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MEMORANDUM TO: File

FROM: Phyllis Sobel, Project Manager
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SUBJECT: DRAFT GUIDANCE ON RADIOACTIVE MATERIALS IN SEWAGE SLUDGE/ASH AT PUBLICLY OWNED TREATMENT WORKS (POTWS)

Attached is the draft POTW guidance document. This document is currently under review by the Interagency Steering Committee on Radiation Standards (ISCORS) Sewage Subcommittee. The subcommittee has not completed parts of the document, including a table of acceptable concentrations of radioactive materials. However, the subcommittee wishes to place this document in the NRC's Public Document Room at this time so that the wastewater industry and the States can comment on the scope of the document.

Attachment: As stated

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> DISCLAIMER
>
> This guidance document resulted from interagency discussions. The ISCORS Sewage Subcommittee is composed of representatives from the Nuclear Regulatory Commission, Environmental Protection Agency, Department of Energy, and Department of Defense. This document has not been approved by the respective federal agencies and does not represent the official position of any participating agency at this time.

Guidance on Radioactive Materials in Sewage Sludge/Ash at POTWs

May 1997 Draft

1. What is the Purpose of this Guide?

The Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA) developed this guide to provide information about radioactive materials in sewage sludge and ash from the incineration of sewage sludge at publicly owned treatment works (POTWs). It also provides background information about the regulatory policies of NRC and EPA, sources of radioactive materials in sewage, guidance on sampling and analysis of these materials in sewage sludge and ash, and methods to assess levels of radioactive materials in these byproducts of wastewater treatment. Appendix A is a background discussion about radioactivity.

Although it is unlikely that radionuclide levels in 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 sludge products at some POTWs. However, there is no general concern for worker safety or general public exposures because of the low amounts of radioactive materials that are legally authorized to be disposed into the sanitary sewer system by Federal or State law and regulations.

Even though NRC and the States regulate industrial and medical discharges of liquid wastes containing low levels of licensed radioactive material to the sewer system, it is important for the POTW manager and operator to understand what types and amounts, if any, of radioactive materials may be entering the POTW. There are several ways to develop this understanding. One way to obtain this information is by sampling and testing the sludge products. Another way to obtain information is to identify what licensed and other activities discharge into the POTW and work with the licensees and other industries to understand what they are discharging. Analysis of radioactive materials can be made part of the existing analysis programs for other pollutants, or the POTW manager or operator may want to set up a program whereby any licensed discharger routinely notifies the POTW of the type, level and timing of discharges to the system. While monitoring of the POTW influent may seem to be a viable option, measurement systems may not be able to detect the diluted radioactive materials.

At the request of Senator John Glenn, the General Accounting Office (GAO) published a report, "Actions Needed to Control Radioactive Contamination at Sewage Treatment Plants," in May 1994. The report included recommendations that NRC determine the extent of the contamination and establish acceptable radioactivity limits. This guidance document is part of the NRC's response to the GAO report.

The operator of a POTW may decide to sample sewage sludge and ash for radioactive materials based on the nature of industries discharging to the collection system or to establish background measurements. If measured levels of radioactivity exceed the levels suggested in Section 8, it may be appropriate or necessary to limit certain sludge/ash use or disposal practices, further restrict radioactive material discharges by specific licensees, or alter operations at the treatment works.

2. Who Regulates Radioactive Material?

Regulatory responsibility for radioactive material in the U.S. is shared by Federal, State and local agencies. The following summary should help clarify the responsibilities of the different agencies. Appendices B, C, D and E list NRC, EPA and State contacts.

NRC: NRC is responsible for ensuring that discharges of radioactive materials by their licensees into the sewage system are in compliance with applicable NRC regulations under Title 10 of the Code of Federal Regulations (CFR) Part 20. Under the Atomic Energy Act of 1954, NRC regulates the civilian uses of certain radioactive materials (byproduct, source, and special nuclear materials) in the United States. These radioactive materials are used at nuclear power reactors, and industrial, academic, medical, and research and development facilities. NRC's mission is to ensure adequate protection of the public health and safety, and to protect the environment. This mission is accomplished through licensing of nuclear facilities and the possession, use and disposal of nuclear materials; the development and implementation of guidance and requirements governing licensed activities; and inspection and enforcement activities to ensure compliance with these requirements. People who have a license and are regulated by NRC are called "licensees."

States: NRC has entered into agreements with 30 States to allow these States to regulate most types of radioactive material within their borders, in lieu of NRC. These States are referred to as Agreement States. Agreement States have established regulations and procedures comparable to those established by NRC. The only facilities not regulated by Agreement States are nuclear power plants and Federal facilities.

Radioactive materials that occur naturally, other than uranium and thorium, are not regulated by NRC. In lieu of Federal regulations, States have the responsibility to regulate naturally-occurring radioactive material. At this time, several States have issued regulations for the control of sources of very low level radiation derived from naturally occurring materials that have been concentrated by human activities. The regulations are intended to provide radiation protection to members of the public and workers who might be exposed to that radiation. The non-federal Conference of Radiation Control Protection Directors is developing model regulations for use by State agencies in controlling these sources of radiation in their own States.

DOE: The Department of Energy (DOE) regulates the defense-related uses of radioactive materials under authority of the Atomic Energy Act, the Price-Anderson Act Amendments, and other related legislation. Nuclear weapons production, testing and research facilities, as well as former commercial radiation sites and inactive uranium mill tailings sites are subject to DOE regulatory control.

Discharges from DOE facilities of liquid wastes containing radioactive materials are regulated by internal DOE Orders and regulations. DOE Order 5400.5 (Radiation Protection of the Public and the Environment) establishes treatment and discharge requirements for any liquid waste containing radioactive materials. Any liquid wastes discharged to a sanitary sewer must be below five times the Derived Concentration Guides (Chapter III of Order DOE 5400.5) levels at the point of discharge, or must be treated by a Best Available Treatment technology to achieve levels that are at least equivalent to these concentration limits. In addition, all releases are required to be evaluated by an "As Low As Reasonably Achievable" process. Liquid wastes discharged to a sanitary sewer system must also achieve levels that do not interfere with handling or disposal of solids at the POTW, and that do not result in general public exposures that are more than a small fraction of the annual dose limit. DOE is in the process of updating these requirements in a regulation (10 CFR Part 834) which, when promulgated, will replace Order DOE 5400.5. The proposed rule includes 10 CFR Part 20 source term limits, along with the Order DOE 5400.5 concentration limits.

EPA: EPA is responsible for regulations to protect the health and safety of workers at POTWs and the public and the environment that are exposed to sewage sludge and ash produced by POTWs. EPA has responsibility for establishing generally applicable standards for the protection of the environment from radioactive materials under the Atomic Energy Act. EPA also administers the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund") to provide for remedial action in response to releases or substantial threats of releases of hazardous substances into the environment. EPA regulates the management of hazardous waste under the Resource Conservation and Recovery Act, and toxic materials under the Toxic Substances Control Act. While radioactivity is not a listed characteristic for defining hazardous wastes under the Resource Conservation and Recovery Act (RCRA), sites contaminated with radioactive substances have become regulated as Superfund sites under CERCLA or under other regulatory programs. EPA has authority to delegate these programs to State agencies while providing regulatory oversight. There are currently no EPA regulations for radionuclides under the Clean Air Act that apply to POTWs; however, NRC's regulations in 10 CFR Part 20 include regulations for air emissions from its licensees.

EPA, under its authority to provide guidance for all Federal agencies in the formulation of radiation standards and in establishing cooperative programs with the States, has issued proposed guidance in 1994 for radiation protection of the general public. This authority stems from an executive order of the President and the Atomic Energy Act. In addition, under the authority of the Safe Drinking Water Act, EPA limits radiation content in drinking water. EPA also protects groundwater from introduction of radioactive pollution under several programs, including by regulation or statute.

The EPA POTW "pretreatment program" under the Safe Drinking Water Act is designed to protect the POTWs by (1) preventing the introduction of pollutants into sewer systems that would interfere with the operation of a POTW, including interference with its use or disposal of municipal sludge, (2) preventing the introduction of pollutants into POTWs which will pass through the treatment works or otherwise be incompatible with such sources, and (3) improving opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

Local Authorities: Local authorities are derived from the Federal and State statutes and regulations and will vary from locality to locality. The NRC has found that if a municipality has sound reasons, other than radiation protection, a municipality can require the pretreatment of wastes to eliminate or reduce radioactivity. Furthermore, although NRC regulations allow users of regulated materials to discharge to treatment plants, these regulations do not compel a sewage treatment operator to accept radioactive materials from NRC licensees. Some localities are addressing the potential problem of concentration of radioactive material at POTWs by either (1) requiring pretreatment of waste by specific licensees or (2) limiting the discharge of radioactive materials. For example, the State of Oregon and the city of Portland, Oregon, ordered a state licensee to install a pretreatment system to control the discharge of thorium oxide into sewer lines. The Metropolitan St. Louis Sewer District passed an ordinance in 1991 that limits the aggregate discharge of radioactive materials into the sewage system. Other cities seem unsure whether a municipality or treatment plant can lawfully regulate or prohibit a licensee's discharge of radioactive materials in the sewage system. Appendix F describes two examples from the cities of Albuquerque and St. Louis.

3. Why is There Radioactivity in Sewage Sludge?

There are three general sources of radioactivity in the environment: a natural source, a natural source but concentrated or "enhanced" by human activities, and a human-made source. Natural sources of radioactivity are found widely spread in the environment. All geological formations and soils contain uranium, radium, radon, and other radioactive elements in small amounts. Water that originates in or moves through geologic deposits containing naturally-occurring radioisotopes could result in these radioisotopes being carried to the treatment facility with the drinking water supply, storm water runoff or infiltration entering the sewer system, and water treatment plant residuals discharged to the sewer system.

Almost everything, including people, contain some radioactive material. Naturally-occurring radioactive materials are found in the food and water we ingest, and even the air we breathe contains some radioactive gases. These small amounts of radioactive materials can be incidentally enhanced, either physically or chemically, by human activity and technologies associated with extraction processes. Examples of sources of natural radiation which have been enhanced by human activities include wastes from mineral ores and the petroleum industry, sludge and scale from drinking water treatment, wastes from the burning of coal, waste from geothermal energy production, and articles made from naturally-occurring radioactive materials such as thorium in lantern mantles.

Sewage sludge and ash at POTWs may contain both naturally-occurring radioactive materials and radioactive materials made by humans. Industrial and medical facilities may be licensed to discharge radioactive materials to the sanitary sewer system. In addition, radioactive materials administered to patients for the diagnosis or treatment of illnesses are discharged to the sewer system. Certain radioactive materials may be exempt from licensing, and these radioactive materials can be discharged into the sanitary sewer systems. Other industrial or residential discharges can contain naturally-occurring radioactive materials that are not subject to licensing or regulation, such as fertilizer residues. It is also possible that industrial, commercial, or medical facilities might discharge into the sanitary sewer system outside of regulations or license conditions.

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 a concentration of the radionuclides in the treatment facility's other byproduct, sewage sludge (or ash if the sewage sludge is incinerated). What was once disposed of into the sanitary sewer in a dilute form, may be concentrated during some stages of wastewater treatment or sludge processing.

Concentration of radioactive materials occurs in the same manner as non-radioactive materials such as heavy metals. The concentration may occur during several stages of wastewater treatment, including various physical, chemical, and biological wastewater treatment processes. Sludge treatment and processing may result in increasing the concentration by weight of the radioactive contaminant by decreasing the concentration of other components. Incineration of sludge has proven to be the greatest concentration process. Final concentration will depend on the numerous aspects of the entire processes used at the treatment facility, such as the chemical form of the radionuclide, its half-life, the processes used, and the efficiencies of those processes. A recent study by Ainsworth et al (1994) indicated that with the currently available information, it was not possible to quantitatively estimate concentration factors for specific processes or for wastewater treatment plants in general.

The EPA report "Radioactivity of Municipal Sludge" and the 1994 GAO report cited in Section 1 summarize the data available on radioactive materials in sewage sludge. At specific sites, the radionuclides ranged from numerous radionuclides to specific radionuclides from specific sources. Most radionuclides were present at very low concentrations. At most sites, sewage sludge contained radionuclides from medical treatment and research facilities (Iodine-131, Chromium-51 and Selenium-75). Radionuclides are released to the sewer system through releases of isotopes during handling and through excretion by patients. These medical contaminants were found to not produce a significant dose when the sludge was land applied due to their short half-lives. (The term half-life and other background information on radioactivity are discussed in Appendix A.)

The 1986 EPA report cites some examples of elevated levels of radionuclides found at POTWs. For example, Americium-241 in the sludge at two facilities was attributed to producers of foil elements in smoke detectors. At one of these sites, the State of New York paid for cleaning up the treatment plant and sewer lines.

High concentrations of Radium-226 are found in the groundwater in some areas of the U.S., for example Illinois and Wisconsin. Under the Safe Drinking Water Act, many drinking water facilities are required to treat their drinking water to reduce radium concentrations to acceptable levels. At some POTWs, radium found in sewage sludge has been attributed to residuals discharged to the sewer system from drinking water treatment facilities.

A more recent case of contaminated sludge involves the Northeast Ohio Regional Sewer District's (NEORSD) Southerly Sewage Treatment Plant. A 1991 aerial radiological survey, intended to measure radiation around an NRC licensee, detected elevated levels of radiation at the POTW, which were found to be from Cobalt-60, Radium-226 and Cesium-137 in the ash from incinerating their sewage sludge. The latter two radionuclides were in the normal range of naturally-occurring radioactivity found in the area. At least part of the Cobalt-60 contamination was due to releases from a licensed manufacturing facility. NRC, the State, and NEORSD have funded surveys of the site. NEORSD has funded site remediation activities and installed a fence to prevent public access.

4. What are Background Radiation and Naturally-Occurring Radioactive Materials?

Background radiation is the radiation that is emitted from naturally-occurring radioactive materials in and on the Earth and in space, and does not include medical and occupational activities. 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.

The average dose of radiation exposure to an individual in the U.S. is slightly more than 300 mrem/yr from their exposure to background radiation. (The term "dose" and other background information on radioactivity are described in Appendix A.) The annual exposure to background radiation is summarized in the following table (Huffert et al, 1994):

Source	Average Dose (mrem/yr)	Typical Range of Variability (mrem/yr)
Terrestrial	30	10 - 80
Radon	200	30 - 500
Cosmic	30	30 - 80
Internal	40	20 - 100

Terrestrial radiation comes from radioactive material that is naturally occurring in the environment. Radon occurs in the environment and is listed separately in the following table because of the large contribution it gives compared to the other terrestrial sources. Cosmic radiation comes from outer space and 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 from substances that are in the human body naturally, and that are naturally radioactive, primarily Potassium-40.

As shown, these doses can vary greatly, as the various factors that contribute to background radiation are not constant from location to location, and our lifestyles and daily activities vary these amounts to some extent. Since the atmosphere serves as a shield against cosmic radiation, this dose increases with altitude; the dose at an altitude of 1 mile (for example, in the Rockies) is about double that at sea level (30 mrem/yr). Also a flight on a commercial airliner increases your dose from cosmic gamma rays about 4 to 5 mrem for each cross-country flight.

Dose rates from terrestrial sources vary from about 10 to 100 mrem/yr across the U.S. The major sources in the ground are potassium, thorium, and uranium. The higher doses are associated with uranium deposits in the Colorado Plateau, granitic deposits in New England, and phosphate deposits in Florida. The lowest rates are the sandy soils of the Atlantic and Gulf coastal plains. If you live in a brick house, instead of one made of wood, you may add up to 10 mrem/yr to your annual dose due to naturally-occurring thorium, uranium, and radium found in the clays of which bricks are made.

Doses vary according to the amount of naturally-occurring material that people ingest in food and drinking water. The principal naturally-occurring radionuclides are potassium and radium. Potassium is commonly ingested from bananas and one source of radium is Brazil nuts. Radium in water, particularly ground water, varies across the U.S.; it is in higher concentrations in some States such as Georgia, Illinois, Minnesota, Missouri, and Wisconsin.

The following table lists background radionuclides that may be present in POTW sewage sludge and ash. All these radionuclides are from terrestrial sources, except Strontium-90 and Cesium-137, which are due to radioactive fallout from atmospheric testing of nuclear weapons.

Radionuclide	Type of Radiation	Half-life
Potassium-40	gamma	1.4 billion years
Rubidium-87	beta	52 billion years
Strontium-90	beta	28 years
Cesium-137	beta,gamma	30 years
Radon-222	alpha	4 days
Radium-226	alpha,gamma	1600 years
Radium-228	beta	6 years
Thorium-232	alpha	14 billion years
Uranium-238	alpha	4.5 billion years

5. What are the Sources of Radioactivity in Sludge Caused by Human Activity?

In addition to radioactivity from a natural origin or global fallout from weapons testing, a known source of radioactive materials in the influent to POTWs is from the disposal of radioactive materials enhanced by human activity or produced by humans. This radioactive material is discharged into the sanitary sewer system by licensed users of radioactive materials and other activities.

Laboratories and universities use radioactive materials (e.g. Carbon-14) in research, including the marking and detection of molecules in genetic research, the study of human and animal organ systems, and in the development of new drugs.

Radioactive materials may also be found in consumer products, such as smoke detectors (Americium-241), luminous watches, and tobacco products. It is estimated that the dose to an individual from consumer products is about 9 mrem/yr.

An individual also receives radiation exposure from medical procedures. In the practice of nuclear medicine, radioactive materials (e.g. Iodine-131, Phosphorus-32, and Strontium-90) are administered to patients for the diagnosis or treatment of illnesses such as cancer or Graves disease.

There are currently about 24,000 NRC and Agreement State licensees in the United States. About one third of these are NRC licensees, while the remainder are licensed by Agreement States. Licensees include utilities, nuclear fuel fabricators, universities, medical institutions, radioactive source manufacturers, and companies that use radioisotopes for industrial purposes.

About 50% of NRC's materials licensees use either sealed radioactive sources or small amounts of short-lived radioactive materials. Sealed sources do not pose a contamination problem unless the encapsulation is broken. Examples of facilities that do not discharge to the sanitary sewer because they use only sealed sources are well logging licensees, industrial radiography licensees, and nuclear power plants.

The remaining 50% of the NRC's materials licensees are conditionally authorized to dispose radioactive materials into the sewer system. For example, radioactive material is handled in "unsealed" forms in the nuclear fuel fabrication industry, in production of radiopharmaceutical medicines, and in research. The limits in quantities and concentrations NRC and the Agreement States allow to be discharged to the sanitary sewer are based on the dose limit that could be received by an individual member of the public, assuming certain conservative conditions in calculating the potential dose.

The following table lists types of NRC licensees that could dispose radioactive materials into the sewer system and isotopes previously found in POTW sewage or those that could be present. It should be noted that a broad scope licensee is usually authorized for any isotope with an atomic number from 1 to 83, which means that many more isotopes than those listed here could be found being disposed into the sanitary sewer, thus this table is not all inclusive.

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Type of NRC Licensee	Number of NRC Licensees That Have the Potential to Discharge (as of 11/1/96)	Typical Radionuclides That May be Found in POTWs
Academic (broad scope)	75	Carbon-14 Cobalt-60 Cesium-137 Hydrogen-3 Iodine-125/131 Iron-59 Manganese-54 Phosphorus-32 Sulphur-35
Medical (broad scope, nuclear pharmacies)	1936	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
Manufacturing and Distribution (broad scope, nuclear laundries, decontamination services)	259	Americium-241 Antimony-125 Cobalt-60 Cesium-134/137 Hydrogen-3 Manganese-54 Niobium-95 Phosphorus-32 Plutonium-238/239/240 Polonium-210 Strontium-89/90 Sulphur-35 Uranium-233/234/235/238 Zirconium-95

Research and Development (broad scope)	660	Carbon-14 Cesium-134 Hydrogen-3 Iodine-125/131 Phosphorus-32 Sulphur-35
Others (e.g. mills, uranium enrichment plants)	149	Plutonium-238/239/240 Radium-226 Thorium-228/232 Uranium-233/234/235/238

The half lives and types of radiation emitted by these radionuclides are listed in Appendix A.

6. How Could People be Exposed to Radioactivity in Sewage?

Workers at POTWs could be exposed to low levels of radioactive materials (and radiation emitted from the radioactive materials) in sludge and incinerator ash. The most exposed workers would likely be sludge process operators, workers at incinerator operations, and operators of heavy equipment loading sludge or ash for transport.

Many facilities dispose of their sewage sludge or ash offsite of the treatment facility, for example by land application or into a solid waste landfill. Land application of sewage sludge improves soil properties and serves as an organic fertilizer. The POTW worker, farmer or gardener would receive direct exposure to the applied sludge and consumers could be exposed by ingesting crops. Workers at a landfill, farmers, or gardeners could also be exposed by inhaling or ingesting the sludge in dust particles. Radioactivity could also migrate into the groundwater and be consumed with drinking water.

7. How do I Analyze the Radioactive Material in Sewage Sludge and Ash?

Under what circumstances would I sample? The decision to sample should be based on an assessment of the nature of industries discharging to the collection system. The NRC or the Agreement State can help you determine the licensees in your sewage collection system. Radioanalysis can be performed to understand the levels of naturally-occurring radioactivity or made part of the routine analyses for other pollutants. Examples are discussed in Appendix F.

Where do I sample? Collect samples of sewage sludge, ash, or other sludge products produced at your facility. Collect the samples as close as possible to the point where the material leaves the POTW. Examples of sampling locations could be a digester, filter press or drying bed, lagoon or storage pile.

Who analyzes the samples? It is generally necessary to send the samples to a laboratory for analysis because POTWs do not have the equipment or training necessary to perform analyses of radioactive materials. Laboratories that perform such tests can be found in the American Society of Testing and Materials Catalog of Laboratories or in the Yellow Pages of a telephone directory. Professional organizations such as the Water Environment Federation, American Water Works Association, or the Health Physics Society will have listings of laboratories, and may have suggestions; or call your State agency for radiation control for suggestions.

How do I sample? Samples can be collected by the POTW operator. Call the laboratory first to discuss the types of analyses, confirm sample volumes needed and types of containers, and discuss quality control procedures. The laboratory may supply some of the sample materials. The amount of sample collected will depend on the solid content of the material and the type of analysis. Among the equipment and supplies needed to collect samples are plastic jugs, trowels, scoops and Chain-of-Custody forms.

Sample collection procedures are discussed in the 1989 EPA report "POTW Sludge Sampling and Analysis Guidance Document." If a sample is well-mixed, then a representative sample can be easily obtained. If a sample is not well-mixed, then incremental aliquots (small grab samples of equal volume) must be collected and composited, to obtain a representative sample. For example, the sample might be collected from a digester, filter press or drying bed, truck, tank, or pile. A liquid or slurry sample from a digester or tank should be from an outlet stream. The outlet or sample port should be opened and allowed to flow until a representative sample is available. If a sample of the total stream cannot be collected, then the stream should be cut across for equal time periods until the sample container is full. A sample collected from a filter press should be a composite of several small samples collected at different locations across the press or within the filter cake. A sample collected from a drying bed, truck, or pile should be scoops from various areas and levels of the drying bed, truck or pile. A sample of incinerator ash should be from the location where it is collected or stored. The collection date and time should be close to the date that the sludge or ash leaves the plant for transport to a landfill or for land application.

How do I ship the samples to the laboratory? The following are general instructions. If you have any questions or need assistance, contact the laboratory performing the analysis.

Ensure that the samples are properly labeled with the name of the facility, location or source of the sample, the name of the person taking the sample, and the sample date and time. Complete a Chain-of-Custody form with the name of the facility, location or source of the sample, the name of the person taking the sample, and the sample date and time. Place the samples in the shipping container. The person taking the sample should sign the completed Chain-of-Custody form and enclose the form with the samples. Seal the shipping container and place the security seal across the top of the container, and attach the appropriate shipping labels. Send the samples to the laboratory as quickly as possible (e.g. overnight delivery) after collection. This will eliminate the need for refrigeration of the samples.

What analyses should I request? At a minimum, the laboratory should perform gamma spec analysis and gross alpha/beta analysis. Consider the licensees in the collection system before deciding on any additional alpha- or beta-emitting radionuclide analysis. Typical radionuclides from various types of NRC licensees are listed in Section 5 and Appendix A. For example, Americium-241, an alpha and gamma emitter, could be discharged by a smoke detector manufacturer. Tritium, a beta emitter, is used in manufacturing luminous signs. Phosphorus-32 and Strontium-90, both beta emitters, are medical isotopes.

What will the analysis cost? The cost will depend on the type of analysis that is requested. The more detailed or complicated the analysis, the more expensive and time demanding the analysis becomes. For instance, gamma analysis of samples is relatively easy, as well as gross alpha and beta radiation counting. But alpha and beta energy analysis to identify specific radionuclides can be time consuming and expensive. Gamma spec analysis for one sample should cost several hundred dollars, gross alpha/beta analysis several hundred dollars, and radiochemical analysis for alpha and beta emitters from several hundred to several thousand dollars, depending on the radionuclides analyzed.

8. How Do I Evaluate the Results?

NOTE: NRC and EPA do not currently have regulations addressing radioactive materials in sludge products at POTWs. NRC and EPA are developing the following table to describe concentrations of radioactive materials in sludge or ash. These estimated concentrations will be based on dose modeling calculations which assume how individuals could be exposed to these radioactive materials. These models, for example, assume that an individual spends __% of the year on site and __ hours a day outside. So far, a dose level has not been chosen for the calculations. We welcome any comments on the need for this table and the appropriate dose level for the calculations. In the interim, the table will be developed for factors to convert concentration to dose or risk.

Concentration to Dose (or Risk) Conversion Factors
for Radioactive Materials in Sewage Sludge and Ash
(UNDER DEVELOPMENT)

Radionuclide	Dose (or risk) per pCi/g of Sludge Concentration	Dose (or risk) per pCi/g of Ash Concentration
Americium-241		
Cesium-137, etc.		

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If radioactive material exceeding these values is detected at a POTW that is located in an Agreement State, contact the appropriate State regulatory authority (Appendices B and E). If the POTW is located in a non-Agreement State, contact the NRC regional office (Appendix C). The appropriate regulatory authority will help you trace the origin of the radioactive material. For example, the NRC or the Agreement State can help you determine the licensees in your sewage collection system if you provide a list of zip codes in your collection system. If measured levels of radioactivity exceed the above levels, it may be necessary to further restrict discharges of wastes to the sewer system by a specific licensee, alter operations at the treatment works, or limit certain sludge/ash use/disposal practices.

9. Comments or Questions on this Guidance?

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

U.S. Nuclear Regulatory Commission
Low-Level Waste and Decommissioning Projects Branch
(301) 415-7234 or contact through NRC's operator on the toll-free telephone number 800-368-5642.

or

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Office of Wastewater Management
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Appendices

A. Fundamentals of Radiation

B. NRC and EPA Regional Offices by State and Identification of Agreement States

C. NRC Regional Offices

D. EPA Regional Offices

E. State Agencies for Radiation Control

F. Examples of POTWs that have Radionuclide Materials Programs

G. Bibliography and Sources of Additional Information

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APPENDIX A

FUNDAMENTALS OF RADIATION

What is Radiation?

People are subjected to natural radiation from outer space, from naturally-occurring radioactive materials in soils, in the food and water we consume, and in the buildings where we live and work. The term "radiation" as it relates to radioactive material describes the energy given off by the material as it decays. Ionizing radiation produces charged particles, or ions, in the material in which it encounters. 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. Uranium, thorium and radium emit alpha radiation and so they are called "alpha emitters." The alpha particle has the least penetrability. Most alpha particles can be stopped by a single sheet of paper or skin. Consequently, the principle hazard from alpha emitters to humans is caused 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 the naturally-occurring radionuclides radon, radium, thorium and uranium.

- Beta radiation - negatively charged particles 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.

- 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. Potassium-40, a common naturally-occurring radionuclide, is also a gamma emitter.

Some radionuclides emit more than one type of radiation. For example, Cesium-137 and Iodine-131 are both gamma and beta emitters.

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 radioactive material to decrease by half is called the *radioactive half-life*. After one half-life, the remaining activity would be one-half (1/2) 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 1/2 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, Iodine-131, used in medical procedures, has a half-life of 8 days. 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.

Some radioactive materials decay to form other radioactive materials. These so-called decay products, in turn, decay to stable nuclides or other radioactive materials. 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 at POTWs, the radioactive materials present may consist of one or more separate decay "chains" or "series." The naturally-occurring uranium and thorium decay chains are summarized in the following table.

Series: Uranium	Thorium
Uranium-238	Thorium-232
↓	↓
Uranium-234	Radium-228
↓	↓
Thorium-230	Thorium-228
↓	↓
Radium-226	Radium-224
↓	↓
Radon-222	Radon-220
↓	↓
Lead-210	Lead (Stable)
↓	
Lead (Stable)	

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 the 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). "CPM" refers to the number of ionizing particles striking the detector surface in a minute. A fraction of these particles are recorded by the detector as counts. The number of counts per minute can then 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 is one-millionth of a rem (1/1,000,000). 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 microrem/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?

When radiation interacts in and through living tissue, it may damage some cells in the body. Some cells may not survive the damage and die while other cells will survive the damage and reproduce normally. Other damaged cells may survive, but in a modified form, which may later result in cancer. Other health 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 can 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 less 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 produced by other sources, such as harmful chemicals in the environment. Therefore, in estimating the consequences of any exposure to radiation, it is assumed that the risk of developing cancer is linearly proportional to dose and that there is no threshold below which there is no chance of cancer. This chance, or risk, is expressed in terms of *probability* of an adverse health effect because a given dose of radiation does not produce a cancer in all cases. The NRC uses the linear assumption and the philosophy that radiation exposure should be kept as low as reasonably achievable (ALARA) for purposes of regulating the use of radioactive materials.

What are the types of radiation and half-lifes for the radionuclides that are caused by human activities and may be present at POTWs?

Radionuclide	Type of Radiation	Half-life
Americium-241	alpha, gamma	458 years
Antimony-125	gamma	3 years
Beryllium-7	gamma	53 days
Carbon-14	beta	5730 years
Cesium-134 Cesium-137	beta, gamma beta, gamma	2 years 30 years
Chromium-51	gamma	28 days
Cobalt-57 Cobalt-60	gamma beta, gamma	271 days 5 years
Gallium-67	gamma	3 days
Hydrogen-3 (tritium)	beta	12 years
Indium-111	gamma	3 days

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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	gamma	45 days
Lead-210	alpha, beta, gamma	22 years
Manganese-54	gamma	303 days
Niobium-95	beta, gamma	35 days
Phosphorus-32 Phosphorus-33	beta beta	14 days 25 days
Plutonium-238 Plutonium-239 Plutonium-240	alpha alpha alpha	86 years 24,400 years 6580 years
Polonium-210	alpha	138 days
Radium-226	alpha, gamma	1600 years
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	gamma	3 days
Thorium-228 Thorium-232	alpha, gamma alpha	2 years 14 billion years
Uranium-233 Uranium-234 Uranium-235 Uranium-238	alpha, gamma alpha alpha alpha	162,000 years 247,000 years 710 million years 4.5 billion years
Xenon-133	beta, gamma	5 days
Zinc-65	beta, gamma	245 days
Zirconium-95	beta, gamma	64 days

What are the Standards for Protection of Human Health from Exposure to Hazards such as Ionizing Radiation and Radioactivity in Sewage Sludge?

EPA standards and criteria pertinent to setting standards or guidance for levels of radioactivity in sewage sludge might include:

Standard or Guideline	Type	Year	Limit (dose or risk)
Standards for the Use or Disposal of Sewage Sludge (does not include radionuclides)	Regulation (40 C.F.R.503)	1993	Concentration of carcinogens at 1 x 10^{-4} risk and risk reference doses for metals
Radiation Site Cleanup	Draft regulation (40 C.F.R. 196)	1994	15 mrem/year and protection of ground water to Safe Drinking Water Act Maximum Contaminant Levels (MCLs)
Uranium Mill Tailings	Regulation (40 C.F.R. 192)	1983	Concentration-based criteria for land, buildings, and ground water, e.g., 5 pCi/g of radium-226 over the first 15 cm of soil averaged over 100 square meters
Resource Conservation and Recovery Act (RCRA) - Corrective Action for Releases From Solid Waste Management Units at Hazardous Waste Management Facilities	Advance Notice of Proposed regulation (40 C.F.R 264, Subpart S)	1996	10^{-4} to 10^{-6} risk range and protection of ground water to MCLs
Management and Disposal of Spent Fuel, High Level, and Transuranic Waste	Regulation (40 C.F.R. 191, subpart A-management)	1985	NRC regulated facilities: 25 mrem/yr whole body or critical organ; 75 thyroid; DOE regulated facilities: 25 whole body, 75 critical organ
National Oil and Hazardous Substances Pollution Contingency Plan (Superfund)	Regulation (40 CFR 300)	1990	10^{-4} to 10^{-6} risk range, protection of ground water to MCLs
Certification Criteria for WIPP Compliance With 40 CFR Part 191	Final regulation (40 C.F.R. 194)	1996	15 mrem/yr and MCLs

Standard or Guideline	Type	Year	Limit (dose or risk)
Radiation Protection Guidance to Federal Agencies for Occupational Exposure	Final guidance	1967	As low as reasonably achievable (ALARA) and not to exceed 5 rems in any year by an adult worker. Also includes guidance to not exceed 0.5 rem to an unborn worker's child or not exceed one-tenth of the adult value for individuals under eighteen years old
Federal Radiation Protection Guidance for Exposure of the General Public	Proposed guidance	1994	No exposure to the public unless it is justified by an expected overall benefit from activity causing exposure; dose to individuals as low as reasonably achievable (ALARA); 100 mrem/yr from all sources covered by guidance combined; standards or regulations at a fraction of 100 for individual sources
Management and Disposal of Spent Fuel, High-Level, and Transuranic Waste	Regulation (40 C.F.R. 191, Subpart B-disposal)	1993	15 mrem/yr and MCLs
National Emission Standards for Hazardous Air Pollutants; Radionuclides	Regulation (40 C.F.R. 61, Subparts H and I)	1989	10 mrem/yr
Uranium Fuel Cycle	Regulation (40 C.F.R. 190)	1977	25 mrem/yr whole body or critical organ; 75 thyroid
Drinking Water MCLs - Beta/photon emitters	Regulation (40 C.F.R. 141)	1976	4 mrem/yr
Drinking Water MCLs - Alpha emitters	Regulation (40 C.F.R. 141)	1976	15 pCi/l

Standard or Guideline	Type	Year	Limit (dose or risk)
Drinking Water MCLs - Radium	Regulation (40 C.F.R. 141,	1976	5 pCi/l

The basic radiation protection standards formulated by the NRC for radionuclide users are published in the Code of Federal Regulations (CFR), Title 10, Part 20. These standards were prepared from the recommendations of advisory boards such as the National Council on Radiation Protection and Measurements (NCRP, 1971, Report 39) and the International Committee on Radiological Protection. The requirements for disposal of radioactive materials into the sanitary sewer are in 10 CFR 20.2003.

Radiation protection standards applicable to DOE facilities are found in the following regulations and internal DOE Orders:

10 CFR Part 834 - Radiation Protection of the Public and the Environment (to be issued soon)

10 CFR Part 835 - Occupational Radiation Protection

Order DOE 5400.1 - General Environmental Protection Program

Order DOE 5400.5 - Radiation Protection of the Public and the Environment

Order DOE 5820.2A - Radioactive Waste Management

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APPENDIX B

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

State *	NRC Regional Office	EPA Regional Office
ALABAMA*	II	4
ALASKA	IV	10
ARIZONA*	IV	9
ARKANSAS*	IV	6
CALIFORNIA*	IV	9
COLORADO*	IV	8
CONNECTICUT	I	1
DELAWARE	I	3
DST OF COLUMBIA	I	3
FLORIDA*	II	4
GEORGIA*	II	4
HAWAII	IV	9
IDAHO	IV	10
ILLINOIS*	III	5
INDIANA	III	5
IOWA*	III	7
KANSAS*	IV	7
KENTUCKY*	II	4
LOUISIANA*	IV	6
MAINE*	I	1
MARYLAND*	I	3
MASSACHUSETTS*	I	1
MICHIGAN	III	5
MINNESOTA	III	5
MISSISSIPPI*	II	4
MISSOURI	III	7
MONTANA	IV	8
NEBRASKA*	IV	7
NEVADA*	IV	9
NEW HAMPSHIRE*	I	1
NEW JERSEY	I	2
NEW MEXICO*	IV	6
NEW YORK*	I	2
NORTH CAROLINA*	II	4
NORTH DAKOTA*	IV	8
OHIO	III	5
OKLAHOMA	IV	6
OREGON*	IV	10
PENNSYLVANIA	I	3
RHODE ISLAND*	I	1
SOUTH CAROLINA*	II	4
SOUTH DAKOTA	IV	8
TENNESSEE*	II	4
TEXAS*	IV	6

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State *	NRC Regional Office	EPA Regional Office
UTAH*	IV	8
VERMONT	I	1
VIRGINIA	II	3
WASHINGTON*	IV	10
WEST VIRGINIA	II	3
WISCONSIN	III	5
WYOMING	IV	8
CANAL ZONE	II	
PUERTO RICO	II	2
VIRGIN ISLANDS	II	2
GUAM	IV	9
AMERICAN SAMOA	IV	9

* indicates Agreement State as of 3/31/97

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APPENDIX C

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Region III 801 Warrenville Road Lisle, IL 60532-4351	(630) 829-9800	(630) 829-9818
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APPENDIX D

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APPENDIX F

EXAMPLES OF POTWS THAT HAVE RADIONUCLIDE MATERIALS PROGRAMS

Albuquerque, New Mexico

The City of Albuquerque has established a Radioactive Discharge Monitoring Program (RDMP). This is 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 has implemented 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 are issued and monitoring of the dischargers is 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 includes an initial walk-through to familiarize the RDMP staff with the nature of the operation and potential opportunities for waste minimization.

The POTW negotiated 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 also works 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 are 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 radioisotopes found in the sewage have been of medical origin. Gamma radiation detectors installed at the plant have indicated that no measurable radiation exposure is being received by plant workers.

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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.

APPENDIX G

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Summary of dose limits & target populations

Dose or Dose Limit	Regulatory Basis	Target Population	Reference
500 rem	ICRP & NCRP Recommendation	Max equivalent dose to the skin of an occupational workers for emergency life-saving efforts	NCRP #116 (p. 44)
400 rem	NCRP Recommendation	Career Male astronaut whole body dose equivalent limit[1]	NCRP #98 (p. 7)
300 rem	NCRP Recommendation	Career Female astronaut whole body dose equivalent limit[1]	NCRP #98 (p. 7)
300 rem	10 CFR 100	Max total radiation dose for a 2 hour period to the thyroid from a postulated fission product release if an individual were present at any point of a nuclear reactor's exclusion area boundary	10 CFR 100.11(a)(1)
250 rem	NCRP Recommendation	Theoretical occupational Lifetime dose	NCRP #98 (p. 7)
100 rem	NCRP Recommendation	Whole body dose for life-saving actions (valid until 1986)	NCRP #39[2] (p. 100)
50 rem	ICRP & NCRP Recommendation	Max effective dose to an occupational worker for emergency life-saving efforts	NCRP #116 ICRP 60
50 rem	10 CFR 20	Annual organ or tissue dose other than lens of the eye; Shallow dose equivalent to the skin or any extremity	10 CFR 20.1201
>25 rem	EPA Protective Action Guides	Voluntary Whole body dose for life-saving actions & protection of large populations	EPA-400-R-92-001 (May 1992)
25 rem	10 CFR 100	Max total radiation dose for a 2 hour period to the whole body from a postulated fission product release if an individual were present at any point of a nuclear reactor's exclusion area boundary	10 CFR 100.11(a)(1)
25 rem	EPA Protective Action Guides & USNRC RG 8.29	Whole body dose for life-saving actions & protection of large populations	EPA-400-R-92-001 (May 1992); RG 8.29 (p.13)
25 rem	10 CFR 20 & 10 CFR 835	Lifetime dose limit for individuals participating in planned special exposures	10 CFR 20.1206(e)(2) & 10 CFR 835.204

[1] Career whole body dose equivalent limit at age 55 based on a lifetime excess risk of cancer mortality of 3×10^{-4} per rad.

[2] NCRP Report No. 39 (1971) has been superseded by NCRP report No. 116 (1993)

Dose or Dose Limit	Regulatory Basis	Target Population	Reference
18.75 rem	29 CFR 1910	Max quarterly dose for hands and forearms; feet and ankles (OSHA-regulated activities)[3]	29 CFR 1910.96 (b)
15 rem	10 CFR 20	Annual eye dose equivalent (lens of the eye)	10 CFR 20.1201
10 rem	USNRC RG 8.29	Acute emergency exposure for protecting valuable property	RG 8.29 (1996) (p. 8.29-13)
10 rem	NCRP Recommendation	Acute emergency exposure for life-saving actions	NRCP # 91 (p. 36)
7.5 rem	29 CFR 1910	Max quarterly dose to skin of whole body of occupational workers (OSHA-regulated activities)	29 CFR 1910.96 (b)
5 rem	10 CFR 20 & 10 CFR 835	Annual Exposure Limit for Occupational Workers (NRC, DOE & States)	10 CFR 20.1201 & 10 CFR 835.202
5 rem	10 CFR 72	Max whole body dose to any individual located on or beyond the nearest boundary of the controlled area of an ISFSI or MRS[4]	10 CFR 72.106
5 rem	10 CFR 35	Notification limits for medical misadministrations involving members of the public	60 FR 48623 (Oct 1995)
3 rem	29 CFR 1910	Max quarterly dose to the whole body (OSHA-regulated activities)	29 CFR 1910.96
2 rem	EPA	Remedial annual action level for naturally occurring radiation (radon) for members of the public (corresponds to 2 WLM[5])	NCRP #116 (p. 49)
1.875 rem	OSHA	Max quarterly hand or forearm dose to a minor (under age 18)	29 CFR 1910.96(b)(3)
1.5 rem	IAEA Recommendation	Threshold for conducting environmental monitoring and assessments of radiation exposure levels in work areas due to the transport of radioactive material	IAEA Safety Series #6 (1985)
1.25 rem	49 CFR 172	Max quarterly EDE for occupational radiation exposure resulting from transportation activities	49 CFR 172.803 (b)(1)
1 rem	—	Avg astronaut Exposure per Flight Mission	NCRP #94

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[3] OSHA-Regulated activities include occupational exposure from facilities other than those regulated by NRC or an agreement state. These may include radiation exposures from x-rays or linear accelerators operated by non-agreement states.

[4] ISFSI = Independent Spent Fuel Storage installation; MRS = Monitored retrievable storage installation

[5] One working level month (WLM) is approximately equal to an annual exposure to an average of 4 pCi per liter of radon if the radon products are in 50% equilibrium with the radon. One WLM exposure would result from being exposed to 1 working level (WL) for a period of 1 working month (i.e. 170 hrs)

Dose or Dose Limit	Regulatory Basis	Target Population	Reference
1 rem	EPA	EPA public protection action guide limit for evacuation & shelter	EPA 400-R-92-001 (pp. 2-6)
750 mrem	OSHA	Max quarterly skin of whole body dose to a minor (under age 18)	29 CFR 1910.96(b)(3)
650 mrem	—	Avg EDE[6] per diagnostic Nuclear brain scan	NCRP #93 (p 46)
540 mrem	10 CFR 20[7]	Avg annual measurable dose per radiographer (1993)[8]	NUREG-0713 Vol 15 (p. 4-6)
500 mrem	10 CFR 35	Proposed patient release criteria	SECY-96-100 & NUREG-1492
500 mrem	10 CFR 20, 10 CFR 835 & 49 CFR 172	Max dose equivalent limit to the embryo/fetus (entire gestation period)	10 CFR 20.1208, 10 CFR 835.206 & 49 CFR 172.803 (b)(3)
500 mrem	ANSI, Non-agreement State regs	Design criteria for shielding for radiation-producing machines (i.e., teletherapy, x-ray machines, irradiators)	ANSI N433.1 & NCRP #49
500 mrem	NCRP Recommendation	Max annual effective dose limit for infrequent annual exposures to members of the public	NCRP #116 (p. 46)
500 mrem	NCRP Recommendation	remedial annual action limit recommended for continuous exposures from natural sources (excluding radon)	NCRP #116 (p. 50)
500 mrem	49 CFR 172 & EPA FRC Guidance[9]	Max annual radiation exposure to members of the general public from transporting radioactive material	49 CFR 172.803 (b)(2) IAEA Safety Series #6
360 mrem	—	Annual TEDE for public (including annual medical exposure)	NCRP #101 (p. 73)
300 mrem	—	Annual TEDE for public (Excluding annual medical exposure)	NCRP #94

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6 EDE = Effective dose equivalent

7 Resultant Average dose from the application of regulatory requirements in 10 CFR Part 20 (i.e., ALARA)

8 Number of radiographers monitored for radiation exposure in 1993 was 4720.

9 EPA's Federal Radiation Council (FRC) guidance was issued in 1960. EPA is currently developing guidance for regulatory agencies for limiting radiation exposures to members of the general public, and the anticipated annual limit is expected to be 100 mrem/yr. however, as of 1996, this new EPA guidance document has not been issued.

Dose or Dose Limit	Regulatory Basis	Target Population	Reference
270 mrem	10 CFR 20[10]	Avg annual measurable occupational dose per worker at LWRs (1993)[11]	10 CFR 20.1201
200 mrem	—	Avg annual dose to members of the public from radon	NCRP #93, #116 (p. 59; 45)
160 mrem	OSHA	Avg annual dose equivalent to Airplane Crew Members	NCRP #94 (p. 22)
125 mrem	OSHA	Max quarterly whole body dose to a minor (under age 18)	29 CFR 1910.96(b)(3)
100 mrem	10 CFR 20 & 10 CFR 835	Max annual Dose limits for members of the public	10 CFR 20.1301 & 10 CFR 835.208
100 mrem	IAEA B.S.S.[12]	Max annual dose equivalent for non-radiation workers (& shielding design specifications)	IAEA Safety Series 115-I
100 mR/wk	49 CFR 172	Max weekly radiation exposure to members of the public from transportation of radioactive material	49 CFR 172.803 (b)(2)
85 mrem	Proposed 40 CFR 196	Max dose "cap" to an individual for restricted use (EPA's proposed decommissioning std)	SECY-96-082 & Proposed 40 CFR 196.11 (d)(2)
75 mrem	10 CFR 72	Max annual dose equivalent to the thyroid of any real individual located beyond the controlled area resulting from radioactive materials in effluents and direct radiation from an ISFSI or MRS	10 CFR 72.104
50 mrem	10 CFR 20 App B, Tbl 2	Annual TEDE to members of the public resulting from the inhalation or ingestion of radionuclides continuously for a year	Part 20
50 mrem	29 CFR 1910	Max TEDE from inhalation or ingestion to a minor (under age 18) (Refs to 10 CFR 20)	29 CFR 1910.96(c)(2)
25 mrem	10 CFR 20	Licensees (i.e., fuel cycle facilities) subject to EPA's generally applicable environmental radiation standards in 40 CFR 190	10 CFR 20.1301(d) & 40 CFR 190.10
25 mrem	10 CFR 40, App A	Max annual public dose equivalent cannot exceed 25 mrem whole body, 75 mrem thyroid, and 25 mrem to any other organ as a result of exposure to planned discharges of radioactive materials, Rn-220 and its daughters excepted to environment.	10 CFR Part 40, Criterion 8

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10 Resultant average dose in 1993 from the application of regulatory requirements in 10 CFR Part 20 (i.e., ALARA)

11 Total number of commercial LWR workers monitored for radiation exposure in 1993 was 169,862. NUREG-0713, Vol 15, p 4-6.

12 IAEA B.S.S. = International Basic safety standards for protection against ionizing radiation and for the safety of radiation sources, Safety Series No. 115-I (1994).

Dose or Dose Limit	Regulatory Basis	Target Population	Reference
25 mrem	10 CFR 61	Max offsite releases to any member of the public for both operations and post-closure are limited to 25 mrem whole body, 75 mrem thyroid, & 25 mrem other organ	10 CFR 61.41
25 mrem	10 CFR 72	Max annual dose equivalent to the whole body or other organ of any real individual located beyond the controlled area resulting from radioactive materials in effluents and direct radiation from an ISFSI or MRS	10 CFR 72.104
25 mrem	40 CFR 190	Annual dose equivalent shall not exceed 25 mrem whole body, 75 mrem thyroid, & 25 mrem other organ as the result of planned discharges from uranium fuel cycle operations to the environment	40 CFR 190.10
25 mrem	NCRP Recommendation	Max annual exposure to members of the public from a single source or set of sources under one control	NCRP #116 (p. 47)
20 mrem	—	Max individual public exposure due to transportation of radioactive material	NCRP #92 (p. 165)
20 mrad	10 CFR Part 50 Appendix I	Max annual beta air dose from gaseous effluents at any location near ground level from each LWR for any individual occupying an unrestricted area	10 CFR 50, App I Section II (B.1.)
15 mrem	Proposed 40 CFR 196	Annual EDE from all exposure pathways from a decommissioning site	40 CFR 196.11
15 mrem	10 CFR Part 50 Appendix I	Max annual organ dose or dose commitment from radioactive iodine or RAM in particulate form from effluents release from each LWR for any individual occupying an unrestricted area	10 CFR 50, App I, Section II (C.)
10 mrem	—	Avg annual effective dose equivalent to individuals in the U.S. from consumer products	NCRP #93 (p. 59)
10 mrad	10 CFR Part 50 Appendix I	Max annual gamma air dose from gaseous effluents at any location near ground level from each LWR for any individual occupying an unrestricted area	10 CFR 50, App I Section II (A)
10 mrem	EPA's clean air act	Max dose limit to members of the public from radioactive air effluents resulting from facilities regulated under this subpart	40 CFR Part 61, Subpart I
10 mrem	10 CFR Part 50 Appendix I	Max annual organ dose or dose commitment from liquid effluents from each LWR for any individual in an unrestricted area	10 CFR 50, App I Section II (A)

Dose or Dose Limit	Regulatory Basis	Target Population	Reference
4 mrem	Proposed 40 CFR 196	Max annual dose to any internal organ or the total body[13] corresponding to individual MCLs specified in 40 CFR 141 for protection of groundwater at a remediated site	40 CFR 196.23 (1) (See also 40 CFR 141.16)
3 mrem	10 CFR Part 50 Appendix I	Max annual total body dose or dose commitment from liquid effluents from each LWR for any individual in an unrestricted area	10 CFR 50, App I Section II (A)
2 mrem in any one hr	10 CFR 20	Max Dose Limit to members of the public in an unrestricted area from external sources[14]	10 CFR 20.1301 (a)(2)
2 mR/hr	10 CFR 71	Max external radiation level for packages in any normally occupied space (i.e., location of driver transporting radioactive material)	10 CFR 71.47 (b)(4)
2 mR/hr	49 CFR 172	Max radiation exposure to members of the general public from transportation of radioactive material	49 CFR 172.803 (b)(2)
1 mrem	IAEA Safety Series	Max annual individual dose equivalent per source or practice within the range of risks to be considered "Trivial." Also called "negligible individual dose (NID)"	IAEA Safety Series 89; IAEA-TECDOC-855 & NCRP #116 (p. 5)

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[13] The 4 mrem/yr groundwater standard is derived from the average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water which would produce an annual dose equivalent of 4 mrem to the total body or any internal organ (see 40 CFR 141.16). NBS Handbook 69 (Aug 1963) is used as the basis for deriving these quantities, and each vary from the 4 mrem standard (For example., the MCL for Sr-90 = 0.07 mrem/yr; the MCL for uranium = 0.7 mrem/yr).

[14] In the statements of consideration for the revised 10 CFR Part 20 (see 56 FR 23374), the reason stated for the inclusion of the dose rate limit of 2 mrem in any one hour was that the limit "provides a more readily measurable quantity than the 100 mrem/yr value and can be more easily verified by short-term measurements."

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29 CFR Part 1910 (OSHA Regulations)

40 CFR Part 61 (EPA Regulations)

40 CFR Part 190 (EPA Regulations)

40 CFR Part 196 (EPA Regulations)

49 CFR Part 172 (DOT Regulations)