples of these actions include:

- If the release was a one-time accident and future releases are unlikely, action to prevent reoccurrence may not be needed.
- Require notification of planned or accidental discharges. The POTW may wish to request notification from the source facility when future releases occur. Notification would enable the POTW to monitor the condition at the POTW and take measures to protect workers if necessary. POTWs may lack the authority to require notification, but could request it as a voluntary measure by the user and consult with the Local Emergency Planning Committee (LEPC) and State Emergency Response Committee (SERC).
- Work with dischargers to encourage use of spill prevention measures to reduce the potential for accidental releases.

- Impose appropriate additional local controls on the discharger, such as local discharge limits and regular reporting of discharges.
- Request that regulators take enforcement action against dischargers who violate license conditions and contribute to the elevated levels.
- Provide regulators with information on problems created by the dischargers. This information may be useful for the regulator in deciding whether to modify the release limits.
- Correct infiltration and inflow problems that transport naturally-occurring radionuclides to the POTW.

6.4 Corrective Actions for Contaminated Areas

In rare instances, sewage sludge and ash management may cause contamination of equipment or disposal sites; the POTW may be responsible for removing the contamination. Consultation with the regulatory agencies should be pursued to determine any requirements that may apply.

Cleanup of contaminated sites can be a costly endeavor for the POTW. Depending upon the applicable state or federal laws, some dischargers may be liable for portions of the cleanup costs if their discharges caused the contamination. Legal counsel should be consulted as to whether any dischargers may be liable for portions of the cost.

7 COMMENTS OR QUESTIONS ON THIS GUIDANCE

If you have any questions or comments regarding this guidance document, please contact either NRC or EPA:

Duane Schmidt
U.S. Nuclear Regulatory Commission
Decommissioning Branch
Mail Stop T-7F27
Washington, DC 20555-0001
(301) 415-6919, or e-mail to: dws2@nrc.gov

Robert Bastian
U.S. Environmental Protection Agency
Office of Wastewater Management (4204)
Ariel Rios Building
1200 Pennsylvania Avenue, NW
Washington, DC. 20460
(202) 260-7378, or e-mail to: bastian.robert@epa.gov

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APPENDIX A
FUNDAMENTALS OF RADIATION

What is Radiation?

Radiation is energy in the form of high speed particles and electromagnetic waves (photons) that are released from unstable atoms. Radiation with enough energy to separate molecules or remove electrons from atoms is known as ionizing radiation. Non-ionizing radiation does not have enough energy to remove electrons from their orbits. Radioactivity is the property that some unstable atoms have of undergoing spontaneous transformation, decay, or disintegration, which emits radiation. Materials that contain radioactive atoms are known as radioactive materials.

Radiation is in every part of our lives. It occurs naturally in the earth and can reach us through cosmic rays from outer space. Radiation may also occur naturally in the water we drink or the soils in our backyard. It even exists in food, building materials, and in our own human bodies. Radiation is used for scientific purposes, medical reasons, and power (e.g., the U.S. Navy uses radiation to power submarines through the water). People also come into contact with radiation through man-made sources such as X-rays, nuclear power plants, and smoke detectors.

The radiation of interest in this guidance is ionizing radiation. At excessive levels, the process of ionization can cause disease and injury to plants and animals. The three most common types of ionizing radiation are:

- Alpha radiation - positively charged particles that are emitted from naturally-occurring and man-made radioactive material. The alpha particle has the least ability to penetrate other materials. Most alpha particles can be stopped by a single sheet of paper or the top layer of skin. Consequently, the principal hazard from alpha emitters to humans is occurs when the material is ingested or inhaled. The limited penetration of the alpha particle means that the energy of the particle is deposited within the tissue (e.g., lining of the lungs) nearest the radioactive material once inhaled or ingested. Examples of alpha emitters are radon, thorium, and uranium.

- Beta radiation - negatively charged particles (electrons) that are typically more penetrating but have less energy than alpha particles. Beta particles can penetrate human skin or sheets of paper, but can usually be stopped by thin layers of plastic, aluminum, or other materials. Carbon-14 and hydrogen-3 (or tritium) are two common beta emitters. Although they can penetrate human skin, beta particles are similar to alpha particles in that the predominant hazard to humans comes from ingesting or inhaling the radioactive materials that emit beta radiation. Other examples of beta emitters are phosphorus-32 and strontium-90. Some radioactive materials emit positively charged electrons, or positrons.

- Gamma (or X-ray) radiation - the most penetrating type of radiation. They can pass through the human body and common construction materials. Thick and dense layers of concrete, steel, or lead are used to stop gamma radiation from penetrating to areas where humans can be exposed. Gamma emitters can pose both external and internal radiation hazards to humans. technetium-99m is an example of a gamma emitter that is widely used in medical diagnosis. Other gamma emitters include thallium-201 and selenium-75.

Some radionuclides emit more than one type of radiation. For example, cesium-137 and iodine-131 are both gamma and beta emitters. Potassium-40, a common naturally-occurring radionuclide, is also a beta/gamma emitter. Radium-226 emits both alpha and gamma radiation.

How is Radiation Measured?

Whether it emits alpha or beta particles or gamma rays, the quantity of radioactive material is typically expressed in terms of its radioactivity or simply its activity and is measured in curies. One curie equals 37 billion atomic disintegrations per second. Activity is used to describe a material, just as one would discuss the length or weight of a material. For example, one would say "the activity of the uranium in the container is 2 curies." Generally, the higher the activity of the material, the greater the potential health hazard associated with that material if it is not properly controlled. At nuclear power reactors, the activity of radioactive material may be described in terms of hundreds to millions of curies, whereas the units typically used to describe activity in the environment and at POTWs are often microcuries (μCi) or picocuries (pCi). A microcurie is one one-millionth (1/1,000,000) of a curie and a picocurie is one one-trillionth (1/1,000,000,000,000) of a curie.

The activity of a radionuclide decreases or decays at a constant rate. The time it takes the activity of a radioactive material to decrease by half is called the radioactive half-life. After one half-life, the remaining activity would be one-half (½) of the original activity. After two half-lives, the remaining activity would be one fourth (1/4), after three half-lives one eighth, and so on. For example, if a radionuclide has a half-life of 10 years, the amount of material remaining after 10 years would be ½ of that originally present. After 100 years (10 half-lives), the remaining activity would be 1/1024 of the amount that was originally present. Some radioactive materials have extremely short half-lives measured in terms of minutes or hours; for example, technetium-99m, used in medical procedures, has a half-life of 6 hours. Others have half-lives measured in terms of millions to billions of years; for example, naturally occurring thorium-232 has a half-life of 14 billion years, and natural uranium-238 has a half-life of 4.5 billion years. Half-lives for a number of radionuclides are shown in Table A-1.

Table A-1. Radiation Types and Half-Lives for Radionuclides		
Radionuclide	**Type of Radiation**	**Half-life**
Actinium-228	beta, gamma	6.1 hours
Americium-241	alpha, gamma	458 years
Antimony-125	beta, gamma	3 years
Barium-140	beta, gamma	13 days
Beryllium-7	gamma	53 days
Bismuth-212 Bismuth-214	alpha, beta, gamma beta, gamma	61 minutes 20 minutes
Carbon-14	beta	5730 years
Cesium-134 Cesium-137	beta, gamma beta, gamma	2 years 30 years
Chromium-51	gamma	28 days
Cobalt-56 Cobalt-57 Cobalt-60	positron, gamma gamma beta, gamma	77 days 271 days 5 years
Europium-154	beta, gamma	16 years
Gallium-67	gamma	3 days
Hydrogen-3 (tritium)	beta	12 years
Indium-111	gamma	2.8 days
Iodine-123 Iodine-125 Iodine-129 Iodine-131	gamma gamma beta, gamma beta, gamma	13 hours 60 days 20 million years 8 days
Iridium-192	beta, gamma	74 days
Iron-59	beta, gamma	45 days
Lead-210 Lead-212 Lead-214	beta, gamma beta, gamma beta, gamma	22 years 11 hours 27 minutes
Manganese-54	gamma	303 days
Niobium-95	beta, gamma	35 days
Phosphorus-32 Phosphorus-33	beta beta	14 days 25 days

Table A-1. Radiation Types and Half-Lives for Radionuclides (continued)		
Radionuclide	**Type of Radiation**	**Half-Life**
Plutonium-238 Plutonium-239 Plutonium-240	alpha alpha alpha	86 years 24,400 years 6580 years
Polonium-210	alpha	138 days
Potassium-40	beta, gamma	1.25 billion years
Protactinium-234 Protactinium-234m	beta, gamma beta, gamma	6.7 hours 1.2 minutes
Radium-223 Radium-224 Radium-226 Radium-228	alpha, gamma alpha, gamma alpha, gamma beta	11 days 3.6 days 1600 years 5.8 years
Radon-222	alpha	3.8 days
Selenium-75	gamma	120 days
Strontium-89 Strontium-90	beta beta	52 days 28 years
Sulphur-35	beta	87 days
Technetium-99m	gamma	6 hours
Thallium-201 Thallium-202 Thallium-208	gamma gamma beta, gamma	3 days 12 days 3.1 minutes
Thorium-227 Thorium-228 Thorium-230 Thorium-232 Thorium-234	alpha, gamma alpha, gamma alpha, gamma alpha beta, gamma	18.5 days 2 years 75,000 years 14 billion years 24 days
Uranium-233 Uranium-234 Uranium-235 Uranium-238	alpha, gamma alpha alpha, gamma alpha	162,000 years 247,000 years 710 million years 4.5 billion years
Zinc-65	beta, gamma	245 days
Zirconium-95	beta, gamma	64 days

Some radioactive materials decay to form other radioactive materials. These decay products, in turn, decay, eventually forming stable nuclides. Each material formed through decay has a unique set of radiological properties, such as half-life and energy given off through decay. In the case of the radioactive materials found at POTWs, the radioactive materials present may consist of one or more separate decay "chains" or "series." The naturally-occurring uranium, actinium, and thorium decay chains are illustrated in Figures A-1, A-2, and A-3.

Some of the radioactive materials in these chains emit gamma rays when they decay. The intensity of gamma radiation in air or exposure rate is measured in roentgens (R) or microroentgens (μR) per unit time, usually an hour, as in R/hr or μR/hr. In the environment, exposure rates are typically measured in terms of μR/hr. For example, in many parts of United States the exposure rate from natural sources of radiation is between 5 and 15 μR/hr. This ambient level is referred to as the background exposure rate.

Many commercially available radiation detectors measure radiation fields in terms of μR/hr or counts per minute (cpm). Counts per minute refers to the number of radiation interaction events of ionizing particles or photons that are detected, or counted, in a minute by the detector. Only a fraction of those particles or photons that interact with the detector result in counts. The number of counts per minute can be related to exposure rate or radiation dose for a known radionuclide for which the instrument has been calibrated.

Radiation dose is a measurement or estimate of the body's exposure to ionizing radiation. It is typically measured in units of rem. In the environment and at POTWs, doses are often measured in terms of millirem (mrem). A millirem is one one-thousandth (1/1,000) of a rem; a microrem (μrem) is one-millionth (1/1,000,000) of a rem. The dose rate is expressed in terms of dose per unit time, again usually an hour, as millirem/hr. For external radiation, exposure rates are often equated to dose rates using the conversion of 1 μR/hr = 1 μrem/hr. Doses from internal exposure to radioactive material that has been ingested or inhaled are more difficult to determine. Computer models that account for the distribution and excretion of the radioactive material within the body are used for estimating doses and dose rates from internal radioactive contamination.

What are the Effects of Radiation Exposure?

Radiation may cause a range of effects when it interacts in, or passes through, living tissue. Human health effects begin at the cellular level. Some cells are unaffected by the radiation while others may be damaged but survive and reproduce normally. However, some damaged cells may survive in a modified form, which could potentially result in cancer. Some cells may die from the exposure to radiation.

Other health effects occur to organs and the whole body. Effects from low doses of radiation (tens of, rems) may include birth defects and genetic effects. High doses of radiation (hundreds of rems) over short periods of time may cause organ damage and, if high enough, death. Doses associated with exposures to natural background radiation or typical radioactive materials in POTWs are thousands of times lower than the high doses that cause significant biological damage.

At low doses, the principal concern associated with radiation exposure is the possible occurrence of cancer years after the exposure occurs. Other effects such as birth defects and genetic effects are not likely. For such low doses, the likelihood of producing cancer has not been directly established because it is not possible to distinguish cancers produced by such low levels of radiation from cancers that occur normally. The risk of developing cancer is usually expressed in terms of probability of an adverse health effect because a given dose of radiation does not produce a cancer in all cases.

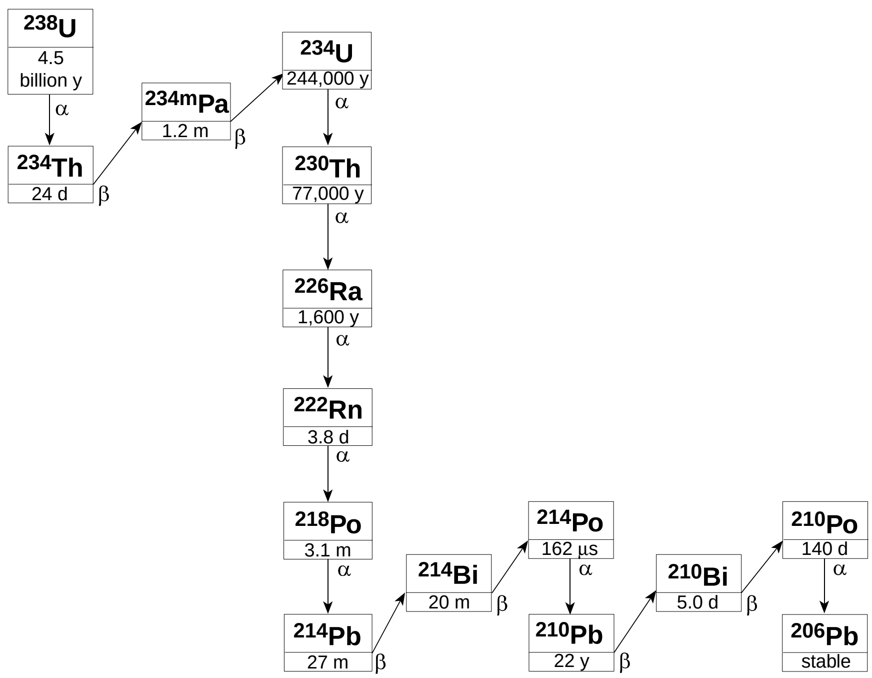

Figure A-1. Uranium (^{238}U) Decay Series.

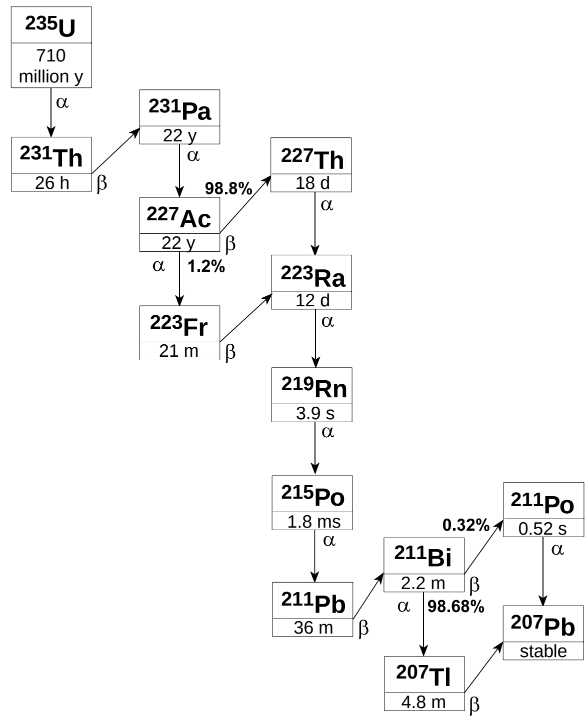

Figure A-2. Actinium (^{235}U) Decay Series.

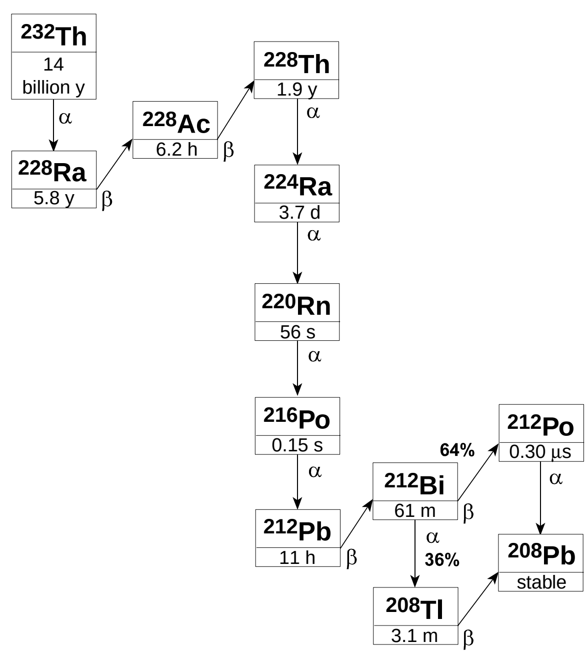

Figure A-3. Thorium (^{232}Th) Decay Series.

APPENDIX B
NRC AND EPA REGIONAL OFFICES BY STATE AND IDENTIFICATION OF AGREEMENT STATES

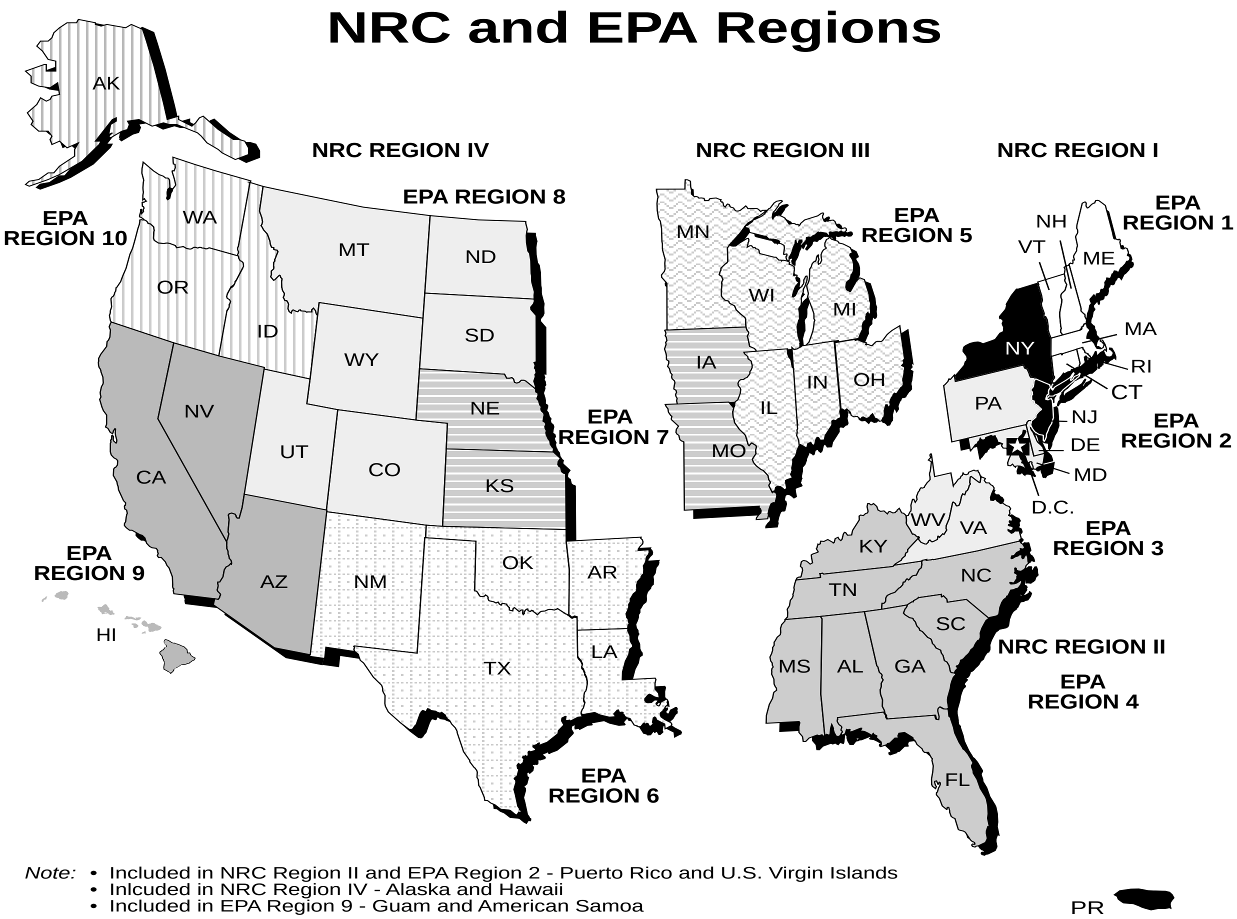

Figure B-1. Delineation of the NRC and EPA regions.

Source: Nuclear Regulatory Commission

Figure B-2. Delineation of NRC Agreement States.

APPENDIX C
NRC REGIONAL OFFICES

Region and address	Division of Nuclear Materials Safety	State Agreements Officer
Region I 475 Allendale Road King of Prussia, PA 19406-1415	(610) 337-5000	(610) 337-5042
Region II Sam Nunn Atlanta Federal Center 61 Forsyth St, SW Suite 23T85 Atlanta, Ga 30303-8931	(404) 562-4000	(404) 562-4704
Region III 801 Warrenville Road Lisle, IL 60532-4351	(630) 829-9500	(630) 829-9661
Region IV Harris Tower 611 Ryan Plaza Drive, Suite 400 Arlington, TX 76011-8064	(817) 860-8100	(817) 860-8116 (817) 860-8287

APPENDIX D
EPA REGIONAL OFFICES

EPA Radiation Program Managers	
Jim Cherniack, RPM USEPA Region 1 1 Congress St. Suite 1100 Boston, MA 02114-2023 Phone: (617) 918-1533 Fax: (617) 918-1505 http://www.epa.gov/region01/	Paul A. Giardino, RPM USEPA Region 2 290 Broadway New York, NY 10007-1866 Phone: (212) 637-4010 Fax: (212) 637-4942 http://www.epa.gov/region02/
Robert Kramer, RPM USEPA Region 3 1650 Arch Street Philadelphia, PA 19103-2029 Phone: (215) 814-2704 Fax: (215) 814-2101 http://www.epa.gov/region03/	Paul Wagner, RPM USEPA Region 4 Atlanta Federal Center 61 Forsyth Street, SW Atlanta, GA 30303-3104 Phone: (404) 562-9100 Fax: (404) 562-9066 http://www.epa.gov/region04/
Mike Murphy, RPM USEPA Region 5 (AE-17J) 77 West Jackson Boulevard Chicago, IL 60604-3507 Phone: (312) 353-6686 Fax: (312) 353-0617 http://www.epa.gov/region5/	Steve Vargo, RPM USEPA Region 6 (6PD-T) Fountain Place 12th Floor, Suite 1200 1445 Ross Avenue Dallas, TX 75202-2733 Phone: (214) 665-6714 Fax: (214) 665-6762 http://www.epa.gov/region06/
Robert Dye, RPM USEPA Region 7 (ARTD/RALI) 901 North 5th Street Kansas City, KS 66101 Phone: (913) 551-7605 Fax: (913) 551-7065 http://www.epa.gov/region07/	Milton W. Lammering, RPM USEPA Region 8 (P2-TX) 999 18th Street Suite 500 Denver, CO 80202-2466 Phone: (303) 312-6147 Fax: (303) 312-6064 http://www.epa.gov/region08/

EPA Radiation Program Managers (continued)	
Michael S. Bandrowski, RPM USEPA Region 9 (Air-6) 75 Hawthorne Street San Francisco, CA 94105 Phone: (415) 744-1048 Fax: (415) 744-1073 http://www.epa.gov/region09/	Jerry Leitch, RPM USEPA Region 10 (OAQ-107) 1200 Sixth Avenue Seattle, WA 98101 Phone: (206) 553-7660 Fax: (206) 553-0110 http://www.epa.gov/region10/

EPA Satellite Locations and Laboratories	
U.S. EPA National Air and Radiation Environmental Laboratory (NAREL) 540 South Morris Avenue Montgomery, AL 36115-2601 Phone: (334) 270-3400 Fax: (334) 270-3454 http://www.epa.gov/narel/	U.S. EPA Radiation and Indoor Environments National Laboratory P.O. Box 98517 Las Vegas, NV 89193-8517 Phone: (702) 798-2476 http://www.epa.gov/radiation/rienl/

APPENDIX E
STATE AGENCIES FOR RADIATION CONTROL
(as of March 4, 1999)

For an up to date listing of the State radiation control contacts given below, see the Conference of Radiation Control Program Directors' (CRCPD) web page at URL: http://www.CRCPD.org/ and then go to the "SR Control Agencies" tab.

Kirksey E. Whatley, Director Division of Radiation Control State Department of Public Health State Office Building 434 Monroe Street Montgomery, AL 36130-1701 Phone - (334) 206-5391	Douglas Dasher Alaska Department of Environmental Conservation 610 University Avenue Fairbanks, AK 99709 Phone - (907) 451-2172
Aubrey V. Godwin, Director Arizona Radiation Regulatory Agency 4814 South 40th Street Phoenix, AZ 85040 Phone - (602) 255-4845 ext. 222	Jared Thompson Division of Radiation Control & Emergency Management Department of Health 4815 West Markham Street, Slot 30 Little Rock, AR 72205-3867 Phone - (501) 661-2173
Edgar D. Bailey, C.H.P., Chief Radiologic Health Branch Food, Drugs & Radiation Safety Division State Department of Health Services P.O. Box 942732 Sacramento, CA 94234-7320 Phone - (916) 322-3482	Warren (Jake) Jacobi Laboratory and Radiation Services Division Colorado Department of Public Health and Environment 8100 Lowry Blvd Denver, CO 80220-6928 Phone - (303) 692-3036
Dr. Edward L. Wilds, Jr., Director Department of Environmental Protection Bureau of Air Management Division of Radiation 79 Elm Street Hartford, CT 06106-5127 Phone - (860) 424-3029	Allan Tapert, Program Administrator Office of Radiation Control Division of Public Health Plan Review, Permitting & Enforcement Federal and Water Streets, Room 224 P.O. Box 637 Dover, DE 19903 Phone - (302) 739-3787
Phillip Sumner, Supervisory Health Physicist Department of Health Environmental Health Administration 614 H Street, NW, Room 1016 Washington, DC 20001 Phone - (202) 727-7218	William A. Passetti, Chief Office of Radiation Control Department of Health 2020 Capital Circle SE, Bin# C21 (HSER) Tallahassee, FL 32399-1741 Phone - (850) 487-1004

Thomas E. Hill, Manager Radioactive Materials Program Department of Natural Resources 4244 International Parkway, Suite 114 Atlanta, GA 30354 Phone - (404) 362-2675	Russell Takata, Supervisor Radiation Section Noise, Radiation, and Indoor Air Quality Branch Department of Health 591 Ala Moana Boulevard Honolulu, HI 96813-4921 Phone - (808) 586-4700
Doug Walker INEEL Oversight Program Laboratory Improvement Section State Laboratories, Division of Health Department of Health and Welfare 900 N. Skyline Drive Idaho Falls, ID 83402 Phone - (208) 528-2617	Richard Allen, Manager Office of Environmental Safety Illinois Department of Nuclear Safety 1035 Outer Park Drive Springfield, IL 62704 Phone - (217) 782-1322
John Ruyack, Director Indoor and Radiologic Health Division State Department of Health 2 North Meridian Street, 5F Indianapolis, IN 46204-3003 Phone - (317) 233-1325	Donald A. Flater, Chief Bureau of Radiological Health Iowa Department of Public Health Lucas State Office Building 321 East 12th Street Des Moines, IA 50319 Phone - (515) 281-3478
Vick Cooper, Director X-Ray & RAM Control Section Bureau of Air & Radiation Department of Health & Environment Forbes Field, Building 283 J Street & 2nd North Topeka, KS 66620 Phone - (785) 296-1561	Vicki D. Jeffs, Supervisor Radioactive Materials Section Kentucky Radiation Control Program 275 East Main Street Frankfort, KY 40621 Phone - (502) 564-3700
J. Kilren Vidrine, ES Coordinator Office of Water Resources Louisiana Department of Environmental Quality P.O. Box 82215 Baton Rouge, LA 70884-2215 Phone - (225) 765-0534	Jay Hyland, Program Manager Radiation Control Program Division of Health Engineering State House, Station 10 157 Capitol Street Augusta, ME 04333 Phone - (207) 287-5677

Carl Trump Radiological Health Program Air and Radiation Management Administration Maryland Department of the Environment 2500 Broening Highway Baltimore, MD 21224 Phone - (410) 631-3300	Robert M. Hallisey, Director Radiation Control Program Department of Public Health 305 South Street, 7th Floor Jamaica Plain, MA 02130 Phone - (617) 727-6214
David W. Minnaar, Chief Radiological Protection Section Drinking Water & Radiological Protection Division Michigan Department of Environmental Quality 3423 N. Martin Luther King, Jr. Boulevard P.O. Box 30630 Lansing, MI 48909-8130 Phone - (517) 335-8197	Judith Ball Minnesota Dept of Health Environmental Health Division 717 Delaware St SE Minneapolis, MN 55440-9441 Phone - (651) 215-0945
Robert W. Goff, Director Division of Radiological Health State Department of Health 3150 Lawson Street P.O. Box 1700 Jackson, MS 39215-1700 Phone - (601) 987-6893	Gary W. McNutt, Environ. Specialist IV Bureau of Environmental Epidemiology Department of Health 930 Wildwood Drive P.O. Box 570 Jefferson City, MO 65102-0570 Phone - (573) 751-6160
George Eicholtz, Coordinator Radiological Health Program Montana Department of Public Health and Human Services Cogswell Building Licensure Bureau P.O. Box 200901 Helena, MT 59620-2951 Phone - (406) 444-5266	Richard P. "Dick" Nelson, Director Department of Regulation and Licensure Nebraska Health and Human Services 301 Centennial Mall South P.O. Box 95007 Lincoln, NE 68509-5007 Phone - (402) 471-2133
Stanley R. Marshall, Supervisor Radiological Health Section Department of Human Resources 400 West King Street, Room 101 Carson City, NV 89710 Phone - (702) 687-5394 x 276	Diane E. Tefft, Administrator Radiological Health Bureau Division of Public Health Services Health and Welfare Building 6 Hazen Drive Concord, NH 03301-6527 Phone - (603) 271-4588

Dr. Jill Lipoti Assistant Director for Radiation Protection Programs Division of Environmental Safety, Health & Analytical Programs Department of Environmental Protection P.O. Box 415 Trenton, NJ 08625-0415 Phone - (609) 984-5636	William Floyd Bureau of Hazardous & Radioactive Materials Water and Waste Management Division Department of Environment 2044 Galisteo Road P.O. Box 26110 Santa Fe, NM 87502 Phone - (505) 827-1862
Barbara Youngberg, Radiation Section Chief New York State Department of Environmental Conservation 50 Wolf Road Albany, NY 12233 Phone - (518) 457-2225	Wendy Tingle, Radioactive Waste Coordinator Division of Radiation Protection 3825 Barrett Drive Raleigh, NC 27609-7221 Phone - (919) 571-4141
Dana K. Mount, Director Division of Environmental Engineering Department of Health 1200 Missouri Avenue, Room 304 P.O. Box 5520 Bismarck, ND 58506-5520 Phone - (701) 328-5188	Roger L. Suppes, Chief Ohio Department of Health Bureau of Radiological Health 35 East Chestnut Street P.O. Box 118 Columbus, OH 43266-0118 Phone - (614) 644-2727
Mike Broderick, Environmental Program Administrator Department of Environmental Quality Radiation Management Section 1000 NE 10th Street Oklahoma City, OK 73117-1212 Phone - (405) 702-5100	Ray D. Paris, Manager Radiation Protection Services State Health Division 800 N.E. Oregon Street Portland, OR 97232 Phone - (503) 731-4014 x 660
William Kirk, Section Chief Environmental Monitoring Bureau of Radiation Protection 400 Market Street P.O. Box 8469 Harrisburg, PA 17101 Phone - (717) 783-9730	Marie Stoeckel, Chief Division of Occupational & Radiological Health Department of Health 3 Capital Hill, Room 206 Providence, RI 02908-5097 Phone - (401) 222-2438

Pearce O'Kelley, Chief Bureau of Radiological Health Department of Health & Environ. Control 2600 Bull Street Columbia, SC 29201 Phone - (803) 737-7403	Virgil R. Autry, Director Division of Radioactive Waste Management Bureau of Solid and Hazardous Waste Department of Health & Environmental Control 2600 Bull Street Columbia, SC 29201 Phone - (803) 896-4244
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Charles R. Meyer, Chief Bureau of Radiation Control Texas Department of Health 1100 West 49th Street Austin, TX 78756-3189 Phone - (512) 834-6688	William J. Sinclair, Director Division of Radiation Control Department of Environmental Quality 168 North 1950 West P.O. Box 144850 Salt Lake City, UT 84114-4850 Phone - (801) 536-4250
Paul E. Clemons, Chief Division of Occupation & Radiological Health Department of Health 108 Cherry Street P.O. Box 70 Burlington, VT 05042 Phone - (802) 865-7731	Leslie P. Foldesi, M.S., CHP Director, Radiological Health Program Commonwealth of Virginia Department of Health P.O. Box 2448 Richmond, VA 23218 Phone - (804) 786-5932
Terry C. Frazee, Supervisor Radioactive Materials Section Division of Radiation Protection 7171 Cleanwater Lane, Bldg 5 P.O. Box 47827 Olympia, WA 98504-7827 Phone - (360) 236-3221	Beattie DeBord, Chief Radiological Health Program 815 Quarrier Street Charleston, WV 25301 Phone - (304) 558-3526

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APPENDIX F
EXAMPLES OF POTWS THAT HAVE RADIONUCLIDE MATERIALS PROGRAMS

Albuquerque, New Mexico

The City of Albuquerque has drafted a Radioactive Discharge Monitoring Program (RDMP). This will be a voluntary program of monitoring and reporting. The Albuquerque POTW has found they have the responsibility to be aware of all discharges to the sewer system that could impact operations at the treatment plant or impact the health and safety of employees and the public. The POTW will implement a program of discharger registration that requires dischargers to (1) periodically report their radionuclide discharges, (2) allow the POTW to perform surveillance monitoring, and (3) commit to voluntarily limit their discharges to levels that are as low as reasonably achievable (ALARA). These registrations will be issued and monitoring of the discharges will be permitted in accordance with a city sewer use and wastewater control ordinance. The agreement could be in the form of an amendment to an existing sewer discharge permit.

The Albuquerque POTW obtained a list of licensed radioactive materials users in the municipal service area from the appropriate regulatory authority (New Mexico is an Agreement State). Each of the licensees was evaluated to determine whether or not they discharge or have the potential to discharge radioactive materials to the sewer. This included an initial walk-through to familiarize the RDMP staff with the nature of the operation and potential opportunities for waste minimization.

The POTW will negotiate discharge limits with the dischargers so that the aggregate regulated discharges from all licensed facilities is ALARA and produces no greater than 1 in 10,000 excess risk of fatal cancer to the most exposed individual. The POTW will work with potential dischargers to prevent accidental releases of radioactive materials.

The Albuquerque POTW retains a certified Health Physicist to interpret the reports from the dischargers and from monitoring the dischargers and the treatment facility. The health physicist uses radiation exposure models to ensure the radiation dose to the "most exposed" individual is ALARA.

The dischargers will be asked to provide annual reports regarding the discharges they have made or plan to make to the sewer. In addition, the RDMP staff collects samples from the facilities' sample locations on a regularly scheduled basis and/or unannounced. The samples are analyzed by the State. To date the radionuclides found in the sewage have been of medical origin. Gamma radiation detectors installed in the plant have indicated that no measurable radiation exposure is being received by plant workers.

Formal adoption of the RDMP plan awaits passage of a revised sewer use and wastewater control ordinance. It has been stalled for more than 2 years due to its "political sensitivity." Unless there is a demand by dischargers for the change to occur, the situation will remain "as is."

St. Louis, Missouri

The City of St. Louis has its own requirements to limit radioactive discharges from industrial users. The district is concerned that low-level radioactive materials being discharged to the sewer system by numerous small sources may be concentrated by the district's wastewater treatment processes and possibly pose a hazard for the employees and adversely affect the district's sludge disposal options.

The District Ordinance for sewer use contains a limit of 1 curie/yr for the aggregate discharge from all users in a watershed (except excreta from individuals undergoing medical treatment or diagnosis). This number is currently under review.

The district requested lists of licensees from the NRC and the State and wrote the licensees letters informing them of the limits for radionuclide dischargers. Licensees are required to write the sewer district requesting approval to discharge radioactive materials and indicating the isotopes and the amounts to be discharged annually. The district then approves the discharges. The district requires quarterly reports from the licensees to ensure compliance with the District Ordinance and State and Federal regulations. The licensee's discharge permit is then modified to incorporate the approval of discharges and the reporting requirements.

As alternatives to discharging to the sewer system, licensees are encouraged to consider shipping the waste to an approved low-level radioactive waste disposal site or storing the waste for at least ten half-lives to allow sufficient decay to background levels prior to disposal to the sewer.

Oak Ridge, Tennessee

In response to its sewage sludge contamination problems (see Section 1.2), Oak Ridge developed a site-specific, risk-based methodology for establishing radionuclide limits for its sewage sludge. The sewage sludge criteria were then used to determine allowable plant releases that provided a basis for setting facility specific discharge criteria through the city's existing pretreatment program. Additionally, the city included a "radioactive materials" section in its pretreatment questionnaire which is filled out by all industrial users. The city also established an inexpensive screening program designed to ensure that elevated levels of radionuclides from spills or illegal discharges, would not reach the land application site.

The city of Oak Ridge was strongly supported by Tennessee's state radiation control program. Also aiding in the success of the program was ORWTP's close working relationship with local industry. The city of Oak Ridge expended considerable effort in developing a program that controlled radionuclide discharges in a manner that was not detrimental to local industry and still provided protection for the POTW.

APPENDIX G
GLOSSARY AND ACRONYMS

AEA ... Atomic Energy Act

Agreement State ... States with formal agreements with NRC that grant the states the authority to develop and oversee the implementation of specific regulations regarding the generation and use of AEA material and maintain radiation protection programs that are adequate to protect public health and safety compatible with that of the NRC.

Background Radiation ... Radiation from cosmic sources, *naturally occurring radioactive material (NORM)*, including radon (except as a decay product of *source* or *special nuclear material*), and global fallout as it exists in the environment from the testing of nuclear explosive devices or from nuclear accidents like Chernobyl which contribute to *background radiation* and are not under the control of the cognizant organization. *Background radiation* does not include radiation from *source*, *byproduct*, or *special nuclear materials* regulated by the cognizant Federal or State agency.

Becquerel (Bq) ... The International System (SI) unit of activity equal to one nuclear transformation (disintegration) per second. 1 *(Bq)* = 2.7×10^{-11} *curies* (Ci) = 27.03 picocuries.

Byproduct Material ... In general, 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*.

Contamination ... The presence of *elevated levels of radiation* where you don't want it.

CPM ... counts per minute

Curie ... The customary unit of radioactivity. One *curie* (Ci) is equal to 37 billion atomic disintegrations per second (3.7×10^{10} dps = 3.7×10^{10} Bq), which is approximately equal to the decay rate of one gram of ^{226}Ra. Fractions of a *curie*, e.g., picocurie (pCi) or 10^{-12}Ci and microcurie (µCi) or 10^{-6} Ci, are levels typically encountered in the environment.
***microcurie* (µCi)** ... one one-millionth (1/1,000,000) of a curie
***picocurie* (pCi)** ... one one-trillionth (1/1,000,000,000,000) of a curie

Elevated Levels of Radiation ... Levels of radioactive material in sewage sludge or ash that should alert a POTW that some appropriate action(s) may be warranted (see Section 1 of the report).

Exposure Rate ... The amount of ionization produced per minute in air by X-rays or gamma rays. The unit of exposure rate is roentgens/hour (R/h); typical units are microroentgens per hour (μR/h), i.e., 10^{-6} R/h.

Gamma Radiation ... Penetrating high-energy, short-wavelength electromagnetic radiation (similar to X-rays) emitted during *radioactive decay*. Gamma rays are very penetrating and require dense materials (such as lead or steel) for shielding.

HP ... Health Physicist

ISCORS ... The Interagency Steering Committee on Radiation Standards.

NARM ... Naturally occurring or accelerator-produced radioactive material, such as radium, and not classified as *source material*.

Naturally Occurring Radionuclides ... Radionuclides and their associated progeny produced during the formation of the earth or by interactions of terrestrial matter with cosmic rays.

NORM ... Naturally-occurring radioactive materials.

Radioactivity (or activity) ... The mean number of nuclear transformations occurring in a given quantity of radioactive material per unit of time. The International System (SI) unit of radioactivity is the *becquerel (Bq)*. The customary unit is the *curie (Ci)*.

Radioactive Half Life ... The time required for one-half of the atoms of a particular *radionuclide* present to disintegrate.

Radioactive Decay ... The spontaneous transformation of an unstable atom into one or more different nuclides accompanied by either the emission of energy and/or particles from the nucleus, nuclear capture or ejection of orbital electrons, or fission. Unstable atoms decay into a more stable state, eventually reaching a form that does not decay further or has a very long *radioactive half-life*.

Radionuclide ... An unstable nuclide that undergoes *radioactive decay*.

Reconcentration ... The increase in the concentration of radioactive materials in sewage sludge or ash resulting from wastewater and sludge treatment within the POTW.

rem (radiation equivalent man) ... The conventional measurement unit of radiation dose for estimating the body's effects from exposure to ionizing radiation. The corresponding International System (SI) unit is the *sievert (Sv)*: 1 Sv = 100 rem.
millirem ... one one-thousandth (1/1,000) of a rem
microrem ... one one-millionth (1/1,000,000) of a rem

Roentgen (R) ... intensity of photon (gamma or x-ray) radiation.
microroentgen (μR) ... one one-millionth (1/1,000,000) of a roentgen.

Source Material ... In general, uranium and/or thorium other than that classified as *special nuclear material.*

Special Nuclear Material ... In general, plutonium, ^{233}U, and uranium enriched in ^{235}U; material capable of undergoing a fission reaction.

TENORM ... Naturally occurring radioactive materials whose concentrations are increased by or as a result of past or present human practices. TENORM does not include background radiation or the natural radioactivity of rocks or soils. TENORM also does not include uranium or thorium in source material as defined in the AEA and NRC regulations.

APPENDIX H
SOURCES OF ADDITIONAL INFORMATION

ASTM E 181-82 (Reapproved 1991), "Standard General Methods for Detector Calibration and Analysis of Radionuclides," American Society for Testing and Materials, Philadelphia, Pennsylvania 19103.

CRCPD Publication 94-1, "Directory of Personnel Responsible for Radiological Health Programs," Conference of Radiation Control Program Directors, Inc., Frankfort, Kentucky 40601.

Miller, W.H., et al, 1996, "The Determination of Radioisotope Levels in Municipal Sewage Sludge," Health Physics, v. 71, no. 3, p. 286.

Miller, M.L., Bowman, C.R., an M.G. Garcia, 1997, "Avoiding Potential Problems ...

NCRP Report No. 50, "Environmental Radiation Monitoring," 1976, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

NCRP Report No. 58, "A Handbook of Radioactivity Measurement Procedures." 1985, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

APPENDIX I
ADDITIONAL INFORMATION ON NRC AND AGREEMENT STATE LICENSING AND ENFORCEMENT

This appendix provides additional information about how NRC and Agreement States License users of radioactive materials, and how the agencies enforce the regulations.

Who Must Obtain a License and What Happens If this Isn't Done?

According to NRC's 10 CFR Part 30, Section 30.3:

> Except for persons exempt as provided in this part and Part 150 of this chapter, no person shall manufacture, produce, transfer, receive, acquire, own, possess, or use byproduct material except as authorized in a specific or general license issued pursuant to regulations in this chapter.

This means that, with a few specified exceptions, any activity involving byproduct material must be conducted under a license issued by the NRC or an Agreement State. The exempt activities are described in NRC's 10 CFR Part 30. Most exemptions from specific licensing are for consumer products, such as smoke detectors.

Persons who are required to obtain an NRC license but fail to do so would be in violation of federal law and, when discovered, would be subject to the penalties appropriate for such violations. In any case, such persons would most likely be unable to obtain the byproduct materials they need, because suppliers of such materials generally require copies of the license authorizing possession and use of the materials before the materials are delivered to the user.

What Radioactive Materials Are Exempt from Licensing?

Section 30.3 cited above mentions certain exemptions from the NRC licensing requirements. These exemptions include certain DOE activities and also users of articles containing byproduct materials in concentrations and quantities below specified levels. These articles include some instruments containing luminous dials, such as timepieces, balances, marine compasses, electron tubes, gas or smoke detectors, and some other products. It should be noted that the manufacturers and distributors of these exempt devices are subject to NRC licensing.

In addition to the above, some radioactive materials may be exempt from licensing because they fall below NRC-established concentration or quantity levels. These levels do not apply to materials that have already been licensed but have for some reason, such as decay, diminished to activities below these levels. The exemption applies only to the initial determination of whether or not a potential user or owner of byproduct material needs to be licensed or is exempt from such a requirement. Once licensed, byproduct material remains under the conditions of the license regardless of how small the activities become because of decay or any kind of partitioning of the original licensed quantity.

Why Are Some Industrial and Medical Facilities Not Licensed?

Some facilities that use radioactive materials may not be licensed by the NRC if the material they use is not byproduct material. Examples of such facilities would be those that use accelerators or accelerator-produced radioactive materials. However, even though such facilities may not come under NRC's jurisdiction, and are therefore not licensed by the NRC, they are usually within the jurisdiction of a state and may be licensed by that state if their activity requires licensing. Exceptions to this may be certain federal facilities and their prime contractors, such as DOE facilities which, although not licensed by NRC or the states, are regulated by internal DOE Orders.

What Monitoring/Oversight Do NRC and the Agreement States Provide for Licensees under Their Control?

Both NRC and Agreement States monitor their licensees by means of periodic inspections. The frequency of inspections depends on the type of license issued to the licensee, and will vary from annual inspections for the larger licensees, such as hospitals, radiopharmaceutical companies, and other large users of byproduct materials, to inspections once every 3-5 years for small licensees who may use only one small radioactive source in a routine and well-established application. The inspections are designed to review the licensee's operation to make sure that it is being conducted safely and in accordance with good practices and the conditions specified on the license. Inspection frequencies may be increased if the NRC or Agreement State believes that the licensee requires closer oversight to implement improvements in their program to raise its standards. In addition, the license may be suspended or revoked if NRC or the Agreement State finds that the licensee's operation does not meet minimum safety standards.

Some facilities may be under the jurisdiction of more than one entity, such as many medical facilities that are licensed by NRC for those parts of their operation that use byproduct materials, and by the state in which they operate for those parts that use accelerator-produced radioactive materials. Most states regulate naturally-occurring and accelerator-produced radioactive materials.

What Causes Discharges Outside of Regulations or License Conditions?

The probable causes of illegal discharges are poor licensee programs, lack of knowledge of the regulations, or deliberate violations. Discharges to the sanitary sewers by NRC or Agreement State licensees must comply with NRC or equivalent Agreement State regulations governing this aspect of the licensee's operation. There are many mechanisms in place to provide reasonable assurance that licensees will comply with this regulatory requirement. Licenses are issued to licensees only after NRC or the Agreement State is satisfied that the licensee has the qualified staff, equipment, procedures, instrumentation, training programs, and management oversight deemed necessary to operate the proposed program in a safe manner and within the restrictions specified in the license. Any signs of program weaknesses or irregular activities identified during inspection are brought to the licensee's attention for corrective action, and if these are found to be sufficiently serious, the license may be suspended pending completion of corrective actions, or revoked, thereby ending the licensee's use of licensed materials.

All these measures cannot prevent illegal discharges to the sewers, but they help to minimize such a possibility, and they provide an opportunity to identify such illegal activities if they occurred.

What Enforcement Actions Do NRC and Agreement States Take When Licensees Discharge Outside Regulations or License Conditions?

The enforcement actions that could be taken in such cases depend on the specifics of the situation. If the discharge above the limits is found to have been a one-time, inadvertent error in an otherwise sound program, the licensee could be issued a violation and the licensee's management may be called to the NRC or state offices for a meeting with NRC or state management to discuss the incident and the corrective actions the licensee intends to take to prevent recurrence. The NRC or state may also issue a letter to the licensee summarizing the corrective actions to be taken and the completion schedule. Follow-up inspections might be used to confirm completion of the corrective actions and their adequacy. The NRC and some States could also impose monetary penalties.

If, on the other hand, the discharge above the limits is found to be the result of a generally poor program, additional and more escalated enforcement actions could be taken to change the licensee's program. Such changes may involve hiring more competent professionals or managers, retraining of personnel, rewriting operating procedures, and any other measures that may be needed to improve the quality of the program. The program is then monitored closely. In more serious cases, the license could be revoked. In situations where willfulness is found and the matter is under NRC jurisdiction, the matter could be referred to the Department of Justice for appropriate legal action. If the matter is under State jurisdiction, it could be referred to the State Attorney General.

APPENDIX J
RADIOLOGICAL ANALYSIS LABORATORIES

The table below provides a list of laboratories that should be able to provide radiological analyses of sewage sludge samples for POTWs. A list is maintained by the Conference of Radiation Control Program Directors (CRCPD) of laboratories that provide radiological analysis of diverse materials, have quality assurance and quality control programs, and will perform work for both government and private firms. The laboratories listed here are those from the January 2000 CRCPD list that have indicated they perform analyses of sludge samples. The list is available from the CRCPD by phone at 502/227-4543, and is posted to the CRCPD web page, at URL: http://www.CRCPD.org (then go to the "Free Documents" tab, then to "Orphan Source Documents," and then to "Radioassay and TCLP Services"). The list is updated periodically by the CRCPD. The CRCPD does not guarantee that the list is comprehensive, nor is there any certification of the quality of services provided. Thus, the authors of this report provide this list only as a convenience to POTWs in locating laboratories that they may wish to evaluate. The NRC, EPA, and the ISCORS Sewage Sludge Subcommittee do not certify, approve, or endorse these laboratories. Section 5.4.2 of this guidance document provides criteria that POTWs can use to help evaluate laboratories.

Firm	State	Contact person	Phone
Accu-Labs Research, Inc.	Colorado	Karen Schoendaler	303/277-9514
Barringer Laboratories	Colorado	Gerald Ritenour	800/654-0506
Envirotest (nee Core Labs)	Wyoming	Dave Demorest	307/235-5741
Data Chem	Utah	Kevin Griffiths	801/266-7700
Duke Engineering (Yankee Atomic)	Massachusetts	Edward Maher	978/568-2522
General Engineering Labs	South Carolina	J. Westmoreland	843/556-8171
Kentucky Radiation Control Branch	Kentucky	Eric Scott	502/564-8390
Nuclear Technology Service	Georgia	Herman Rao	770/663-0711
Paragon Analytical Inc	Colorado	Lori Pacheco	800/443-1511
Pembroke Laboratory	Florida	Gene Whitney	941/285-8145
Quanterra (multiple labs)	Washington (main office)	Project manager	509/375-3131
Post, Buckley, Schuh & Jernigan	Florida	Tom French	407/277-4443
Rhode Island Nuclear Science Center	Rhode Island	Terry Tehan	401/789-9391
RSA Labs	Connecticut	Jay Dockendorff	860/228-0721
Teledyne-Brown Engineering	New Jersey	Alan Latham	201/664-7070
Teledyne-Brown Engineering	Illinois	Ms. Grob	847/564-0700
ThermoRetech	California	Rod Melgard	510/235-2633
ThermoRetech	Tennessee	Mike McDougal	423/481-0683
ThermoRetech	New Mexico	Ernie Sanchez	505/345-3461
Thornton Laboratories, Inc.	Florida	Drey Taylor	813/223-9702
Univ. of Iowa, State Hygienic Lab	Iowa	Marinea Mehrhoff	319/335-4500
Wisconsin State Hygiene Laboratory	Wisconsin	Lynn West	608/224-6227