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Final Report

ISCORS Assessment of Radioactivity in Sewage Sludge: Radiological Survey Results and Analysis

ISCORS Technical Report 2003-02

ISCORS Assessment of Radioactivity in Sewage Sludge: Radiological Survey Results and Analysis

Developed by the Sewage Sludge Subcommittee on Radiation Standards

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ABSTRACT

From 1998 to 2000, through the Interagency Steering Committee on Radiation Standards (ISCORS), the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA) conducted a joint survey (hereafter referred to as the ISCORS sewer survey) to collect information on radioactivity in sewage sludge and ash from sewage treatment plants referred to in the industry as publicly owned treatment works (POTWs).

The objectives of the survey were to (1) obtain national estimates of high-probability occurrences of elevated levels of radioactive materials in sludge and ash at POTWs, (2) estimate how much radioactive contamination comes from NRC and Agreement State licensees and how much from naturally occurring radioactivity, and (3) support rulemaking decisions by NRC and EPA.

The voluntary survey had two components: a questionnaire and a program for sampling and analyzing sewage sludge and incinerator ash. Questionnaires were sent to 631 POTWs, requesting information regarding wastewater sources, wastewater and sludge treatment processes, and sewage sludge disposal practices. Using the information from the 420 returned questionnaires, NRC and EPA selected 313 POTWs to be sampled. The selection emphasized POTWs with the greatest potential to receive waste from licensees and in areas with higher levels of naturally occurring radioactive material (NORM). Altogether 311 sewage sludge samples and 35 ash samples were taken. Approximately half of the samples were analyzed by the U.S. Department of Energy's Oak Ridge Institute for Science and Education (ORISE) in Oak Ridge, Tennessee, under contract to NRC, and the remainder were analyzed by the EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama.

The results of the analyses revealed that samples primarily contained NORM such as radium. With the exception of NORM, most other samples were at or near the limit of detection. Based on the results obtained, ISCORS found that the levels are generally comparable to what is found in other media (e.g. soil and fertilizer). The specific results of the analyses and data obtained by the questionnaire are discussed in detail in this report.

The survey and the sampling and analysis program results respond, in part, to the recommendations of the 1994 GAO report (GAO/RCED-94-133) that the NRC estimate the occurrence of elevated levels of radioactive materials at POTWs. The Subcommittee is preparing several supplemental reports (both to be published in final form after public review and comment). The first is a dose assessment report that describes exposure scenarios for sewage sludge processing, use, and disposal. The parameters used in the dose modeling for the scenarios and the dose conversion factors calculated for each radionuclide detected are included. A second report provides recommendations for POTW operators on determining sources of radioactivity at POTWs, describe sampling and analysis procedures, and suggest alternative courses of action if circumstances (e.g. location in a high NORM area) or actual measurements indicate that a problem may exist. The reports and laboratory data used in the sewage sludge analyses can be publicly accessed at http://www.iscors.org/.

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FOREWORD

This report is prepared in response to a May 1994 U.S. General Accounting Office (GAO) report, "Nuclear Regulation: Action Needed to Control Radioactive Contamination at Sewage Treatment Plants" (GAO/RCED-94-133), and Congressional interest expressed in joint House/Senate hearings. Through the Interagency Steering Committee on Radiation Standards (ISCORS)*, the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA) conducted a survey of radioactivity in sewage sludge and ash from publicly owned treatment works (POTWs) to determine whether the public's health and safety and the environment are being adequately protected. The objectives of the survey were to (1) obtain national estimates of high-probability occurrences of elevated levels of radioactive materials in sludge and ash at POTWs, (2) estimate the extent to which radioactive contamination comes from either NRC/Agreement State licensees or naturally occurring radioactivity, and (3) support rulemaking decisions by NRC and EPA.

The sewage sludge/ash survey was coordinated by a subcommittee of ISCORS. The Sewage Sludge Subcommittee was formed in 1995 to coordinate efforts to address the recommendations of the 1994 GAO report.

This report summarizes the information collected in the survey and developed through the analysis of samples. It also presents the sampling results in a series of tables broken down with respect to the characteristics of classes of POTWs that participated in the survey. Companion reports address the significance of the measured values of radionuclides present in sewage sludge and ash and provide recommendations for POTW operators on how to deal with any potential future problems.

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*ISCORS was formed in 1994 to address inconsistencies, gaps, and overlaps in current radiation protection standards. ISCORS is co-chaired by representatives of the NRC and the EPA, and includes representation by 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, the Office of Science and Technology Policy, and various State and local regulatory agencies are observers at ISCORS meetings.

ACKNOWLEDGMENTS

The Sewage Sludge Subcommittee of the federal ISCORS (1) conducted a survey to collect information concerning radioactive materials in sewage sludge and ash from POTWs; (2) performed dose modeling to help with the interpretation of the results of the survey; and (3) developed a guidance on radioactive materials in sewage sludge and ash for POTW owners and operators. Sewage Sludge Subcommittee members who actively participated in the development of the three reports associated with this project include (listed alphabetically):

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ABBREVIATIONS

Am-241	americium-241
AMSA	Association of Metropolitan Sewerage Agencies
Be-7	beryllium-7
Bi-212/214	bismuth-212/214
Bq	becquerel
C-14	carbon-14
Ce-141	cerium-141
Ci	curie
CFR	*Code of Federal Regulations*
Co-57/60	cobalt-57/60
Cr-51	chromium-51
Cs-137	cesium-137
CWNS	Clean Water Needs Survey
EHA	Environmental Health Associates
EPA	U.S. Environmental Protection Agency
Eu-154	europium-154
Fe-59	iron-59
FR	*Federal Register*
GAO	General Accounting Office
GBq	gigabecquerel
ISCORS	Interagency Steering Committee on Radiation Standards
ICR	information collection request
H-3	hydrogen-3 (tritium)
I-125/131	iodine-125/131
In-111	indium-111
K-40	potassium-40
kg	kilogram
La-138	lanthanum-138
MDC	minimum detectable concentration
MGD	million gallons per day
NAREL	National Air and Radiation Environmental Laboratory
NCRP	National Council on Radiation Protection
ND	not detected
NORM	Naturally Occurring Radioactive Material
NPDES	National Pollution Discharge Elimination System
NR	not reported
NRC	U.S. Nuclear Regulatory Commission
NSSS	National Sewage Sludge Survey
OMB	U.S. Office of Management and Budget
ORIA	Office of Radiation and Indoor Air
P	probability
Pa-234	protactinium-234
Pb-210/214	lead-210/214
PCS	Permit Compliance System
PE	Performance Evaluation

ABBREVIATIONS (con't)

pCi	picocurie
POTWs	publicly owned treatment works
QAPP	Quality Assur0ance Project Plan
Ra-228	radium-228
Sm-153	samarium-153
Sr-89	strontium-89
Th-227/228/230	thorium-227/230
Tl-201/208	thalium-201/208
U-234/235/238	uranium-234/235/2388
U.S.	United States
Pu-238/239	plutonium-238/239
Rn-219	radon-219
Sm-153	samarium-153
Sr-89/90	strontium-89/90
WEF	Water Environment Federation
Zn-65	zinc-65

1 INTRODUCTION

1.1 Congressional Interest

This survey responds, in part, to recommendations in the 1994 General Accounting Office (GAO) report, "Nuclear Regulation: Action Needed to Control Radioactive Contamination at Sewage Treatment Plants" (GAO/RCED-94-133). The GAO report recommended that NRC determine the extent to which radioactive contamination of sewage sludge, ash, and related byproducts from sewage treatment plants is occurring; directly notify the treatment plants that receive discharges from NRC's and the Agreement State's licensees of the potential for radioactive contamination because of the concentration of radioactive materials and of the possibility that the plants may need to test or monitor their sludge for radioactive content; and establish acceptable limits for radioactivity in sludge, ash, and related byproducts to protect the health and safety of treatment workers and the public.

A joint House/Senate hearing was held in 1994 to officially release and address questions raised in the GAO report. The hearing (U.S. Congress,1994) was prompted by concerns associated with elevated levels of radioactivity in incinerator ash at a major sewage treatment plant in the Cleveland, Ohio, area. The GAO stated that, over the past 20 years, NRC had documented elevated levels of radioactivity in sewage sludge or sludge incinerator ash from certain publicly owned treatment works (POTWs). There had been no national surveys of radiation levels present in sewage sludge or sludge incinerator ash to determine the extent of potential radioactive contamination.

On the basis of limited information on radiation levels in sewage sludge and ash across the country, GAO concluded that reconcentration of radionuclides may have been associated with authorized effluent releases from both NRC and Agreement State licensees (GAO documented this information and used it as a basis for its 1994 report). However, these problems occurred prior to revisions to NRC's regulations with regard to releases from NRC licensees which became effective in 1991.

1.2 POTW Industry Interest

In 1996, the Association of Metropolitan Sewerage Agencies (AMSA) conducted a limited, confidential, voluntary survey of concentrations of radioactivity in sewage sludge and ash samples from some of its member POTWs. The objective was to develop a better estimate of the concentration of radioactivity in sewage sludges and sludge incinerator ashes. Samples from 55 wastewater treatment plants in 17 States were supplied voluntarily and analyzed for radioactivity. These plants were distributed across the country and ranged in size from small to some of the largest POTWs in the U.S. The most significant levels of radioactivity were the potassium and radium isotopes, which are naturally occurring radioactive materials.

1.3 Sources of Radioactivity at POTWs

Radionuclides are found naturally throughout the United States in varying concentrations (Eisenbud and Gesell, 1997). Levels of naturally occurring radioactive materials (NORM) vary throughout the States in soil and water used for drinking and industrial processes. Sewage treatment facilities receive waste flows from residential, commercial, and industrial uses. NORM from industrial process and drinking water treatment residuals (e.g., filter backwash, ion exchange fluids) may be a source of radioactive material entering a POTW. Another possible source of radioactivity at a POTW is the authorized release of man-made radioactive materials into the sewer system by NRC and Agreement State licensees.[1] A major source of these releases is radioactive materials used for medical diagnosis and treatment. Patient excreta containing medical isotopes may contribute a significant fraction of the radioactive materials released to sewer systems, but the significance would vary by location and by the facilities and population served by the collection system. The removal and concentration of many contaminants into residual solids by various processes used by POTWs and the reduction of the volume of organic solids that contain these contaminants (e.g., by digestion or incineration of sludge solids) can cause reconcentration of radioactive materials in the sewage treatment facility's sewage sludge or ash.

Background information on the nature of radioactivity in sewage sludge can be found in NRC reports entitled "Evaluation of Exposure Pathways to Man From Disposal of Radioactive Materials Into Sanitary Sewer Systems" (NUREG/CR-5814) and "Reconcentration of Radioactive Material Released to Sanitary Sewers in Accordance with 10 CFR 20" (NUREG/CR-6289), published in 1992 and 1994 respectively. Another useful background document is a report entitled "Radioactivity of Municipal Sludge" (EPA, 1986), issued by EPA during the development of the first round of rulemaking for the 40 CFR Part 503 Biosolids Rule. Two useful publications on naturally occurring radioactive materials are *Environmental Radioactivity from Natural, Industrial, and Military Sources* by Eisenbud and Gesell (1997) and "Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials" by the National Academy of Sciences (1999).

1.4 Federal Agency Regulations and Guidance

Federal and State regulations allow the disposal of specific amounts and concentrations of radioactivity into sanitary sewer systems. In 1991, NRC revised its sewer disposal criteria, partially in response to evidence that certain radioactive materials were reconcentrating in sewage sludge or incinerator ash. The revised NRC regulations further limited the radioactive materials that NRC licensees are allowed to discharge to sewer systems. The current NRC regulations in 10 CFR 20.2003 permit release of specific quantities of soluble material into a sanitary sewer. Monthly average concentrations must not exceed the concentrations listed in Table 3 of Appendix B to Part 20, and the total quantities released in a year must not exceed 185 gigabecquerel (GBq) (5 curies [Ci]) of H-3, 37 GBq (1 Ci) of C-14, and 37 GBq (1 Ci) of all other radionuclides combined. These limits do not apply to excreta from patients undergoing diagnosis or treatment with radioactive material.

The EPA technical standard for the use and disposal of sewage sludge (biosolids) in 40 CFR Part 503 does not include limits for radioactive material. Some POTW operators have requested that EPA regulations address radioactive materials to provide a basis for POTWs to restrict discharges of radioactive materials to the sewage collection system.

[1]Industrial users of radioactive materials that hold active licenses from the NRC or a State which licenses theses activities based on an agreement with the NRC.

1.5 1998–2000 Sewage Sludge Survey

Based on the 1994 GAO report recommendations, NRC and EPA decided to jointly fund a voluntary survey of POTW sewage sludge and ash to help assess the potential need for NRC and/or EPA regulatory decisions. While developing the information collection request (ICR) and working with the U.S. Office of Management and Budget (OMB) to receive approval to conduct the full survey, the agencies conducted a pilot study involving nine POTWs to field-test the questionnaire for eliciting operating information from POTWs validate the sampling methods and analytical procedures, and obtain feedback from the participating POTWs. The results of the pilot study were summarized in a report issued jointly by NRC and EPA in 1999 (EPA 833-R-99-900, May 1999). The final survey procedures were slightly refined based on the experiences with the pilot test cases and public comments on the ICR submitted to OMB for approval of the survey. The final survey began in 1998 when the questionnaires was sent to 631 POTWs. More than 66% of the POTWs (420) responded by returning completed questionnaires. Sewage sludge and ash samples from approximately 25 POTWs per month were collected and shipped to the survey labs for analyses between October 1999 and November 2000.

2 SURVEY DESIGN AND IMPLEMENTATION

2.1 Survey Objectives

The objectives of the sewage sludge/ash survey were to (1) obtain national estimates of high-probability occurrences of elevated levels of radioactive materials in sludge and ash at POTWs, (2) estimate the extent to which radioactive contamination comes from either NRC/Agreement State licensees or naturally occurring radioactivity, and (3) support rulemaking decisions by NRC and EPA.

The important parameters of the survey are as follows (1) it is a voluntary survey, (2) only one sample was collected at most POTWs at a single point in time, and (3) the survey was biased to POTWs with the greatest potential to receive releases of radionuclides from NRC and Agreement State licensees and to POTWs in areas of higher concentrations of NORM. The reason for selecting POTWs for the survey was to obtain sufficient samples with radionuclides above the minimum detection limits to allow some characterization of the levels and sources of radioactivity and therefore, meet the objectives of this survey. The survey results are not a statistically valid representation of radionuclide levels in sludge and ash nationwide. However, the survey does provide a range for the possible concentrations of radionuclides in sludge and ash nationwide.

2.2 Questionnaire Phase

The Subcommittee developed a questionnaire (Appendix C) to obtain information from POTWs about their wastewater sources, wastewater and sludge treatment processes, and sewage sludge disposal practices. The questionnaire also requested the ZIP codes for their collection systems so that NRC could match licensees to their POTWs. NRC requested from each Agreement State the names and addresses of licensees that could discharge to sewage treatment facility sewer systems. The questionnaire was sent to 631 POTWs selected from the more than 16,000 POTWs across the country. The Subcommittee used information from many sources to identify POTWs with the greatest potential to receive radionuclides from licensees or from naturally occurring sources. Information was obtained from the EPA regional offices, EPA's Permit Compliance System[2] and the 1996 NEEDS Survey,[3] the NRC, the Association of Metropolitan Sewerage Agencies (AMSA), the Water Environment Federation (WEF), the State Water Pollution Control Programs and State Radiation Programs, Agreement State licensee lists, and various State and Federal agency reports.

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[2] EPA's Permit Compliance System (PCS) is the system used by EPA to track permits issued under the NPDES (National Pollution Discharge Elimination System) Program, which controls water pollution by regulating point sources that discharge effluents into waters of the U.S.

[3] The 1996 Needs Survey is the latest available report to Congress on the estimated clean water needs of the U.S. The survey is a product of the Clean Water Needs Survey (CWNS), which is a joint effort by the States and EPA to provide information on POTW collection and treatment facilities in response to §205(a) and §516(b)(1) of the Clean Water Act.

2.3 Sampling Phase

2.3.1 POTW Selection Process

The data from the POTWs that responded to the questionnaire were entered into a database developed and maintained by Environmental Health Associates (EHA)[4]. Each month, the Subcommittee Co-chairs selected 25 different POTWs from this database. The selection process considered POTWs in one or more of the following categories:

1. All geographic areas of the U.S.
2. Recommended by States
3. High NORM areas as designated in the September 1998 EPA/Office of Radiation and Indoor Air (ORIA) contractor report, "Identification of POTWs for NORM Analysis"
4. Receive discharges from landfills (receiving landfill leachates) or Superfund or Federal cleanup sites
5. Have (or used to have had) sludge incinerators
6. Different flow rates serving different size service areas
7. Sampled in the National Sewage Sludge Survey
8. Receive drinking water treatment plant residuals
9. Serve areas with industrial uses of radioactive materials likely to discharge to the sewer system

Samples were obtained from POTWs in each of the 10 physiographic regions of the US (Table 2.1). The divisions were obtained from Fenneman and Johnson (1946). Figure 1 shows the approximate geographic locations of the 313 POTWs sampled.

[4]EHA has an NRC contract to manage the database survey.

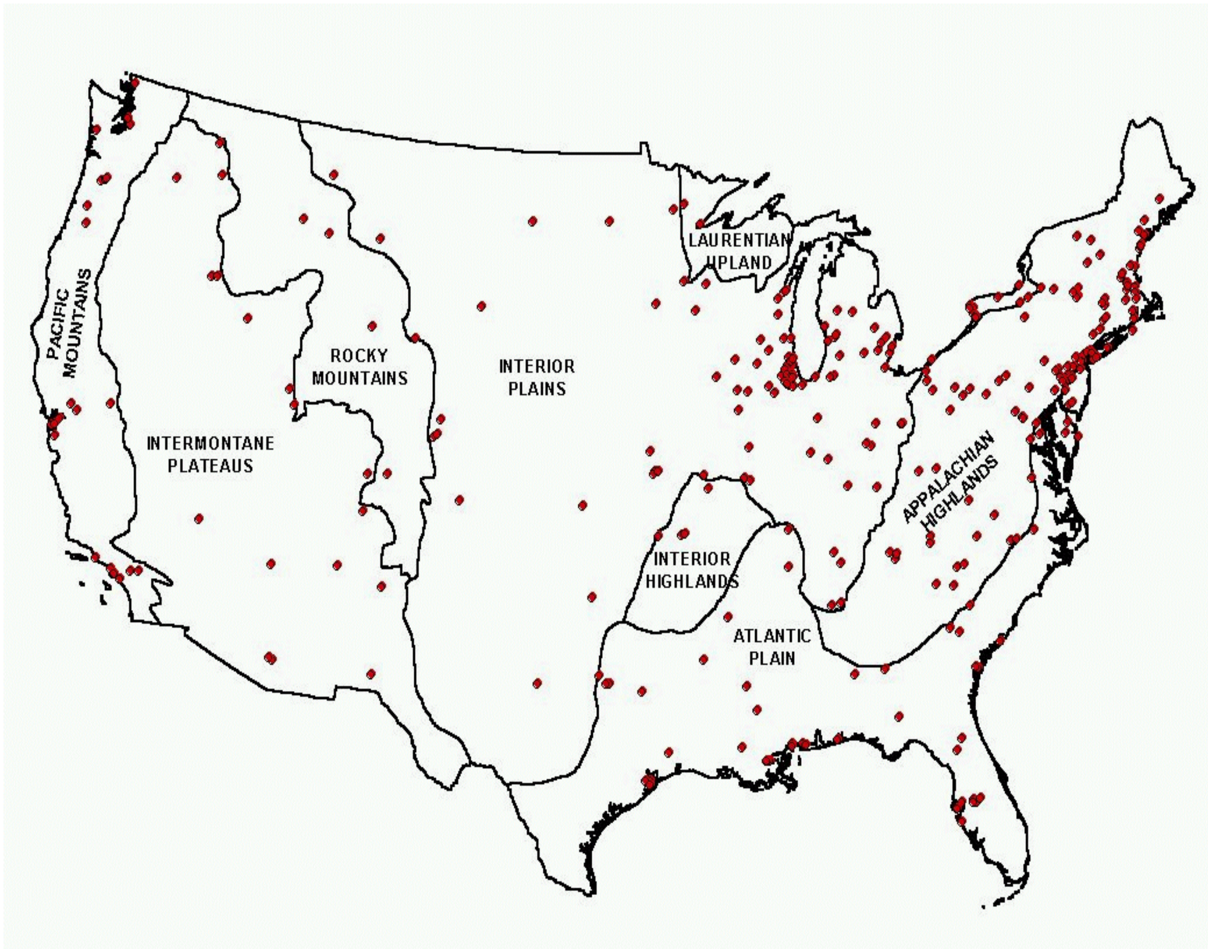
TABLE 2.1 Samples From POTWS in Each Physiographic Region

Physiographic Division	No. of POTWs
Alaska	2
Appalachian Highlands	91
Atlantic Plain	58
Hawaii	4
Interior Highlands	4
Interior Plains	106
Intermontane Plateaus	18
Laurentian Upland	2
Pacific Mountain System	24
Rocky Mountain System	4
Total	313

2.3.2 Sample Collection

A list of selected POTWs for sample collection and analyses was sent to ORISE each month. ORISE assigned survey codes and sent sampling kits to the POTWs. This process was repeated monthly to accommodate the workload at the laboratories. The POTW operators collected the samples using containers and guidance provided to them in the sampling kit from ORISE. The POTWs were instructed to follow procedures similar to those they use to take routine samples for monitoring chemical pollutants. The samples were shipped to the designated laboratory. ORISE maintained the key to the assigned codes to ensure anonymity (a feature of the survey intended to encourage participation). The key was later transferred to the data management contractors (EHA) to allow reporting back to the facilities of their individual results.

Figure 1 POTWs Located by Geographic Division



2.3.3 General Analytical Procedures

Sludge/ash analyses were performed by ORISE and EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama. Each laboratory used approved analytical procedures for routine environmental samples. The comparability of these procedures was previously evaluated during the pilot study. Additional information on analytical procedures is contained in the Quality Assurance Project Plan (QAPP) (Appendix D). The laboratories screened operate under laboratory quality assurance/quality control programs and participate in external performance evaluation (PE) programs. Quality assurance activities conducted on the project included an audit conducted by U.S. EPA headquarters to assess NAREL compliance with the QAPP. The audit concluded that activities relating to the QAPP were in compliance. The laboratories screened samples using their standard procedures for gross alpha, gross beta, and gamma spectrometry. Each month a minimum of 10% of the sludge/ash samples that had gross alpha or gross beta activity detected were chosen for radionuclide-specific analysis. The specific radionuclides analyzed were Sr-89, Sr-90, several isotopes of thorium and uranium, and their progeny, Pu-238, Pu-239, and Am-241. These radionuclides are of specific interest because of their potential presence in sewage sludge and ash. The isotopes of uranium and thorium are present in rock in the earth and leach into surface waters on the earth by natural processes such as erosion after rain and floods. Such radionuclides are referred to as NORM. Uranium and plutonium may be found in the effluents of nuclear fuel processing facilities. Certain radionuclides are commonly used in medical procedures including Co-57, Cr-51, In-111, I-125, I-131, Sm-153, Sr-89, Tl-201, and Tl-202. All detectable radionuclides were decay corrected to the time of the sample collection. Uncertainties were rounded to one significant figure. Concentrations were rounded to the same decimal place as the corresponding uncertainty.

2.3.4 Sampling and Data Quality Limitations

The survey was not random. It was biased to favor those POTWs most likely to have measurable levels of radioactivity. The survey was also voluntary and individual sewage treatment facilities could choose not to participate. Because the survey was biased and voluntary, statistical inference and probability cannot be used to interpret the results as representative of radionuclide levels in sludge and ash nationwide. The survey was designed to obtain data on the levels of radioactivity in sludge and ash at POTWs from across the country emphasizing POTWs with the greatest potential to have detectable levels of radioactive materials.

Use of this data to characterize sewage sludge at a particular POTW is inappropriate. The results cannot be used to make any conclusions about the levels of radioactive materials in sewage sludge and ash products over a longer period of time, nor can the results be used to determine whether any of the measured results were in fact levels that occurred only for a shorter period of time. This would require a much more extensive survey focused on individual POTWs of interest.

Some facilities have more than one type of sewage sludge product (e.g., liquid slurry, dewatered cake, compost, heat dried pellets). These facilities were requested to send a sample for each of their final products. Thirty-five POTWs sent ash samples resulting from incineration of their sewage sludge. No samples were lost in transit or during analysis, and no resampling was conducted. In total, sludge or ash samples from 313 POTWs (2 of which sent only an ash sample) were analyzed, and these results were included in all further data analyses conducted in this study.

The greatest uncertainty in the survey results is probably due to the field sample design. Specifically, the field sample design did not assess the variability over spatial and temporal boundaries either at a particular POTW or over all POTWs or groups of POTWs. Field uncertainty was not controlled more closely because of the voluntary participation by the POTWs and because of a small number of samples and because the POTWs particpated voluntarily and did the sampling. The field sample design uncertainty was not estimated and quantitative values are not provided.

With respect to the actual field sampling procedures used and the representativeness of each sample, there was control in that the field sampling procedures provided to the POTWs were based on the same procedures that POTWs use for compliance with the 40 CFR Part 503 Biosolids Rule (EPA, November 9, 1990). Only basic assumptions can be made about the representativeness of a particular sample because the sample collection is based on the judgement of the POTW operator who took the samples and on the processes sampled. Since each POTW collected its own samples, a higher field sampling variability was expected than if one organization collected all samples. There is also the possibility of intrasample variability, which is more significant for certain analyses such as alpha spectrometry.

Sources of field uncertainty include sample shipping error and sample contamination (e.g., cross-contamination) but are assumed to be minimal. Seals and chain of custody were used (see QAPP, Appendix D), and radioactivity likely to be the source of cross contamination was controlled by transportation regulations. The likelihood of field bias is low because the sample procedures are based on the same procedures that POTWs use for their routine regulatory compliance sampling. Likelihood of field sampling loss is low because the likelihood of sample loss (e.g., volatiles) is low for most radionuclides.

The field results are not reproducible individually, especially if there is variability of radioactivity concentration over space and/or time. However, in the aggregate, they are considered to be representative of the upper range of the distribution of values of radionuclide concentrations in sludge and ash. The lab results were designed to be reproducible and comparable (a major objective of the pilot study discussed in Section 1.5 of this document).

3 QUESTIONNAIRE SUMMARY

The Radiological Survey Questionnaire is reproduced in Appendix C. While 420 POTWs responded to the survey, only 313 facilities actually supplied sludge and/or ash samples. Responses to the survey questionnaire from these 313 POTWs are summarized in table format (see Table 3.1) to provide a detailed description of the population of POTWs that participated in the full survey.

3.1 Characteristics of the Population of 313 POTWs

Although not a statistically valid representation of the more than 16,000 POTWs in operation in the U.S. the population of 313 POTWs generally exhibits characteristics that are typical of POTWs serving most areas of the country. The majority of the 313 POTWs in the survey (86%) employ at least a secondary level of treatment of the wastewater stream. Many (nearly 40%) employ advanced treatment techniques. Most of the POTWs are small or medium sized. Approximately half of the POTWs reported a flow rate of 10 million gallons per day (MGD) or less. Only 15 of the 313 POTWs indicated that they treat greater than 100 MGD. This size range is comparable to that of the POTWs nationwide, where approximately 97% treat 10 MGD or less, and less than 1% have a capacity of 100 MGD or greater. Over 90% of the POTWs state that the industrial component of the wastewater stream is less than 50%. Approximately 30% of the POTWs have combined sanitary and storm water collection systems.

TABLE 3.1 Summary of Survey Questionnaire Responses of 313 Facilities Sampled

Treatment level	
Primary	180
Secondary	271
Advanced	121
Flow Rate	
10 MGD or less	153
More than 10 MGD, less than/equal to 50 MGD	96
More than 50 MGD, less than/equal to 100 MGD	30
Greater than 100 MGD	15
No response/no units reported	19
Treatment Process	
No processing in the last 12 months	7
Thickening	239
Mechanical dewatering	239
Heat treatment/wet air oxidation	12
Aerobic digestion	64
Anaerobic digestion	146
Composting	32
Lime stabilization	34
Alkaline stabilization	16
Air drying beds	37
Heat drying/pelletizing	6
Sewage sludge treatment/storage lagoon(s)	29
Sewage sludge storage bins or piles	44
Incineration	54
Other sewage sludge treatment processes	24
Use and Disposal Practice	
Land application	175
Surface disposal	21
Disposal in municipal solid waste landfill	130
Transfer to another facility	60
Other disposal	35
No Response	1
Primary Drinking Water Source	
Municipal water supply from surface water(s)	193
Municipal water supply from groundwater well(s)	166
Private wells	54
Private water supply from surface water source(s)	19
No Response	3

TABLE 3.1 Summary of Survey Questionnaire Responses of 313 Facilities Sampled (con't)

Receive Discharges of Drinking Water Residuals	
Yes	102
No	208
No response	3
Combined Sanitary and Storm Water Sewers	
Yes	94
No	219
Receive Sludge From Other Facilities for Processing	
Yes	80
No	233
Receive Septage	
Yes	187
No	120
No response	6
Percentage of Annual Average Daily Flow Rate That Is Industrial	
Less than 50%	285
50% or greater	15
No response/unknown	13
Have Previously Tested for Radioactive Materials	
Yes	61
No	249
No response	3
More Than One Final Sewage Sludge Production Facility	
Yes	32
No	281
State Recommendation From Request in State Letter (NRC, 1998)	
Yes	64
No	249
Located in High NORM Area From EPA/ORIA report, "Identification of POTWs for NORM Analysis" (EPA, 1998)	
Yes	89
No	224
Potentially Receives From Landfill, SUPERFUND, or Federal Cleanup Sites	
Yes	28
No	285
Participated in National Sewage Sludge Survey	
Yes	87
No	226

4 RADIOACTIVITY DATA ANALYSIS

4.1 Summary of Concentrations of Radionuclides in Sewage Sludge and Ash

After the data were entered into the database, summary statistics (including median, minimum and maximum detected concentrations, 95th percentile, and frequency of detection) were calculated for each radionuclide in each sampled medium (ash and sludge). Negative concentrations were treated as not detected for these calculations. In cases where there was an even number of analyses and the median fell between a nondetected (ND) and detected concentration, a range was reported. For example, the results of a set of four analyses were (ND, ND, 5, and 7), the median would be reported as “ND to 5." The minimum detectable concentration (MDC) of a radionuclide in a sample is the smallest concentration of analyte expressed in this study as pCi/g (1 pCi/g = 37 Bq/kg) of sludge or ash that produces a signal with a 95% confidence of exceeding a decision (detection) level. Finally, the number of times a radionuclide was detected relative to the total number of analyses is listed to provide for a more complete perspective for interpreting the results. These summary statistics presented in Tables 4.1 and 4.2 allow the reader to examine patterns of occurrence.

No widespread or nationwide public health concern was identified by the survey because no significant adverse condition or excessive concentrations of radioactivity were observed in sludge or ash. The survey was not designed to identify unique or isolated instances in which high levels of radionuclides may be present in sewage sludge or ash, and inferences to high levels of radionuclides cannot be made from the survey results alone (see Section 3.4.4). The dose modeling report, survey results and recommendations will provide information that may be useful in making decisions as to site-specific sampling or testing.

Table 4.1 Concentrations of Radionuclides in Sludge:

All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.

Radionuclide	Min	Median	95th P	Max	No. Detects/ No. Analyses
Alpha	ND	7	34	137	309/311
Beta	1.7	13	34	93	311/311
Am-241	ND	ND	ND	2.5	10/311
Be-7	ND	1.2	9	22	263/311
Bi-212	ND	ND	1.3	13	101/311
Bi-214	ND	0.3	2.3	16	238/311
C-14*	ND	ND	1	3	63/158
Ce-141	ND	ND	ND	0.016	1/311
Co-57	ND	ND	ND	0.26	6/311
Co-60	ND	ND	ND	5.1	13/311
Cr-51	ND	ND	ND	3.5	6/311
Cs-134	ND	ND	ND	0.04	1/311
Cs-137	ND	ND	0.11	3.6	133/311
Eu-154	ND	ND	ND	21	1/311
Fe-59	ND	ND	ND	0.4	1/311
H-3*	ND	0.3	5	8	111/158
I-125	ND	ND	ND	40	11/311
I-131	ND	1.8	51	840	246/311
In-111	ND	ND	0.04	3.6	19/311
K-40	ND	4	12	26	308/311
La-138	ND	ND	ND	0.07	1/311
Pa-234m	ND	ND	7	27	80/311
Pb-210	ND	ND	4	13	135/311
Pb-212	ND	0.44	1.9	15	303/311
Pb-214	ND	0.31	2.6	17	253/311
Pu-238	ND	0.01	0.07	0.19	75/92
Pu-239	ND	0.003	0.04	0.12	68/92
Ra-223	ND	ND	ND	0.09	2/311
Ra-224	ND	ND	0.9	12	47/311
Ra-226	ND	2	13	47	289/311
Ra-228	ND	0.82	5.1	38	271/311
Rn-219	ND	ND	ND	ND	0/311
Sm-153	ND	ND	ND	27	1/311
Sr-89	ND	0.35	20	70	68/98
Sr-90	ND	0.1	1	9.4	64/98
Th-227	ND	ND	0.1	0.5	49/207
Th-228	0.07	0.605	4.1	9	92/92
Th-230	0.09	0.34	1	1.7	92/92
Th-232	0.02	0.2	0.6	1.6	92/92
Th-234	ND	0.6	6.7	23	191/311
Tl-201	ND	ND	46	241	151/311
Tl-202	ND	ND	0.53	1.16	73/311
Tl-208	ND	0.07	0.96	4.8	180/311
U-234	0.18	1.95	17	44	92/92
U-235	ND	ND	0.45	3.1	112/311
U-238	0.18	1.4	12	26	92/92
Zn-65	ND	ND	ND	0.06	1/311

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table 4.2 Concentrations of Radionuclides in Ash:

All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.

Radionuclide	Minimum	Median	95th P	Maximum	No. Detects/ No. Analyses
Alpha	5	27	93	178	35/35
Beta	15	43	95	140	35/35
Am-241	ND	ND	ND	0.21	2/35
Be-7	ND	4.3	15.4	30	34/35
Bi-212	ND	1.2	3.5	15.7	25/35
Bi-214	ND	2.4	14	16	34/35
C-14*	ND	ND	1	1	5/18
Ce-141	ND	ND	ND	ND	0/35
Co-57	ND	ND	ND	0.17	1/35
Co-60	ND	ND	ND	3.46	2/35
Cr-51	ND	ND	0.3	35	5/35
Cs-134	ND	ND	ND	ND	0/35
Cs-137	ND	0.07	0.23	0.37	34/35
Eu-154	ND	ND	ND	ND	0/35
Fe-59	ND	ND	ND	ND	0/35
H-3*	ND	ND	4	8	7/18
I-125	ND	ND	0.4	1	4/35
I-131	ND	0.22	20	81	23/35
In-111	ND	ND	ND	ND	0/35
K-40	7.4	14.2	20.9	22.4	35/35
La-138	ND	ND	ND	ND	0/35
Pa-234m	ND	3	11	77	30/35
Pb-210	ND	ND	8.5	12.3	16/35
Pb-212	0.36	1.5	3.3	15	35/35
Pb-214	0.61	2.9	14.8	16.4	35/35
Pu-238	ND	0.015	0.1	0.1	20/28
Pu-239	ND	0.01	0.06	0.17	21/28
Ra-223	ND	ND	0.2	0.8	4/35
Ra-224	ND	ND	2	4.9	15/35
Ra-226	ND	3	18	22	33/35
Ra-228	0.65	2.5	17	30	35/35
Rn-219	ND	ND	0.2	0.4	3/35
Sm-153	ND	ND	ND	ND	0/35
Sr-89	ND	1	60	300	20/30
Sr-90	ND	0.2	1	6	24/30
Th-227	ND	ND	0.3	1.1	14/33
Th-228	ND	1.6	6.7	14	27/28
Th-230	ND	0.75	2.3	2.6	27/28
Th-232	ND	0.505	1	1.7	27/28
Th-234	ND	3.6	11	80	31/35
Tl-201	ND	0.62	73	105	19/35
Tl-202	ND	ND	0.99	1.53	7/35
Tl-208	ND	0.66	2.3	13.5	32/35
U-234	1.2	5.55	49	91	28/28
U-235	ND	0.15	0.7	3.4	30/35
U-238	0.8	3.3	35	74	28/28
Zn-65	ND	ND	ND	0.06	1/35

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

4.2 Comparison of Radioactivity in Sewage Sludge and Ash to Radioactivity in Other Products

To provide a perspective for interpreting the data in this report, Table 4.3 provides a comparison of concentrations of radionuclides detected in sludge and ash samples analyzed in this survey to typical ranges of radionuclide concentrations previously reported in U.S. soils and commonly used products such as phosphate fertilizers and building materials. The sources for these values are noted in the footnotes to Table 4.3. Although concentrations for some radionuclides in phosphate fertilizers are high relative to the other sources considered, phosphate fertilizers are usually blended with other fertilizer components (containing nitrogen and potassium) before application, frequently before point-of-sale. This results in a 10% to 50% reduction of the concentrations listed in Table 4.3 at the point-of-use for typical fertilizers or in commercially available blended fertilizer products (National Council on Radiation Protection and Measurements [NCRP],1987). Therefore, it is inappropriate to use the values in this table to infer possible levels of radionuclides in commercially available fertilizers, in fertilizers at point-of-use, or in the soil after application. Values in this table do not reflect the uncertainty associated with the ranges.

Table 4.3 Survey Concentration Ranges and Typical U.S. Background Concentrations of Radionuclides in Soil, Fertilizer, and Common Building Materials (All values are in pCi/g-dry weight)[1]

Radionuclide	Soil[2]	Phosphate Fertilizer[3]	Building Materials[2]	Sludge Concentrations[4]	Ash Concentrations[4]
Bi-212	0.1 - 3.5	0.1 - 4.6	0.1 - 3.7	0 - 13	0 - 16
Bi-214	0.1 -3.8	4.0 - 140	2.5 - 5.0[5]	0 - 16	0 - 16
Cs-137	0.1 - 0.2[6]	NDA[7]	NDA	0 - 3.6	0 - 0.37
K-40*	2.7-19	32 - 160[8]	0.8 - 30	0 - 26	7.4 - 22
Pa-234m*	0.1 - 3.8	4.0 - 140	0.2 - 5.0[5]	0 - 27	0 - 77
Pb-212*	0.1 - 3.5	0.1 - 4.6	0.1 - 3.7	0 - 15	0.36 - 15
Pb-214*	0.1 - 3.8	4.0 - 140	0.2 - 5.0	0 - 17	0.61 - 16
Ra-223*	<0.1 - 0.2	0.2 - 6.6	0.1 - 0.2[5]	0 - 0.09	0.1 - 0.8
Ra-224*	0.1 - 3.5	0.1 - 4.6	0.1 - 3.7[2]	0 - 12	0 - 4.9
Ra-226*	0.1 - 3.8	0.1 - 24	0.1 - 3.5	0 - 47	0 - 22
Ra-228*	0.1 - 3.5	0.1- 4.6	0.1 - 3.7[2]	0 - 38	0.65 - 30
Th-227*	<0.1 - 0.2	0.2 - 6.6	0.1 - 0.2	0 - 0.5	0 - 1.1
Th-228*	0.1 - 3.5	0.1 - 4.6	0.1 - 3.7	0.07 - 9	0 - 14
Th-230*	0.1 - 3.8	4.0 - 140	0.2 - 5.0	0.09 - 1.7	0 - 2.6
Th-232*	0.1 - 3.5	0.1 - 4.6	0.1 - 3.7	0.02 - 1.6	0 - 1.7
Th-234*	0.1 - 3.8	4.0 - 140	0.2 - 5.0	0 - 23	0 - 80
Tl-208*	0.1 - 3.5	0.1 - 4.6	0.1 - 3.7	0 - 4.8	0 - 14
U-234*	0.1 - 3.8	4.0 - 140	0.2 - 5.0	0.18 - 44	1.2 - 91
U-235*[9]	<0.1 - 0.2	0.2 - 6.6	0.1 - 0.2	0 - 3.1	0 - 3.4
U-238*	0.1 - 3.8	4.0 - 140	0.2 - 5.0[5]	0.18 - 26	0.8 - 74

* Naturally occurring radionuclide

Notes:

1. The curie (Ci) is the unit for expressing a quantity of radioactivity. The unit normally used to describe the concentrations of radioactivity in the environment is picocuries per gram (pCi/g); 1 pCi/g=37 Bq/kg.
2. *Low-Level Environmental Radioactivity - Sources and Evaluation* (1995) by Tykva and Sabol 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 9 and 6, respectively. The concentrations of the daughters or decay products of U-238 (such as Th-234 and Ra-226) 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.
3. NCRP Report No. 95 (pp. 24-32) is the source of data for the concentrations of radionuclides in phosphate fertilizers (not typical blended fertilizers), except for the concentration of K-40 in phosphate fertilizers, which came from the reference in Note 8. The concentrations of typical blended commercial fertilizers would be 10% to 50% of these values.
4. A value of zero as the lower boundary of the range occurs when a very low concentration is rounded to reflect the same number of decimal places as the two sigma laboratory uncertainty. Nondetected values are not included in this range.
5. Eisenbud and Gesell, 1997.
6. The Cs-137 concentration range in soil was obtained from Figure 4-4 (p. 94) of NCRP Report No. 50, 1976.
7. NDA means no data available
8. Source for data on K-40 in fertilizers, S. Cohen and Associates, 1997.
9. The values for U-235 in soil, fertilizer, and building materials are based on the concentrations of U-238 in the same materials and the natural ratio of U-235 to U-238.

4.3 Correlation Analysis

To examine the relationships among the different radionuclide concentrations observed in the survey, a correlation analysis was run. The analysis grouped radionuclides into clusters having similar patterns of concentrations in the survey data. Because so few ash samples were submitted, only the sludge samples were considered in this analysis. Data were standardized to a distribution with a mean of zero and a standard deviation equal to one both with and without a logarithmic transformation. Standardization of concentration values provides a consistent variable for comparing radionuclides in the survey, and a logarithmic transformation often increases the efficiency of the calculations used in the correlation analysis. When log-transformed, nondetected values were set to a minimal value of 0.001 pCi/g, and a sensitivity analysis confirmed that treating nondetected values in this way did not change the overall results. The correlations were determined by examining the correlation matrix of the data for clusters, both by inspection of the matrix itself and through principal component analysis.

Clusters among the members of the Ra-226 and Ra-228 decay chains in the survey (Ra-226, Bi-214, Pb-214, Ra-228, Th-228, Ra-224, Pb-212, Bi-212, and Tl-208) indicate a not unexpected strong association in the samples for these radionuclides. A strong clustering was also found among the uranium isotopes U-234, U-235, U-238 and the U-238 decay chain daughters Th-234 and Pa-234m. Again, such a relationship would be expected from the decay chain relationship. A negative correlation was observed between detection of the radium group and the uranium group. This correlation indicates that when radium was present in relatively high concentrations in a sample, it is likely that uranium was present at relatively low concentrations or not detected, and vice versa. In addition, the medical isotopes In-111, I-131, Tl-201, Tl-202, and Co-57 tended to cluster together. Due to the limitations of the survey design, weaker correlations were not considered adequate to support conclusions about general relationships and are not discussed in this report.

These observed clusters are generally in line with what would be expected due to common radionuclide sources and their degradation products. Examples of expected clusters are summarized in the following table.

Table 4.4 Expected [Groupings] Clustering of Radionuclides Based on Process and Degradation Relationships

Group	Radionuclides
Medical radionuclides[5]	Co-57, Cr-51, In-111, I-125, I-131, Sm-153, Sr-89, Tl-201, Tl-202
Fission and activation products other than Medical Radionuclides	Cr-51, Fe-59, Co-57, Co-60, Zn-65, Sr-89, Sr-90, Ba-140, Cs-134, Cs-137, Ce-141, Sm-153, Eu-154
C-14 and H-3	C-14 and H-3
NORM other than U or Th series	Be-7, K-40, La-138
Th-232 decay series	Th-232, Ra-228, Th-228, Ra-224, Pb-212, Bi-212, Tl-208
Transuranics	Pu-238, Pu-239, Am-241
U-235 decay series	U-235, Th-227, Ra-223, Rn-219
U-238 decay series	U-238, Th-234, Pa-234m, Pa-234, U-234, Th-230, Ra-226, Pb-214, Bi-214, Pb-210

Physical processes in the environment and types of radionuclide releases are likely to underlie some of the observed correlations among clusters of radionuclides. For example, the negative correlation between radium and uranium could be explained by the pH-dependent solubility of the two elements. In natural waters of pH 7-10, uranium ions in geologic formations form complexes with carbonate and become soluble, thereby entering the drinking water source (Cothern and Rebers, 1990). Radium becomes soluble at a lower pH (5 or less), and is, therefore, most likely to be present in acidic groundwater (USGS, 1998). Little can be concluded about other expected groups (e.g., fission/activation products) because lower activities in these radionuclides were observed, and the correlations were weaker.

Further analyses of the data were performed to determine if geographic location or POTW characteristics, as identified in the questionnaire responses, had any relationship to radionuclide concentrations. The radionuclide concentrations were grouped by relationships of source or decay series as shown in Table 4.4 above. The data were sorted by these radionuclide groupings and by information provided by the POTWs in response to the survey questionnaires. The tables in Appendix A show the summary statistics of minimum, median, 95th percentile, maximum radionuclide concentration, and frequency of detection. Tables 4.1 and 4.2 summarize the complete data set. The remaining tables in Appendix A summarize the data by radionuclide group for other POTW characteristics identified in the questionnaire responses.

[5] University of Arkansas for Medical Sciences, College of Pharmacy (http://nuclearpharmacy.uams.edu/RPLIST.html)

4.4 Association of Questionnaire Responses With Radionuclide Concentrations

Analyses were performed to determine whether different questionnaire response categories were related to shifts in radionuclide concentrations. The analyses were restricted to radionuclides with at least a 50% frequency of detection, except for Cs-137 (detect rate = 43%). Cesium-137 was included because it had the highest detect rate of any radionuclide analyzed in all 311 samples of the fission and activation product group. Altogether 23 radionuclides were analyzed.

Performing multiple analyses (N = 23 radionuclides) for each survey question increases the chances of defining spurious relationships in the data. In other words, because statistical significance is defined as a relationship with a very low probability of occurrence, the more tests performed, the more likely it is that low-probability findings will occur through chance alone. To correct for this effect and increase the confidence that reported significant relationships were the result of actual associations and not simply chance, only relationships with less than a probability of 0.002 were assumed to represent a potentially useful (significant) association between questionnaire response categories and radionuclide concentrations.

4.5 Results

Table 4.5 shows the strength of the association between the factors considered in the survey questionnaire and against the 23 radionuclides analyzed. Physiographic division was the POTW characteristic most strongly associated with radionuclide concentrations (Section 4.5.1). Other POTW characteristics showing strong associations with radionuclide concentrations were (1) the primary source of drinking water and (2) the average daily flow in (million gallons per day [MGD]). No questionnaire responses were associated with differences in radionuclide concentrations in sludge for the C-14 and H-3 group.

The relationship between radionuclide concentrations and the response categories for specific items on the questionnaire was sometimes positive and sometimes negative. In other words, the characteristic or level of response to a questionnaire item was sometimes associated with higher concentrations of a particular radionuclide or radionuclide group, while other categories were sometimes associated with lower concentrations of those or other radionuclides. The direction of association between questionnaire responses and radionuclide concentrations is discussed in the following sections and summarized in Tables 4.6 through 4.9 for the three POTW characteristics most strongly associated with radionuclide concentration patterns: physiographic province, drinking water source, and average daily flow through the POTW.

Table 4.5 Summary of Direction of Effect for Questionnaire Response less Predictive for Radionuclide Concentration in Sludge

Survey Question	C-14 and H-3	Fission and Activation Products			Medical Isotopes		NORM		Th-232 Decay Series					Trans-uranics		U-238 Decay Series							
	H-3	Cs-137	Sr-89	Sr-90	I-131	Tl-201	Be-7	K-40	Pb-212	Ra-228	Th-228	Th-232	Tl-208	Pu-238	Pu-239	Bi-214	Pb-210	Pb-214	Ra-226	Th-230	Th-234	U-234	U-238
Physiographic divisions		**				*	**	**	**	***			**			***		***	**	*	***	***	***
Primary sources of drinking water		**					***			**	**	**	*			***		**	*				
Average daily flow (MGD)					**	***	*		*	*	***	*			*								
Combined sanitary and storm sewers		***				*	***	***				*					**					*	
Percent industrial flow					**	*		*		*									*	*	*		
Highest reported treatment level								*	*											**			
More than one sludge facility		*	*	*																			
Receives waste from other wastewater facilities					*						*									**			
Receives drinking water residuals					*									*									
Reported treatment levels																				*			
Receives septage												*											

The number of asterisks represents the relative strength of association (based on individual nonparametric analyses: * P<0.05, ** P<0.01, and *** P<0.001).

4.5.1 Physiographic Divisions

As expected, the location of POTWs within major physiographic divisions of the United States (Figure 1) affected radionulide concentrations. Physiographic divisions represent distinctive areas having common topography, rock types and structure, and geologic and geomorphic history (Fenneman and Johnson, 1946) and should have similar levels of naturally occurring radioactive materials (NORM). Concentrations of U-234 and U-238 were higher than the average in the Intermontane Plateaus and lower than the average in the Atlantic Plain. However, some other members of the U-238 series (Bi-214 and Pb-214) were highest in the Atlantic Plain and the Interior Plains. The Interior Plains showed a strong association with higher concentrations of Ra-228, while Hawaii and the Pacific Mountains showed a strong association with the lower concentrations. These relationships are summarized in Table 4.6.

Table 4.6 Relationships of Physiographic Division to Concentrations of Radionuclides in Sludge Samples

Group	Nuclide[1]	Lower concentrations[2]	Higher concentrations[3]
Fission and Activation Products	Cs-137		Rocky Mountains
Medical Isotopes	Tl-201	Atlantic Plain	Appalachian Highlands
NORM	Be-7	Rocky Mountains, Hawaii	Appalachian Highlands
	K-40		Rocky Mountains
Th-232 Decay Series	Pb-212	Intermontane Plateaus, Pacific Mountains	Atlantic Plain
	Ra-228[1]	Hawaii, Pacific Mountains	Interior Plains
	Tl-208	Intermontane Plateaus, Pacific Mountains, Hawaii	Rocky Mountains, Interior Plains, Atlantic Plain
U-238 Decay Series	Bi-214[1]	Hawaii, Pacific Mountains, Appalachian Highlands	Atlantic Plain, Interior Plains
	Pb-214[1]	Hawaii, Pacific Mountains, Appalachian Highlands	Atlantic Plain, Interior Plains
	Ra-226	Appalachian Highlands	Atlantic Plain, Interior Plains
	Th-230		Atlantic Plain
	Th-234[1]		Intermontane Plateaus, Rocky Mountains
	U-234[1]	Atlantic Plain	Intermontane Plateaus
	U-238[1]	Atlantic Plain	Intermontane Plateaus

1. These radionuclides showed a strong association with the distribution of responses identifying the physiographic location of the POTW.
2. “Lower concentrations” are significantly lower than the average concentration.
3. “Higher concentrations” are significantly higher than the average concentration.

4.5.2 Primary Source of Drinking Water

Concentrations of radionuclides in sludge showed a stronger association with whether drinking water came from groundwater or surface water than with whether water supplies were public or private. Only two radionuclides, Be-7 and Bi-214, showed strong associations with the source of drinking water. Sludge that included groundwater sources had higher concentrations of Bi-214, while municipal supplies served by surface water had lower concentrations. Sludge from areas with surface water sources showed higher concentrations of Be-7, while areas served primarily by groundwater had lower concentrations. Table 4.7 tabulates these and the weaker relationships observed.

Table 4.7 Relationships of Primary Drinking Water Source to the Relative Concentration of Radionuclides

Group	Nuclide	Lower Concentrations	Higher Concentrations
Fission and Activation Products	Cs-137	B	A
NORM	Be-7*	BC, B	A, ABC
Th-232 Decay Series	Ra-228	A	B
	Th-228	A, ABC	BC
	Th-232		A
	Tl-208	AB	
U-238 Decay Series	Bi-214*	NR, A	B
	Pb-214	A	B
	Ra-226	A	B

A = municipal supply from surface water
B = municipal supply from groundwater
C = private wells
D = private surface water
NR = not reported

*Radionuclides showing a strong association with the questionnaire response regarding primary source of drinking water.

4.5.3 Average Daily Flow

Daily flow volume from POTWs did not show a consistent relationship to radionuclide concentrations. Qualitative correlation of concentrations with flow can be assessed by the pattern of pluses and minuses in Table 4.8. The pluses and minuses indicate flow categories with significantly higher or lower concentrations. Radionuclides with higher concentrations at higher flow volumes have an overall positive correlation and radionuclides with higher than average concentration at low flow volumes have an overall negative correlation with flow volume. Based on this approach, the medical isotopes showed a strong association with increased flow. Thorium-228 showed a strong relationship with POTWs with lower daily flow. Table 4.8 includes other radionuclides showing weaker relationships.

Table 4.8 Effect of Average Daily Flow on Radionuclide Concentration

		Flow (millions of gallons per day)				
Group	Nuclide	<10	10–50	50–100	>100	NR
Medical Isotopes	I-131	–		+		
	Tl-201	–		+		
NORM	Be-7			+		
Th-232 Decay Series	Pb-212	+	–			
	Ra-228	+				
	Th-228	+		–		
	Th-232			–		
Transuranics	Pu-239				+	

Plus and minus symbols identify categories with significantly higher and lower than average concentrations of radionuclides.*

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Table A.1 Concentrations of Radionuclides in Sludge, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Radionuclide Group: Uranium-238 Decay Series											
Bi-214	Min	0.05	ND	ND	ND	ND	ND	ND	0.36	ND	ND
	Median	0.135	0.2	0.405	ND to 0.05	1	0.38	0.24	0.38	ND	0.45
	95th Percentile	0.22	0.9	6	0.07	1.5	4.1	0.51	0.4	0.4	0.52
	Max	0.22	1.5	13	0.07	1.5	16	1	0.4	1	0.52
	No. Detects/ No. Analyses	2/2	54/84	49/60	2/4	3/4	97/110	18/20	2/2	8/21	3/4
Pa-234m	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	2.5	ND	ND	ND to 2
	95th Percentile	ND	6	3	ND	ND	9	20	ND	4	4
	Max	ND	22	6	ND	ND	11	27	ND	10	4
	No. Detects/ No. Analyses	0/2	23/84	11/60	0/4	0/4	28/110	12/20	0/2	4/21	2/4
Pb-210	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND to 0.3	ND	ND	ND to 0	0.5	ND	0.55	ND to 4	ND	1.45
	95th Percentile	0.3	4	3.2	0.4	1.1	4.3	2	4	11	4
	Max	0.3	13	6	0.4	1.1	9	3	4	12	4
	No. Detects/	1/2	38/84	19/60	2/4	3/4	47/110	12/20	1/2	9/21	3/4

Table A.1 Concentrations of Radionuclides in Sludge, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Pb-214	Min	ND	ND	ND	ND	ND	ND	ND	0.4	ND	ND
	Median	ND	0.3	0.43	ND to 0.06	1.05	0.41	0.26	0.405	ND	0.48
	95th Percentile	ND	1.1	4	0.14	1.6	4.4	0.54	0.41	0.5	0.58
	Max	ND	1.5	15	0.14	1.6	17	0.7	0.41	2	0.58
	No. Detects/ No. Analyses	0/2	64/84	51/60	2/4	3/4	100/110	19/20	2/2	9/21	3/4
Ra-226	Min	ND	ND	ND	ND	ND	ND	ND	0.8	ND	1
	Median	ND to 0.4	1.95	3	1.2	1.4	2.15	2	0.9	1.2	1.8
	95th Percentile	0.4	9	19	4.6	2	17	8	1	11	4
	Max	0.4	17	30	4.6	2	47	11	1	16	4
	No. Detects/ No. Analyses	1/2	74/84	57/60	3/4	3/4	106/110	19/20	2/2	20/21	4/4
Th-230	Min	--	0.1	0.14	--	--	0.12	0.09	--	0.22	0.23
	Median	--	0.415	0.495	--	--	0.28	0.29	--	0.22	0.46
	95th Percentile	--	1.6	1	--	--	0.6	0.4	--	0.22	0.6
	Max	--	1.7	1.2	--	--	1.7	0.42	--	0.22	0.6
	No. Detects/ No. Analyses	--	14/14	24/24	--	--	39/39	11/11	--	1/1	3/3
Th-234	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1
	Median	ND to 1.2	0.15	0.4	0.8	0.45	0.8	2.75	ND to 2	0.5	2.8
	95th Percentile	1.2	5	3	4.9	1	7.8	15	2	5	7
	Max	1.2	16	4	4.9	1	12	23	2	19	7
	No. Detects/	1/2	46/84	33/60	3/4	3/4	70/110	18/20	1/2	12/21	4/4

Table A.1 Concentrations of Radionuclides in Sludge, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
U-234	Min	--	0.43	0.18	--	--	0.39	1.1	--	2.6	1.9
	Median	--	1.7	1.1	--	--	2.2	12	--	2.6	2
	95th Percentile	--	20	2.1	--	--	12	34	--	2.6	8
	Max	--	25	2.3	--	--	15.4	44	--	2.6	8
	No. Detects/ No. Analyses	--	14/14	24/24	--	--	39/39	11/11	--	1/1	3/3
U-238	Min	--	0.37	0.19	--	--	0.18	0.55	--	2	1.5
	Median	--	1.45	0.95	--	--	1.4	6.6	--	2	1.6
	95th Percentile	--	15	2	--	--	9	12	--	2	4.5
	Max	--	16	2	--	--	12.5	26	--	2	4.5
	No. Detects/ No. Analyses	--	14/14	24/24	--	--	39/39	11/11	--	1/1	3/3
Radionuclide Group: C-14 and H-3											
C-14*	Min	ND	ND	ND	ND	ND	ND	ND	0	ND	ND
	Median	ND	ND	ND	ND	ND to 1	ND	ND	0	ND	ND
	95th Percentile	ND	1	1	ND	2	1	0	0	0	2
	Max	ND	3	2	ND	2	2	1	0	0.5	2
	No. Detects/ No. Analyses	0/1	16/45	12/26	0/2	2/4	21/51	5/13	1/1	4/12	1/3
H-3 *	Min	ND	ND	ND	ND	ND	ND	ND	0.7	ND	ND
	Median	ND	0.6	0.2	ND to 1	ND to 0.1	0.3	0.3	0.7	0.2	ND
	95th Percentile	ND	5	5	1	0.3	4	4	0.7	2	2
	Max	ND	6	7	1	0.3	6	8	0.7	3	2
	No. Detects/ No. Analyses	0/1	35/45	19/26	1/2	2/4	35/51	9/13	1/1	8/12	1/3

Table A.1 Concentrations of Radionuclides in Sludge, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Radionuclide Group: Thorium-232 Decay Series											
Bi-212	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND to 0.7	ND	ND to 1
	95th Percentile	ND	1	2	ND	ND	2.3	0.7	0.7	0.6	1.4
	Max	ND	1.3	4	ND	ND	13	0.8	0.7	1	1.4
	No. Detects/ No. Analyses	0/2	28/84	23/60	0/4	0/4	41/110	2/20	1/2	4/21	2/4
Pb-212	Min	0.08	ND	ND	0.03	0	ND	ND	0.4	ND	0.5
	Median	0.165	0.435	0.585	0.105	0.27	0.48	0.3	0.49	0.3	0.855
	95th Percentile	0.25	1.2	2.5	0.6	0.5	2.7	0.7	0.58	1.3	1.6
	Max	0.25	1.9	3.3	0.6	0.5	15	1	0.58	1.9	1.6
	No. Detects/ No. Analyses	2/2	81/84	59/60	4/4	4/4	108/110	19/20	2/2	20/21	4/4
Ra-224	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	0.7	0.6	0.4	ND	1.4	0.7	ND	ND	1.1
	Max	ND	1.1	3	0.4	ND	12	5	ND	0.4	1.1
	No. Detects/ No. Analyses	0/2	11/84	11/60	1/4	0/4	20/110	2/20	0/2	1/21	1/4
Ra-228	Min	0.15	ND	ND	ND	ND	ND	ND	0.43	ND	ND
	Median	0.375	0.87	0.87	ND	0.75	1.05	0.85	0.715	0.4	0.85
	95th Percentile	0.6	3.1	8.9	0.14	1.4	9.7	3.4	1	1.7	1.5
	Max	0.6	5	13	0.14	1.4	38	4.6	1	6	1.5
	No. Detects/ No. Analyses	2/2	74/84	54/60	1/4	3/4	101/110	19/20	2/2	12/21	3/4

Table A.1 Concentrations of Radionuclides in Sludge, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Th-228	Min	--	0.16	0.19	--	--	0.19	0.07	--	0.25	0.33
	Median	--	0.75	0.7	--	--	0.7	0.4	--	0.25	0.61
	95th Percentile	--	1.3	3.3	--	--	6.8	0.6	--	0.25	0.9
	Max	--	1.8	4.1	--	--	9	1.1	--	0.25	0.9
	No. Detects/ No. Analyses	--	14/14	24/24	--	--	39/39	11/11	--	1/1	3/3
Th-232	Min	--	0.08	0.07	--	--	0.08	0.02	--	0.14	0.16
	Median	--	0.335	0.18	--	--	0.18	0.2	--	0.14	0.46
	95th Percentile	--	1.1	0.56	--	--	0.4	0.35	--	0.14	0.6
	Max	--	1.6	0.9	--	--	0.6	0.4	--	0.14	0.6
	No. Detects/ No. Analyses	--	14/14	24/24	--	--	39/39	11/11	--	1/1	3/3
Tl-208	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND to 0.02	0.08	0.085	ND to 0.02	ND	0.1	ND	ND to 0.1	ND	0.505
	95th Percentile	0.02	0.8	1.8	0.03	ND	1.3	0.32	0.17	0.15	1.44
	Max	0.02	1.8	3.1	0.03	ND	4.8	0.6	0.17	0.17	1.44
	No. Detects/ No. Analyses	1/2	50/84	36/60	2/4	0/4	71/110	7/20	1/2	9/21	3/4
Radionuclide Group: Medical Isotopes											
I-125	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	0.8	ND	ND	0.7	ND	ND	ND	ND	ND
	Max	ND	40	5.9	ND	0.7	1.1	ND	ND	ND	ND
	No. Detects/ No. Analyses	0/2	6/84	3/60	0/4	1/4	1/110	0/20	0/2	0/21	0/4
I-131	Min	3.2	ND	ND	ND	0.92	ND	ND	0.4	ND	ND
	Median	22.6	1.55	0.855	1.085	12.5	1.5	3.3	4.35	5.1	ND
	95th Percentile	42	65	64	1.8	29	42	51	8.3	220	3.4
	Max	42	230	840	1.8	29	98	105	8.3	280	3.4
	No. Detects/ No. Analyses	2/2	70/84	43/60	3/4	4/4	86/110	18/20	2/2	17/21	1/4

Table A.1 Concentrations of Radionuclides in Sludge,
Summarized by Geographic Division
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
In-111	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	0.09	ND	ND	0.04	ND	ND	ND	ND
	Max	ND	1.19	3.5	ND	ND	3.6	0.4	ND	0.12	ND
	No. Detects/ No. Analyses	0/2	4/84	5/60	0/4	0/4	8/110	1/20	0/2	1/21	0/4
Tl-201	Min	2.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	26.25	1.6	ND	ND to 48	ND	ND	ND	ND	2.6	ND
	95th Percentile	50	56	26	71	176	35	42	ND	16	ND
	Max	50	241	46	71	176	138	110	ND	24	ND
	No. Detects/ No. Analyses	2/2	48/84	23/60	2/4	1/4	52/110	9/20	0/2	14/21	0/4
Tl-202	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND to 0.7	ND	ND	ND to 0.66	ND	ND	ND	ND	ND	ND
	95th Percentile	0.7	0.54	0.51	0.88	ND	0.45	0.55	ND	0.22	ND
	Max	0.7	1.16	0.95	0.88	ND	0.92	0.85	ND	0.4	ND
	No. Detects/ No. Analyses	½	18/84	16/60	2/4	0/4	25/110	4/20	0/2	7/21	0/4
Radionuclide Group: NORM other than Thorium/Uranium											
Be-7	Min	0.5	ND	ND	ND	ND	ND	ND	0.9	ND	ND
	Median	0.7	1.5	0.95	0.4	1.75	1.1	0.85	1.7	1.4	ND
	95th Percentile	0.9	11	4	0.56	3	8	2.4	2.5	9	1
	Max	0.9	17	22	0.56	3	13.5	4	2.5	10.7	1
	No. Detects/ No. Analyses	2/2	79/84	49/60	3/4	3/4	88/110	18/20	2/2	18/21	1/4
K-40	Min	2	ND	0.9	0.3	3.4	ND	1.3	3	1.8	12
	Median	2.6	4	3.8	1.75	7	4	3.85	3.95	3.2	13
	95th Percentile	3.2	13	10.5	4	14	9.1	7.7	4.9	25	15.5
	Max	3.2	15.9	19	4	14	22	8	4.9	26	15.5
	No. Detects/ No. Analyses	2/2	82/84	60/60	4/4	4/4	109/110	20/20	2/2	21/21	4/4

Table A.1 Concentrations of Radionuclides in Sludge, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
La-138	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max	ND	ND	0.07	ND	ND	ND	ND	ND	ND	ND
	No. Detects/ No. Analyses	0/2	0/84	1/60	0/4	0/4	0/110	0/20	0/2	0/21	0/4
Radionuclide Group: Transuranics											
Am-241	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max	ND	0.14	2.5	ND	ND	0.1	0	ND	ND	ND
	No. Detects/ No. Analyses	0/2	1/84	3/60	0/4	0/4	5/110	1/20	0/2	0/21	0/4
Pu-238	Min	--	ND	ND	--	--	ND	ND	--	0.006	0.01
	Median	--	0.0005	0.01	--	--	0.01	0.01	--	0.006	0.02
	95th Percentile	--	0.03	0.14	--	--	0.04	0.03	--	0.006	0.04
	Max	--	0.03	0.19	--	--	0.1	0.07	--	0.006	0.04
	No. Detects/ No. Analyses	--	11/14	19/24	--	--	32/39	9/11	--	1/1	3/3
Pu-239	Min	--	ND	ND	--	--	ND	ND	--	0.003	ND
	Median	--	0.001	0.01	--	--	0.002	0	--	0.003	0.01
	95th Percentile	--	0.04	0.11	--	--	0.01	0.01	--	0.003	0.05
	Max	--	0.1	0.12	--	--	0.04	0.04	--	0.003	0.05
	No. Detects/ No. Analyses	--	8/14	21/24	--	--	29/39	7/11	--	1/1	2/3

Table A.1 Concentrations of Radionuclides in Sludge, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Radionuclide Group: Actinium (U-235) Decay Series											
Ra-223	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.09
	Max	ND	0.06	ND	ND	ND	ND	ND	ND	ND	0.09
	No. Detects/ No. Analyses	0/2	1/84	0/60	0/4	0/4	0/110	0/20	0/2	0/21	1/4
Rn-219	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	No. Detects/ No. Analyses	0/2	0/84	0/60	0/4	0/4	0/110	0/20	0/2	0/21	0/4
Th-227	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	0.07	0.1	ND	ND	0.1	0.06	ND	ND	0.04
	Max	ND	0.19	0.2	ND	ND	0.5	0.1	ND	ND	0.04
	No. Detects/ No. Analyses	0/1	5/50	14/40	0/2	0/4	22/73	7/20	0/1	0/12	1/4
U-235	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	0.095	ND	ND	0.115
	95th Percentile	ND	0.31	0.19	ND	ND	0.5	1.3	ND	0.3	0.19
	Max	ND	1.1	0.3	ND	ND	0.61	3.1	ND	0.43	0.19
	No. Detects/ No. Analyses	0/2	19/84	29/60	0/4	0/4	46/110	11/20	0/2	4/21	3/4

Table A.1 Concentrations of Radionuclides in Sludge, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Radionuclide Group: Fission and Activation Products											
Ce-141	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max	ND	ND	ND	ND	ND	0.016	ND	ND	ND	ND
	No. Detects/ No. Analyses	0/2	0/84	0/60	0/4	0/4	1/110	0/20	0/2	0/21	0/4
Co-57	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	0.04	ND
	Max	ND	ND	0.06	ND	ND	0.05	0.01	ND	0.26	ND
	No. Detects/ No. Analyses	0/2	0/84	2/60	0/4	0/4	1/110	1/20	0/2	2/21	0/4
Co-60	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	0.07	ND	ND	ND	ND	ND	0	ND
	Max	ND	0.07	1.16	ND	ND	0.3	5.1	ND	0.03	ND
	No. Detects/ No. Analyses	0/2	2/84	4/60	0/4	0/4	4/110	1/20	0/2	2/21	0/4
Cr-51	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max	ND	3.5	0.8	ND	ND	0.3	ND	ND	2.8	ND
	No. Detects/ No. Analyses	0/2	2/84	2/60	0/4	0/4	1/110	0/20	0/2	1/21	0/4

Table A.1 Concentrations of Radionuclides in Sludge, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Cs-134	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max	ND	ND	0.04	ND	ND	ND	ND	ND	ND	ND
	No. Detects/ No. Analyses	0/2	0/84	1/60	0/4	0/4	0/110	0/20	0/2	0/21	0/4
Cs-137	Min	ND	ND	ND	ND	ND	ND	ND	0.07	ND	0.08
	Median	ND	ND	ND	ND	ND	ND	ND	0.09	ND	0.12
	95th Percentile	ND	0.11	0.12	0.01	0.03	0.06	0.4	0.11	0.3	0.3
	Max	ND	1.5	3.6	0.01	0.03	0.1	1.1	0.11	0.3	0.3
	No. Detects/ No. Analyses	0/2	37/84	24/60	1/4	1/4	46/110	8/20	2/2	10/21	4/4
Eu-154	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max	ND	21	ND	ND	ND	ND	ND	ND	ND	ND
	No. Detects/ No. Analyses	0/2	1/84	0/60	0/4	0/4	0/110	0/20	0/2	0/21	0/4
Fe-59	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max	ND	ND	ND	ND	ND	0.4	ND	ND	ND	ND
	No. Detects/ No. Analyses	0/2	0/84	0/60	0/4	0/4	1/110	0/20	0/2	0/21	0/4

Table A.1 Concentrations of Radionuclides in Sludge, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalachian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Sm-153	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max	ND	27	ND	ND	ND	ND	ND	ND	ND	ND
	No. Detects/ No. Analyses	0/2	1/84	0/60	0/4	0/4	0/110	0/20	0/2	0/21	0/4
Sr-89	Min	--	ND	ND	--	--	ND	ND	--	0	ND
	Median	--	0.1	1.1	--	--	0.3	0.3	--	0.65	ND to 0
	95th Percentile	--	3	20	--	--	30	2	--	1	0
	Max	--	10	30	--	--	70	2	--	1	0
	No. Detects/ No. Analyses	--	9/15	20/24	--	--	24/38	9/13	--	4/4	2/4
Sr-90	Min	--	ND	ND	--	--	ND	ND	--	ND	ND
	Median	--	0.1	0.1	--	--	0.1	0	--	ND to 0.1	0.15
	95th Percentile	--	9	0.4	--	--	0.6	0.3	--	0.1	1
	Max	--	9.4	1	--	--	2	0.7	--	0.1	1
	No. Detects/ No. Analyses	--	10/15	15/24	--	--	26/38	8/13	--	2/4	3/4
Zn-65	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	95th Percentile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max	ND	0.06	ND	ND	ND	ND	ND	ND	ND	ND
	No. Detects/ No. Analyses	0/2	1/84	0/60	0/4	0/4	0/110	0/20	0/2	0/21	0/4

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Radionuclide Group: Uranium-238 Decay Series											
Bi-214	Min	--	ND	2.8	--	--	1.7	--	--	0.62	--
	Median	--	2.15	3.8	--	--	3.25	--	--	0.68	--
	95th Percentile	--	9	16	--	--	14.1	--	--	1.3	--
	Max	--	13.7	16	--	--	14.1	--	--	1.3	--
	No. Detects/No. Analyses	--	15/16	5/5	--	--	10/10	--	--	4/4	--
Pa-234m	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	3	3	--	--	4.5	--	--	6.5	--
	95th Percentile	--	10	5	--	--	9	--	--	77	--
	Max	--	11	5	--	--	9	--	--	77	--
	No. Detects/No. Analyses	--	14/16	4/5	--	--	9/10	--	--	3/4	--
Pb-210	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND to 2.5	ND	--	--	ND	--	--	2.35	--
	95th Percentile	--	6.4	4.2	--	--	8.5	--	--	8.9	--
	Max	--	12.3	4.2	--	--	8.5	--	--	8.9	--
	No. Detects/No. Analyses	--	8/16	2/5	--	--	3/10	--	--	3/4	--
Pb-214	Min	--	0.92	3.1	--	--	1.9	--	--	0.61	--
	Median	--	2.3	4.1	--	--	3.6	--	--	0.715	--
	95th Percentile	--	10	16.4	--	--	15.1	--	--	1.32	--
	Max	--	14.8	16.4	--	--	15.1	--	--	1.32	--
	No. Detects/No. Analyses	--	16/16	5/5	--	--	10/10	--	--	4/4	--

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Ra-226	Min	--	ND	ND	--	--	2	--	--	0	--
	Median	--	2.5	9.5	--	--	6.2	--	--	1.05	--
	95th Percentile	--	17	15	--	--	22	--	--	1.1	--
	Max	--	18	15	--	--	22	--	--	1.1	--
	No. Detects/No. Analyses	--	15/16	4/5	--	--	10/10	--	--	4/4	--
Th-230	Min	--	0.3	0.6	--	--	ND	--	--	0.4	--
	Median	--	0.8	0.7	--	--	0.9	--	--	0.64	--
	95th Percentile	--	2.3	1.5	--	--	2.2	--	--	0.9	--
	Max	--	2.6	1.5	--	--	2.2	--	--	0.9	--
	No. Detects/No. Analyses	--	11/11	5/5	--	--	8/9	--	--	3/3	--
Th-234	Min	--	ND	ND	--	--	ND	--	--	1	--
	Median	--	2.55	3.8	--	--	3.75	--	--	6.35	--
	95th Percentile	--	7.3	21	--	--	7.5	--	--	80	--
	Max	--	10	21	--	--	7.5	--	--	80	--
	No. Detects/No. Analyses	--	14/16	4/5	--	--	9/10	--	--	4/4	--
U-234	Min	--	1.3	1.2	--	--	2.7	--	--	2.7	--
	Median	--	2.9	1.9	--	--	6.9	--	--	19	--
	95th Percentile	--	13	18	--	--	7.6	--	--	91	--
	Max	--	49	18	--	--	7.6	--	--	91	--
	No. Detects/No. Analyses	--	11/11	5/5	--	--	9/9	--	--	3/3	--

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
U-238	Min	--	0.8	1.1	--	--	2.5	--	--	2.5	--
	Median	--	2.8	1.7	--	--	4.3	--	--	15	--
	95th Percentile	--	9	6.4	--	--	6.2	--	--	74	--
	Max	--	35	6.4	--	--	6.2	--	--	74	--
	No. Detects/No. Analyses	--	11/11	5/5	--	--	9/9	--	--	3/3	--
Radionuclide Group: C-14 and H-3											
C-14*	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	0	--
	95th Percentile	--	1	ND	--	--	0	--	--	1	--
	Max	--	1	ND	--	--	0	--	--	1	--
	No. Detects/No. Analyses	--	1/8	0/2	--	--	2/5	--	--	2/3	--
H-3*	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	0.75	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	8	ND	--	--	ND	--	--	4	--
	Max	--	8	ND	--	--	ND	--	--	4	--
	No. Detects/No. Analyses	--	6/8	0/2	--	--	0/5	--	--	1/3	--
Radionuclide Group: Thorium-232 Decay Series											
Bi-212	Min	--	ND	1.2	--	--	ND	--	--	ND	--
	Median	--	1.3	3.5	--	--	ND to 0.8	--	--	ND to 0.3	--
	95th Percentile	--	2	15.7	--	--	1.8	--	--	1.4	--
	Max	--	2.4	15.7	--	--	1.8	--	--	1.4	--
	No. Detects/No. Analyses	--	13/16	5/5	--	--	5/10	--	--	2/4	--

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Pb-212	Min	--	0.74	1.3	--	--	0.73	--	--	0.36	--
	Median	--	1.55	3.3	--	--	1.28	--	--	1.025	--
	95th Percentile	--	2.5	15	--	--	1.9	--	--	1.3	--
	Max	--	2.6	15	--	--	1.9	--	--	1.3	--
	No. Detects/No. Analyses	--	16/16	5/5	--	--	10/10	--	--	4/4	--
Ra-224	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND to 0.4	0.4	--	--	ND	--	--	ND	--
	95th Percentile	--	2	4.9	--	--	1.3	--	--	ND	--
	Max	--	2.4	4.9	--	--	1.3	--	--	ND	--
	No. Detects/No. Analyses	--	8/16	3/5	--	--	4/10	--	--	0/4	--
Ra-228	Min	--	0.71	3.4	--	--	1.6	--	--	0.65	--
	Median	--	2.6	9.6	--	--	2.15	--	--	1.24	--
	95th Percentile	--	6.3	30	--	--	9.9	--	--	2.2	--
	Max	--	17	30	--	--	9.9	--	--	2.2	--
	No. Detects/No. Analyses	--	16/16	5/5	--	--	10/10	--	--	4/4	--
Th-228	Min	--	0.8	1.7	--	--	ND	--	--	0.4	--
	Median	--	1.5	3	--	--	1.4	--	--	0.68	--
	95th Percentile	--	3.4	14	--	--	2.4	--	--	0.7	--
	Max	--	3.7	14	--	--	2.4	--	--	0.7	--
	No. Detects/No. Analyses	--	11/11	5/5	--	--	8/9	--	--	3/3	--
Th-232	Min	--	0.3	0.46	--	--	ND	--	--	0.22	--
	Median	--	0.7	0.8	--	--	0.5	--	--	0.39	--
	95th Percentile	--	0.9	1.7	--	--	1	--	--	0.49	--
	Max	--	0.9	1.7	--	--	1	--	--	0.49	--
	No. Detects/No. Analyses	--	11/11	5/5	--	--	8/9	--	--	3/3	--

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Tl-208	Min	--	0.23	0.4	--	--	ND	--	--	0.11	--
	Median	--	1.01	2	--	--	0.415	--	--	0.9	--
	95th Percentile	--	2	13.5	--	--	1.66	--	--	1.16	--
	Max	--	2.3	13.5	--	--	1.66	--	--	1.16	--
	No. Detects/No. Analyses	--	16/16	5/5	--	--	7/10	--	--	4/4	--
Radionuclide Group: Medical Isotopes											
I-125	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	0.8	--	--	0.3	--	--	1	--
	Max	--	0.4	0.8	--	--	0.3	--	--	1	--
	No. Detects/No. Analyses	--	1/16	1/5	--	--	1/10	--	--	1/4	--
I-131	Min	--	ND	ND	--	--	ND	--	--	0.03	--
	Median	--	ND to 0.1	0.68	--	--	0.23	--	--	4.285	--
	95th Percentile	--	1.6	46	--	--	4.3	--	--	81	--
	Max	--	20	46	--	--	4.3	--	--	81	--
	No. Detects/No. Analyses	--	8/16	3/5	--	--	8/10	--	--	4/4	--
In-111	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	ND	--	--	ND	--	--	ND	--
	Max	--	ND	ND	--	--	ND	--	--	ND	--
	No. Detects/No. Analyses	--	0/16	0/5	--	--	0/10	--	--	0/4	--

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Tl-201	Min	--	ND	ND	--	--	ND	--	--	26	--
	Median	--	ND	6.8	--	--	ND	--	--	54.5	--
	95th Percentile	--	31	105	--	--	12.4	--	--	73	--
	Max	--	35	105	--	--	12.4	--	--	73	--
	No. Detects/No. Analyses	--	7/16	4/5	--	--	4/10	--	--	4/4	--
Tl-202	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	0.99	1.53	--	--	0.1	--	--	0.77	--
	Max	--	1.1	1.53	--	--	0.1	--	--	0.77	--
	No. Detects/No. Analyses	--	3/16	1/5	--	--	2/10	--	--	1/4	--
Radionuclide Group: NORM other than Thorium/Uranium											
Be-7	Min	--	ND	1.2	--	--	0.5	--	--	1.9	--
	Median	--	5.95	2.3	--	--	5.7	--	--	3.95	--
	95th Percentile	--	15	8.1	--	--	30	--	--	15.4	--
	Max	--	27	8.1	--	--	30	--	--	15.4	--
	No. Detects/No. Analyses	--	15/16	5/5	--	--	10/10	--	--	4/4	--
K-40	Min	--	7.4	8.4	--	--	7.9	--	--	10.8	--
	Median	--	15.9	9.4	--	--	14.1	--	--	13.9	--
	95th Percentile	--	20	22	--	--	20.9	--	--	15	--
	Max	--	22.4	22	--	--	20.9	--	--	15	--
	No. Detects/No. Analyses	--	16/16	5/5	--	--	10/10	--	--	4/4	--

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
La-138	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	ND	--	--	ND	--	--	ND	--
	Max	--	ND	ND	--	--	ND	--	--	ND	--
	No. Detects/No. Analyses	--	0/16	0/5	--	--	0/10	--	--	0/4	--
Radionuclide Group: Transuranics											
Am-241	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	0.04	--	--	ND	--	--	ND	--
	Max	--	0.21	0.04	--	--	ND	--	--	ND	--
	No. Detects/No. Analyses	--	1/16	1/5	--	--	0/10	--	--	0/4	--
Pu-238	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	0.01	0.02	--	--	0.02	--	--	0	--
	95th Percentile	--	0.09	0.05	--	--	0.1	--	--	0	--
	Max	--	0.1	0.05	--	--	0.1	--	--	0	--
	No. Detects/No. Analyses	--	7/11	3/5	--	--	8/9	--	--	2/3	--
Pu-239	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	0.008	0.02	--	--	0.01	--	--	0.01	--
	95th Percentile	--	0.04	0.17	--	--	0.04	--	--	0.05	--
	Max	--	0.06	0.17	--	--	0.04	--	--	0.05	--
	No. Detects/No. Analyses	--	9/11	3/5	--	--	7/9	--	--	2/3	--

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Radionuclide Group: Actinium (U-235) Decay Series											
Ra-223	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	0.5	ND	--	--	0.1	--	--	ND	--
	Max	--	0.8	ND	--	--	0.1	--	--	ND	--
	No. Detects/No. Analyses	--	3/16	0/5	--	--	1/10	--	--	0/4	--
Rn-219	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	0.2	0.2	--	--	ND	--	--	ND	--
	Max	--	0.4	0.2	--	--	ND	--	--	ND	--
	No. Detects/No. Analyses	--	2/16	1/5	--	--	0/10	--	--	0/4	--
Th-227	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	0.1	--	--	ND	--	--	ND	--
	95th Percentile	--	0.3	0.6	--	--	0.2	--	--	0.04	--
	Max	--	1.1	0.6	--	--	0.2	--	--	0.04	--
	No. Detects/No. Analyses	--	6/14	3/5	--	--	4/10	--	--	1/4	--
U-235	Min	--	ND	0.03	--	--	ND	--	--	ND	--
	Median	--	0.11	0.07	--	--	0.24	--	--	0.44	--
	95th Percentile	--	0.5	0.7	--	--	0.6	--	--	3.4	--
	Max	--	1.7	0.7	--	--	0.6	--	--	3.4	--
	No. Detects/No. Analyses	--	13/16	5/5	--	--	9/10	--	--	3/4	--

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Radionuclide Group: Fission and Activation Products											
Ce-141	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	ND	--	--	ND	--	--	ND	--
	Max	--	ND	ND	--	--	ND	--	--	ND	--
	No. Detects/No. Analyses	--	0/16	0/5	--	--	0/10	--	--	0/4	--
Co-57	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	ND	--	--	ND	--	--	ND	--
	Max	--	0.17	ND	--	--	ND	--	--	ND	--
	No. Detects/No. Analyses	--	1/16	0/5	--	--	0/10	--	--	0/4	--
Co-60	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	3.46	--	--	0.038	--	--	ND	--
	Max	--	ND	3.46	--	--	0.038	--	--	ND	--
	No. Detects/No. Analyses	--	0/16	1/5	--	--	1/10	--	--	0/4	--
Cr-51	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND to 0.3	--
	95th Percentile	--	ND	0.2	--	--	0.3	--	--	35	--
	Max	--	0.8	0.2	--	--	0.3	--	--	35	--
	No. Detects/No. Analyses	--	1/16	1/5	--	--	1/10	--	--	2/4	--

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Cs-134	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	ND	--	--	ND	--	--	ND	--
	Max	--	ND	ND	--	--	ND	--	--	ND	--
	No. Detects/No. Analyses	--	0/16	0/5	--	--	0/10	--	--	0/4	--
Cs-137	Min	--	ND	0.03	--	--	0.04	--	--	0.02	--
	Median	--	0.075	0.04	--	--	0.07	--	--	0.06	--
	95th Percentile	--	0.18	0.37	--	--	0.23	--	--	0.1	--
	Max	--	0.27	0.37	--	--	0.23	--	--	0.1	--
	No. Detects/No. Analyses	--	15/16	5/5	--	--	10/10	--	--	4/4	--
Eu-154	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	ND	--	--	ND	--	--	ND	--
	Max	--	ND	ND	--	--	ND	--	--	ND	--
	No. Detects/No. Analyses	--	0/16	0/5	--	--	0/10	--	--	0/4	--
Fe-59	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	ND	--	--	ND	--	--	ND	--
	Max	--	ND	ND	--	--	ND	--	--	ND	--
	No. Detects/No. Analyses	--	0/16	0/5	--	--	0/10	--	--	0/4	--

Table A.2 Concentrations of Radionuclides in Ash, Summarized by Geographic Division

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

		Alaska	Appalacian Highlands	Atlantic Plains	Hawaii	Interior Highlands	Interior Plains	Intermontane Plateaus	Laurentain Upland	Pacific Mountain System	Rocky Mountain System
Sm-153	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	ND	--	--	ND	--	--	ND	--
	Max	--	ND	ND	--	--	ND	--	--	ND	--
	No. Detects/No. Analyses	--	0/16	0/5	--	--	0/10	--	--	0/4	--
Sr-89	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND to 0	2	--	--	1	--	--	1.2	--
	95th Percentile	--	20	12	--	--	300	--	--	30	--
	Max	--	60	12	--	--	300	--	--	30	--
	No. Detects/No. Analyses	--	6/12	4/5	--	--	7/9	--	--	3/4	--
Sr-90	Min	--	ND	0	--	--	ND	--	--	ND	--
	Median	--	0.25	0.1	--	--	0.4	--	--	ND	--
	95th Percentile	--	1	1	--	--	6	--	--	0.1	--
	Max	--	1	1	--	--	6	--	--	0.1	--
	No. Detects/No. Analyses	--	10/12	5/5	--	--	8/9	--	--	1/4	--
Zn-65	Min	--	ND	ND	--	--	ND	--	--	ND	--
	Median	--	ND	ND	--	--	ND	--	--	ND	--
	95th Percentile	--	ND	ND	--	--	0.06	--	--	ND	--
	Max	--	ND	ND	--	--	0.06	--	--	ND	--
	No. Detects/No. Analyses	--	0/16	0/5	--	--	1/10	--	--	0/4	--

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Primary	0.05	0.05	1.7	1.7	3/3
	Secondary	ND	0.24	1.9	16	63/90
	Advanced	ND	0.21	7.9	13	23/33
	Primary and Secondary	ND	0.29	2.1	16	81/101
	Secondary and Advanced	0.27	0.4	0.9	0.9	5/5
	Primary, Secondary, and Advanced	ND	0.38	2.9	4.1	63/79
Pa-234m	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	8	17	26/90
	Advanced	ND	ND	7	22	11/33
	Primary and Secondary	ND	ND	4	27	20/101
	Secondary and Advanced	ND	ND	1.3	1.3	2/5
	Primary, Secondary, and Advanced	ND	ND	9	17	21/79
Pb-210	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND - 0	5	13	45/90
	Advanced	ND	ND	3	12	13/33
	Primary and Secondary	ND	ND	3.1	9	38/101
	Secondary and Advanced	ND	ND	1.2	1.2	2/5
	Primary, Secondary, and Advanced	ND	ND	4.3	6	37/79
Pb-214	Primary	ND	ND	1.8	1.8	1/3
	Secondary	ND	0.27	2	17	72/90
	Advanced	ND	0.28	8.3	15	25/33
	Primary and Secondary	ND	0.31	2.6	17	81/101
	Secondary and Advanced	0.24	0.4	0.9	0.9	5/5
	Primary, Secondary, and Advanced	ND	0.4	3	4.4	69/79

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Ra-226	Primary	0.4	2.1	8	8	3/3
	Secondary	ND	1.95	11	47	80/90
	Advanced	ND	1.8	21	30	30/33
	Primary and Secondary	ND	2.2	13	27	96/101
	Secondary and Advanced	ND	1.1	2	2	4/5
	Primary, Secondary, and Advanced	ND	2.2	10.1	25	76/79
Th-230	Primary	1.2	1.2	1.2	1.2	1/1
	Secondary	0.1	0.435	0.8	1	24/24
	Advanced	0.09	0.38	1.6	1.6	7/7
	Primary and Secondary	0.12	0.375	1.2	1.7	34/34
	Secondary and Advanced	0.4	0.4	0.4	0.4	1/1
	Primary, Secondary, and Advanced	0.09	0.25	0.49	0.5	25/25
Th-234	Primary	ND	1.4	1.6	1.6	2/3
	Secondary	ND	0.55	6.8	15	56/90
	Advanced	ND	0.5	5	19	22/33
	Primary and Secondary	ND	0.5	4.9	23	56/101
	Secondary and Advanced	0.4	0.6	1	1	5/5
	Primary, Secondary, and Advanced	ND	1	7.8	15	50/79
U-234	Primary	1.9	1.9	1.9	1.9	1/1
	Secondary	0.5	1.6	14	17	24/24
	Advanced	0.4	2.3	20	20	7/7
	Primary and Secondary	0.56	2.2	17	44	34/34
	Secondary and Advanced	1	1	1	1	1/1
	Primary, Secondary, and Advanced	0.18	2.1	15.4	25	25/25

Table A.3 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question: Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95^{th} P	Max	No. Detects/ No. Analyses
U-238	Primary	1.7	1.7	1.7	1.7	1/1
	Secondary	0.43	1.25	10.3	12	24/24
	Advanced	0.4	2	16	16	7/7
	Primary and Secondary	0.5	1.55	8	26	34/34
	Secondary and Advanced	0.72	0.72	0.72	0.72	1/1
	Primary, Secondary, and Advanced	0.18	1.3	12.5	15	25/25
Radionuclide Group: C-14 and H-3						
C-14*	Secondary	ND	ND	1	2	22/55
	Advanced	ND	ND	2	2	6/16
	Primary and Secondary	ND	ND	1	3	16/44
	Secondary and Advanced	ND	1	1	1	2/3
	Primary, Secondary, and Advanced	ND	ND	1	2	16/40
H-3*	Secondary	ND	0.4	5	7	41/55
	Advanced	ND	0.35	2	3	12/16
	Primary and Secondary	ND	0.25	5	8	28/44
	Secondary and Advanced	ND	0.3	4	4	2/3
	Primary, Secondary, and Advanced	ND	0.3	3	6	28/40
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	1.3	13	28/90
	Advanced	ND	ND	1	4	10/33
	Primary and Secondary	ND	ND	1.4	6.8	38/101
	Secondary and Advanced	ND	ND	0.6	0.6	2/5
	Primary, Secondary, and Advanced	ND	ND	1.1	3.7	23/79

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Pb-212	Primary	0.08	0.08	0.21	0.21	3/3
	Secondary	ND	0.45	1.5	15	89/90
	Advanced	0.07	0.32	2.2	3	33/33
	Primary and Secondary	ND	0.5	1.9	5.4	100/101
	Secondary and Advanced	0.09	0.19	0.7	0.7	5/5
	Primary, Secondary, and Advanced	ND	0.44	1.9	4.2	73/79
Ra-224	Primary	ND	ND	0.4	0.4	1/3
	Secondary	ND	ND	0.6	12	9/90
	Advanced	ND	ND	1.1	3	5/33
	Primary and Secondary	ND	ND	0.7	2.7	15/101
	Secondary and Advanced	ND	ND	0.6	0.6	2/5
	Primary, Secondary, and Advanced	ND	ND	1	5	15/79
Ra-228	Primary	ND	0.15	0.4	0.4	2/3
	Secondary	ND	0.8	4	20	78/90
	Advanced	ND	0.7	9.7	13	29/33
	Primary and Secondary	ND	0.83	5.1	24	88/101
	Secondary and Advanced	0.3	0.6	0.64	0.64	5/5
	Primary, Secondary, and Advanced	ND	1	4.8	38	69/79
Th-228	Primary	0.2	0.2	0.2	0.2	1/1
	Secondary	0.16	0.7	6.7	9	24/24
	Advanced	0.22	1.1	4.6	4.6	7/7
	Primary and Secondary	0.25	0.75	3	6.8	34/34
	Secondary and Advanced	0.23	0.23	0.23	0.23	1/1
	Primary, Secondary, and Advanced	0.07	0.4	2.4	9	25/25

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Th-232	Primary	0.14	0.14	0.14	0.14	1/1
	Secondary	0.07	0.215	0.6	0.9	24/24
	Advanced	0.06	0.19	1.1	1.1	7/7
	Primary and Secondary	0.08	0.265	0.65	1.6	34/34
	Secondary and Advanced	0.15	0.15	0.15	0.15	1/1
	Primary, Secondary, and Advanced	0.02	0.18	0.4	0.44	25/25
Tl-208	Primary	0.02	0.03	0.04	0.04	3/3
	Secondary	ND	0.055	0.8	4.1	48/90
	Advanced	ND	ND	0.37	0.93	16/33
	Primary and Secondary	ND	0.09	1.4	4.8	65/101
	Secondary and Advanced	ND	ND	0.22	0.22	2/5
	Primary, Secondary, and Advanced	ND	0.08	0.88	2.5	46/79
Radionuclide Group: Medical Isotopes						
I-125	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	0.3	40	5/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	4	5/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	1.5	1/79
I -131	Primary	1.2	1.8	3.2	3.2	3/3
	Secondary	ND	1.35	51	220	68/90
	Advanced	ND	2.9	29	145	28/33
	Primary and Secondary	ND	0.87	101	840	76/101
	Secondary and Advanced	ND	0.13	34	34	4/5
	Primary, Secondary, and Advanced	ND	3.6	50	105	67/79

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
In-111	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	0.18	4/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	0.12	3.6	8/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	0.044	3.5	7/79
Tl-201	Primary	ND	48	50	50	2/3
	Secondary	ND	ND	46	207	41/90
	Advanced	ND	ND	42	241	16/33
	Primary and Secondary	ND	ND	34	176	49/101
	Secondary and Advanced	ND	ND	1.8	1.8	2/5
	Primary, Secondary, and Advanced	ND	0.35	35	189	41/79
Tl-202	Primary	0.05	0.66	0.7	0.7	3/3
	Secondary	ND	ND	0.4	1.16	18/90
	Advanced	ND	ND	0.14	0.85	9/33
	Primary and Secondary	ND	ND	0.54	0.95	26/101
	Secondary and Advanced	ND	ND	0.085	0.085	1/5
	Primary, Secondary, and Advanced	ND	ND	0.51	0.72	16/79
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Primary	0.3	0.4	0.5	0.5	3/3
	Secondary	ND	1.1	11	22	76/90
	Advanced	ND	1	4.6	9.5	27/33
	Primary and Secondary	ND	1.2	8	17	85/101
	Secondary and Advanced	ND	0.58	3	3	3/5
	Primary, Secondary, and Advanced	ND	1.4	9.9	13.5	69/79

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
K-40	Primary	0.8	1.3	2	2	3/3
	Secondary	ND	4.05	13	26	88/90
	Advanced	1.3	3.4	9	25	33/33
	Primary and Secondary	ND	4	13.3	22	100/101
	Secondary and Advanced	2.3	2.9	8.3	8.3	5/5
	Primary, Secondary, and Advanced	0.9	4	10	12	79/79
La-138	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	0.07	1/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	ND	0/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/79
Radionuclide Group: Transuranics						
Am-241	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	0.1	2.5	5/90
	Advanced	ND	ND	ND	0.1	1/33
	Primary and Secondary	ND	ND	ND	0.03	1/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	0.08	3/79
Pu-238	Primary	0.02	0.02	0.02	0.02	1/1
	Secondary	ND	0.0105	0.14	0.19	18/24
	Advanced	ND	0	0.1	0.1	5/7
	Primary and Secondary	ND	0.01	0.03	0.1	30/34
	Secondary and Advanced	0	0	0	0	1/1
	Primary, Secondary, and Advanced	ND	0.007	0.04	0.05	20/25

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95^{th} P	Max	No. Detects/ No. Analyses
Pu-239	Primary	0.02	0.02	0.02	0.02	1/1
	Secondary	ND	0.0035	0.1	0.11	18/24
	Advanced	ND	0.01	0.03	0.03	6/7
	Primary and Secondary	ND	0.003	0.04	0.12	24/34
	Secondary and Advanced	ND	ND	ND	ND	0/1
	Primary, Secondary, and Advanced	ND	0.003	0.01	0.04	19/25
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	0.09	1/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	0.06	1/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/79
Rn-219	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	ND	0/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	ND	0/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/79
Th-227	Primary	0.04	0.04	0.04	0.04	1/1
	Secondary	ND	ND	0.06	0.5	10/65
	Advanced	ND	ND	0.2	0.2	6/22
	Primary and Secondary	ND	ND	0.1	0.19	20/64
	Secondary and Advanced	ND	ND	ND	ND	0/3
	Primary, Secondary, and Advanced	ND	ND	0.1	0.5	12/52

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
U-235	Primary	ND	ND	0.12	0.12	1/3
	Secondary	ND	ND	0.43	1.3	30/90
	Advanced	ND	ND	0.2	0.7	7/33
	Primary and Secondary	ND	ND	0.4	3.1	40/101
	Secondary and Advanced	ND	0.06	0.08	0.08	3/5
	Primary, Secondary, and Advanced	ND	ND	0.58	0.7	31/79
Radionuclide Group: Fission and Activation Products						
Ce-141	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	ND	0/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	0.016	1/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/79
Co-57	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	ND	0/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	0.26	3/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	0.06	3/79
Co-60	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	0.05	1.16	6/90
	Advanced	ND	ND	ND	0.016	1/33
	Primary and Secondary	ND	ND	ND	5.1	3/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	0.1	3/79

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95^{th} P	Max	No. Detects/ No. Analyses
Cr-51	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	2.8	1/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	3.5	1/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	0.8	4/79
Cs-134	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	0.04	1/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	ND	0/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/79
Cs-137	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	0.19	3.6	44/90
	Advanced	ND	ND	0.11	0.73	7/33
	Primary and Secondary	ND	ND	0.11	1.1	44/101
	Secondary and Advanced	ND	0.03	0.06	0.06	4/5
	Primary, Secondary, and Advanced	ND	ND	0.08	0.3	34/79
Eu-154	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	21	1/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	ND	0/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/79

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Fe-59	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	0.4	1/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	ND	0/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/79
Sm-153	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	27	1/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	ND	0/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/79
Sr-89	Primary	20	20	20	20	1/1
	Secondary	ND	0.5	5	5	22/28
	Advanced	ND	ND	10	10	4/9
	Primary and Secondary	ND	0	10	70	19/34
	Secondary and Advanced	0	1	1	1	3/3
	Primary, Secondary, and Advanced	ND	1	30	30	19/23
Sr-90	Primary	0.1	0.1	0.1	0.1	1/1
	Secondary	ND	0.1	1	9.4	16/28
	Advanced	ND	0.1	0.3	0.3	7/9
	Primary and Secondary	ND	0.1	0.7	9	24/34
	Secondary and Advanced	0	0.04	0.3	0.3	3/3
	Primary, Secondary, and Advanced	ND	0.1	1	2	13/23

Table A.3 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Indicate the Level(s) of Wastewater Treatment Achieved by this Treatment Works
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi = 0.037 Bq.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Zn-65	Primary	ND	ND	ND	ND	0/3
	Secondary	ND	ND	ND	0.06	1/90
	Advanced	ND	ND	ND	ND	0/33
	Primary and Secondary	ND	ND	ND	ND	0/101
	Secondary and Advanced	ND	ND	ND	ND	0/5
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/79

* Indicates concentrations for this radionuclide are expressed in pCi/g wet

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Primary	2.2	2.2	2.2	2.2	1/1
	Secondary	0.64	1.7	3.1	3.1	7/7
	Advanced	0.72	1.7	6.3	6.3	7/7
	Primary and Secondary	0.62	2.4	14.1	16	11/11
	Secondary and Advanced	2.8	5.9	9	9	2/2
	Primary, Secondary, and Advanced	ND	3.2	14	14	6/7
Pa-234m	Primary	3	3	3	3	1/1
	Secondary	1.1	5	6	6	7/7
	Advanced	ND	3	11	11	6/7
	Primary and Secondary	ND	3	7	10	9/11
	Secondary and Advanced	ND	ND - 2	2	2	1/2
	Primary, Secondary, and Advanced	ND	5	77	77	6/7
Pb-210	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	5	5	2/7
	Advanced	ND	ND	5.3	5.3	3/7
	Primary and Secondary	ND	3.4	8.5	12.3	8/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	8.9	8.9	3/7
Pb-214	Primary	2.4	2.4	2.4	2.4	1/1
	Secondary	0.69	1.9	3.4	3.4	7/7
	Advanced	0.74	1.9	6.8	6.8	7/7
	Primary and Secondary	0.61	2.9	15.1	16.4	11/11
	Secondary and Advanced	3.1	6.55	10	10	2/2
	Primary, Secondary, and Advanced	0.92	3.5	14.6	14.6	7/7

Table A.4 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Indicate the level(s) of wastewater treatment achieved by this treatment works."

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Ra-226	Primary	3.4	3.4	3.4	3.4	1/1
	Secondary	1.1	2.5	9.4	9.4	7/7
	Advanced	ND	2	7.1	7.1	5/7
	Primary and Secondary	1.1	4	17	22	11/11
	Secondary and Advanced	9.5	13.75	18	18	2/2
	Primary, Secondary, and Advanced	1	6.6	18	18	7/7
Th-230	Primary	1.4	1.4	1.4	1.4	1/1
	Secondary	0.4	0.85	2.2	2.2	4/4
	Advanced	0.3	0.8	2.6	2.6	7/7
	Primary and Secondary	ND	1.1	2.3	2.3	7/8
	Secondary and Advanced	0.6	0.6	0.6	0.6	2/2
	Primary, Secondary, and Advanced	0.55	0.65	1.3	1.3	6/6
Th-234	Primary	2.7	2.7	2.7	2.7	1/1
	Secondary	ND	4.7	7.2	7.2	6/7
	Advanced	1	3.6	21	21	7/7
	Primary and Secondary	1	2.7	5.5	7.3	11/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	4.7	80	80	6/7
U-234	Primary	5.3	5.3	5.3	5.3	1/1
	Secondary	2.7	5.4	9	9	4/4
	Advanced	1.3	2.4	19	19	7/7
	Primary and Secondary	1.2	6.05	49	49	8/8
	Secondary and Advanced	1.9	2.05	2.2	2.2	2/2
	Primary, Secondary, and Advanced	6	7.45	91	91	6/6

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
U-238	Primary	4.3	4.3	4.3	4.3	1/1
	Secondary	2.5	4.25	6.4	6.4	4/4
	Advanced	0.8	1.9	15	15	7/7
	Primary and Secondary	1.1	3.65	35	35	8/8
	Secondary and Advanced	1.4	1.55	1.7	1.7	2/2
	Primary, Secondary, and Advanced	2.8	4.75	74	74	6/6
Radionuclide Group: C-14 and H-3						
C-14*	Secondary	ND	0	1	1	2/3
	Advanced	ND	ND	ND	ND	0/3
	Primary and Secondary	ND	ND	0	0	2/8
	Primary, Secondary, and Advanced	ND	ND	1	1	1/4
H-3*	Secondary	ND	3	8	8	2/3
	Advanced	ND	ND	1	1	1/3
	Primary and Secondary	ND	ND	2	2	2/8
	Primary, Secondary, and Advanced	ND	ND - 0.5	4	4	2/4
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Primary	0.9	0.9	0.9	0.9	1/1
	Secondary	ND	0.8	1.8	1.8	6/7
	Advanced	ND	0.9	5.5	5.5	4/7
	Primary and Secondary	ND	1.6	3.5	15.7	8/11
	Secondary and Advanced	1.2	1.65	2.1	2.1	2/2
	Primary, Secondary, and Advanced	ND	1.4	1.6	1.6	4/7

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Pb-212	Primary	1.14	1.14	1.14	1.14	1/1
	Secondary	0.36	1.3	1.7	1.7	7/7
	Advanced	0.99	1.4	6.6	6.6	7/7
	Primary and Secondary	0.73	1.8	3.3	15	11/11
	Secondary and Advanced	2	2.2	2.4	2.4	2/2
	Primary, Secondary, and Advanced	1	1.6	1.7	1.7	7/7
Ra-224	Primary	0.8	0.8	0.8	0.8	1/1
	Secondary	ND	ND	0.5	0.5	3/7
	Advanced	ND	0.8	4.9	4.9	4/7
	Primary and Secondary	ND	ND	1.3	2.4	3/11
	Secondary and Advanced	0.4	1.2	2	2	2/2
	Primary, Secondary, and Advanced	ND	ND	1.8	1.8	2/7
Ra-228	Primary	2.3	2.3	2.3	2.3	1/1
	Secondary	0.65	1.8	3.4	3.4	7/7
	Advanced	1.46	2.5	24	24	7/7
	Primary and Secondary	0.68	3.7	9.9	30	11/11
	Secondary and Advanced	5.7	11.35	17	17	2/2
	Primary, Secondary, and Advanced	2	3	8.2	8.2	7/7
Th-228	Primary	1.4	1.4	1.4	1.4	1/1
	Secondary	0.4	1	1.7	1.7	4/4
	Advanced	0.68	1.3	6.7	6.7	7/7
	Primary and Secondary	ND	2.25	14	14	7/8
	Secondary and Advanced	1.7	2.7	3.7	3.7	2/2
	Primary, Secondary, and Advanced	0.7	1.7	2.4	2.4	6/6

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Th-232	Primary	0.7	0.7	0.7	0.7	1/1
	Secondary	0.22	0.75	1	1	4/4
	Advanced	0.39	0.8	0.9	0.9	7/7
	Primary and Secondary	ND	0.505	1.7	1.7	7/8
	Secondary and Advanced	0.3	0.4	0.5	0.5	2/2
	Primary, Secondary, and Advanced	0.34	0.495	0.8	0.8	6/6
Tl-208	Primary	0.36	0.36	0.36	0.36	1/1
	Secondary	ND	0.29	1.48	1.48	6/7
	Advanced	0.3	1.05	2	2	7/7
	Primary and Secondary	0.34	1.03	3.1	13.5	11/11
	Secondary and Advanced	0.61	0.67	0.73	0.73	2/2
	Primary, Secondary, and Advanced	ND	0.55	1.6	1.6	5/7
Radionuclide Group: Medical Isotopes						
I-125	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	0.8	1/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	1	1	3/7
I-131	Primary	3.8	3.8	3.8	3.8	1/1
	Secondary	ND	ND	7.4	7.4	3/7
	Advanced	ND	1.6	81	81	5/7
	Primary and Secondary	ND	0.22	1.17	1.2	8/11
	Secondary and Advanced	0.22	0.68	1.14	1.14	2/2
	Primary, Secondary, and Advanced	ND	0.03	4.2	4.2	4/7

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
In-111	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	ND	0/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7
Tl-201	Primary	1.3	1.3	1.3	1.3	1/1
	Secondary	ND	ND	26	26	1/7
	Advanced	ND	0.36	105	105	4/7
	Primary and Secondary	ND	1	12.4	48	8/11
	Secondary and Advanced	1.3	47.15	93	93	2/2
	Primary, Secondary, and Advanced	ND	ND	61	61	3/7
Tl-202	Primary	0.07	0.07	0.07	0.07	1/1
	Secondary	ND	ND	0.77	0.77	1/7
	Advanced	ND	ND	1.1	1.1	1/7
	Primary and Secondary	ND	ND	0.1	0.99	2/11
	Secondary and Advanced	0.14	0.835	1.53	1.53	2/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/79
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Primary	8.3	8.3	8.3	8.3	1/1
	Secondary	0.8	1.2	13	13	7/7
	Advanced	ND	3.6	15	15	6/7
	Primary and Secondary	0.14	7.6	15.4	30	11/11
	Secondary and Advanced	4.3	6	7.7	7.7	2/2
	Primary, Secondary, and Advanced	0.5	4.3	27	27	7/7

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
K-40	Primary	11.4	11.4	11.4	11.4	1/1
	Secondary	9.7	15	22	22	7/7
	Advanced	7.4	12.7	22.4	22.4	7/7
	Primary and Secondary	7.9	16	19.8	20.9	11/11
	Secondary and Advanced	9.4	11.45	13.5	13.5	2/2
	Primary, Secondary, and Advanced	12	14	17.9	17.9	7/7
La-138	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	ND	0/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7
Radionuclide Group: Transuranics						
Am-241	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	0.04	1/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	0.21	0.21	1/7
Pu-238	Primary	0.02	0.02	0.02	0.02	1/1
	Secondary	ND	0.03	0.1	0.1	3/4
	Advanced	ND	0.01	0.06	0.06	6/7
	Primary and Secondary	ND	0.01	0.1	0.1	5/8
	Secondary and Advanced	ND	ND - 0.09	0.09	0.09	1/2
	Primary, Secondary, and Advanced	ND	0.01	0.08	0.08	4/6

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Pu-239	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	0.02	0.04	0.04	3/4
	Advanced	ND	0.01	0.06	0.06	6/7
	Primary and Secondary	ND	0	0.17	0.17	5/8
	Secondary and Advanced	ND	ND - 0.04	0.04	0.04	1/2
	Primary, Secondary, and Advanced	ND	0	0.01	0.04	6/6
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	0.8	1/11
	Secondary and Advanced	ND	ND - 0.5	0.5	0.5	1/2
	Primary, Secondary, and Advanced	ND	ND	0.2	0.2	2/7
Rn-219	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	0.4	1/11
	Secondary and Advanced	0.2	0.2	0.2	0.2	2/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7
Th-227	Primary	0.2	0.2	0.2	0.2	1/1
	Secondary	ND	ND - 0.04	0.2	0.2	3/6
	Advanced	ND	0.02	0.6	0.6	4/7
	Primary and Secondary	ND	ND	1.1	1.1	2/10
	Secondary and Advanced	0.1	0.2	0.3	0.3	2/2
	Primary, Secondary, and Advanced	ND	ND	0.2	0.2	2/7

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
U-235	Primary	0.3	0.3	0.3	0.3	1/1
	Secondary	ND	0.18	0.4	0.4	5/7
	Advanced	0.06	0.11	0.7	0.7	7/7
	Primary and Secondary	ND	0.14	0.7	1.7	9/11
	Secondary and Advanced	0.03	0.05	0.07	0.07	2/2
	Primary, Secondary, and Advanced	ND	0.18	3.4	3.4	6/7
Radionuclide Group:Fission and Activation Products						
Ce-141	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	ND	0/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7
Co-57	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	0.17	0.17	1/7
	Primary and Secondary	ND	ND	ND	ND	0/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7
Co-60	Primary	0.03	0.038	0.038	0.038	1/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	3.46	1/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Cr-51	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	0.3	0.3	2/7
	Advanced	ND	ND	35	35	1/7
	Primary and Secondary	ND	ND	0.3	0.8	2/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7
Cs-134	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	ND	0/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7
Cs-137	Primary	0.09	0.09	0.09	0.09	1/1
	Secondary	0.02	0.06	0.09	0.09	7/7
	Advanced	ND	0.05	0.11	0.11	6/7
	Primary and Secondary	0.03	0.08	0.23	0.37	11/11
	Secondary and Advanced	0.04	0.055	0.07	0.07	2/2
	Primary, Secondary, and Advanced	0	0.08	0.27	0.27	7/7
Eu-154	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	ND	0/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Fe-59	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	ND	0/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7
Sm-153	Primary	ND	ND	ND	ND	0/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	ND	0/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7
Sr-89	Primary	1	1	1	1	1/1
	Secondary	ND	0.6	30	30	3/5
	Advanced	ND	0.4	20	20	4/7
	Primary and Secondary	ND	2	300	300	8/9
	Secondary and Advanced	1	6.5	12	12	2/2
	Primary, Secondary, and Advanced	ND	ND	1	1	2/6
Sr-90	Primary	0.6	0.6	0.6	0.6	1/1
	Secondary	ND	0.1	1	1	3/5
	Advanced	ND	0.1	1	1	5/7
	Primary and Secondary	ND	0.1	6	6	8/9
	Secondary and Advanced	0.1	0.55	1	1	2/2
	Primary, Secondary, and Advanced	ND	0.3	0.9	0.9	5/6

Table A.4 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Indicate the level(s) of wastewater treatment achieved by this treatment works."
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/gm = 37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Zn-65	Primary	0.06	0.06	0.06	0.06	1/1
	Secondary	ND	ND	ND	ND	0/7
	Advanced	ND	ND	ND	ND	0/7
	Primary and Secondary	ND	ND	ND	ND	0/11
	Secondary and Advanced	ND	ND	ND	ND	0/2
	Primary, Secondary, and Advanced	ND	ND	ND	ND	0/7

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.5 Concentrations of Radionuclides in Sludge Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	10 MGD or less	ND	0.36	3.5	16	115/153
	10+ MGD to 50 MGD	ND	0.3	1.9	6	72/91
	50+ MGD to 100 MGD	ND	0.21	1	2.1	24/32
	More than 100 MGD	ND	0.26	1.2	1.37	16/19
	NR	ND	0.205	0.71	1.8	11/16
Pa-234m	10 MGD or less	ND	ND	8	27	36/153
	10+ MGD to 50 MGD	ND	ND	6	17	23/91
	50+ MGD to 100 MGD	ND	ND	6	7	10/32
	More than 100 MGD	ND	ND	11	11	7/19
	NR	ND	ND	3	4	4/16
Pb-210	10 MGD or less	ND	ND	4	13	75/153
	10+ MGD to 50 MGD	ND	ND	4.7	12	32/91
	50+ MGD to 100 MGD	ND	ND	4.3	11	15/32
	More than 100 MGD	ND	ND	3.6	4	6/19
	NR	ND	ND	1.5	2.2	7/16
Pb-214	10 MGD or less	ND	0.4	3.9	17	126/153
	10+ MGD to 50 MGD	ND	0.31	2.1	4.4	72/91
	50+ MGD to 100 MGD	ND	0.255	1.4	2.2	25/32
	More than 100 MGD	ND	0.24	0.9	1.42	17/19
	NR	ND	0.285	0.78	1.9	13/16
Ra-226	10 MGD or less	ND	2	18	47	141/153
	10+ MGD to 50 MGD	ND	2	10	19	85/91
	50+ MGD to 100 MGD	ND	2.05	12	16	29/32
	More than 100 MGD	0	2.4	8	10.1	19/19
	NR	ND	2	5	9.6	15/16
Th-230	10 MGD or less	0.11	0.36	1.2	1.7	49/49
	10+ MGD to 50 MGD	0.18	0.35	0.8	1.7	23/23
	50+ MGD to 100 MGD	0.09	0.3	0.42	0.42	6/6
	More than 100 MGD	0.17	0.4	0.8	1	11/11
	NR	0.1	0.48	1.6	1.6	3/3
Th-234	10 MGD or less	ND	0.7	7	23	97/153
	10+ MGD to 50 MGD	ND	0.3	5	19	50/91
	50+ MGD to 100 MGD	ND	0.9	3	5.7	22/32
	More than 100 MGD	ND	1.3	10.6	12	13/19
	NR	ND	0.45	3.4	5	9/16
U-234	10 MGD or less	0.18	1.6	25	44	49/49
	10+ MGD to 50 MGD	0.5	2.1	8.5	17	23/23
	50+ MGD to 100 MGD	1.2	6.95	15	15	6/6
	More than 100 MGD	0.8	2.1	12	15.4	11/11
	NR	2.1	4.4	14	14	3/3

Table A.5 Concentrations of Radionuclides in Sludge Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: C-14 and H-3						
C-14*	10 MGD or less	ND	ND	2	3	34/85
	10+ MGD to 50 MGD	ND	ND	1	2	18/39
	50+ MGD to 100 MGD	ND	ND	ND	0.5	1/16
	More than 100 MGD	ND	0	0.6	0.6	7/10
	NR	ND	ND	0	0	3/8
H-3*	10 MGD or less	ND	0.3	5	8	58/85
	10+ MGD to 50 MGD	ND	0.3	3	4	27/39
	50+ MGD to 100 MGD	ND	0.45	4	4	13/16
	More than 100 MGD	ND	0.1	2	2	6/10
	NR	ND	0.1	6	6	7/8
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	10 MGD or less	ND	ND	2	13	52/153
	10+ MGD to 50 MGD	ND	ND	0.8	1.6	32/91
	50+ MGD to 100 MGD	ND	ND	0.3	1.1	5/32
	More than 100 MGD	ND	ND	0.8	0.9	6/19
	NR	ND	ND	1	3	6/16
Pb-212	10 MGD or less	ND	0.51	2.7	15	151/153
	10+ MGD to 50 MGD	ND	0.4	1.16	2	88/91
	50+ MGD to 100 MGD	ND	0.275	1	2.5	30/32
	More than 100 MGD	0.16	0.55	1.4	1.55	19/19
	NR	ND	0.255	0.8	2.5	15/16
Ra-224	10 MGD or less	ND	ND	1	12	25/153
	10+ MGD to 50 MGD	ND	ND	0.6	5	12/91
	50+ MGD to 100 MGD	ND	ND	0.4	0.8	4/32
	More than 100 MGD	ND	ND	0.6	0.7	4/19
	NR	ND	ND	0.4	1	2/16
Ra-228	10 MGD or less	ND	1	9.7	38	138/153
	10+ MGD to 50 MGD	ND	0.8	2.9	6	75/91
	50+ MGD to 100 MGD	ND	0.55	3	4.3	26/32
	More than 100 MGD	ND	0.9	3	4.8	17/19
	NR	ND	0.67	1.3	7.8	15/16
Th-228	10 MGD or less	0.16	0.9	6.8	9	49/49
	10+ MGD to 50 MGD	0.19	0.5	1.7	1.8	23/23
	50+ MGD to 100 MGD	0.07	0.27	0.48	0.48	6/6
	More than 100 MGD	0.19	0.6	1.4	1.7	11/11
	NR	0.8	1.1	6.7	6.7	3/3

Table A.5 Concentrations of Radionuclides in Sludge Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Th-232	10 MGD or less	0.08	0.2	0.6	0.7	49/49
	10+ MGD to 50 MGD	0.07	0.17	0.4	1.6	23/23
	50+ MGD to 100 MGD	0.02	0.1	0.4	0.4	6/6
	More than 100 MGD	0.09	0.39	0.56	0.9	11/11
	NR	0.2	0.22	1.1	1.1	3/3
Tl-208	10 MGD or less	ND	0.08	1.3	4.8	87/153
	10+ MGD to 50 MGD	ND	0.08	0.41	1.8	55/91
	50+ MGD to 100 MGD	ND	0.03	0.35	2.3	17/32
	More than 100 MGD	ND	0.07	0.69	0.88	11/19
	NR	ND	0.06	0.53	2.4	10/16
Radionuclide Group: Medical Isotopes						
I-125	10 MGD or less	ND	ND	ND	0.8	4/153
	10+ MGD to 50 MGD	ND	ND	ND	40	5/91
	50+ MGD to 100 MGD	ND	ND	ND	1.5	2/32
	More than 100 MGD	ND	ND	ND	ND	0/19
	NR	ND	ND	ND	ND	0/16
I-131	10 MGD or less	ND	0.7	37	840	111/153
	10+ MGD to 50 MGD	ND	2.6	101	280	75/91
	50+ MGD to 100 MGD	ND	4.4	34	105	29/32
	More than 100 MGD	ND	5.6	28	65	16/19
	NR	ND	2.1	27	60.5	15/16
In-111	10 MGD or less	ND	ND	ND	1.19	3/153
	10+ MGD to 50 MGD	ND	ND	ND	1.9	5/91
	50+ MGD to 100 MGD	ND	ND	0.12	3.5	5/32
	More than 100 MGD	ND	ND	0.033	0.18	2/19
	NR	ND	ND	0.13	3.6	4/16
Tl-201	10 MGD or less	ND	ND	25	241	61/153
	10+ MGD to 50 MGD	ND	0.9	56	207	49/91
	50+ MGD to 100 MGD	ND	4.95	42	110	24/32
	More than 100 MGD	ND	2.7	31	49	11/19
	NR	ND	ND	35	40	6/16
Tl-202	10 MGD or less	ND	ND	0.19	1.16	22/153
	10+ MGD to 50 MGD	ND	ND	0.53	0.92	28/91
	50+ MGD to 100 MGD	ND	ND	0.85	0.95	12/32
	More than 100 MGD	ND	ND	0.28	0.59	5/19
	NR	ND	ND	0.48	0.51	6/16

Table A.5 Concentrations of Radionuclides in Sludge Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	10 MGD or less	ND	1.1	6	17	123/153
	10+ MGD to 50 MGD	ND	0.9	8	14.9	78/91
	50+ MGD to 100 MGD	ND	2.15	9	13.5	31/32
	More than 100 MGD	ND	2	19	22	17/19
	NR	ND	0.95	2.9	3.2	14/16
K-40	10 MGD or less	ND	4	12	22	151/153
	10+ MGD to 50 MGD	ND	3.4	13	25	90/91
	50+ MGD to 100 MGD	0.8	3.65	12	26	32/32
	More than 100 MGD	2.3	5.1	10	10	19/19
	NR	1.8	4.35	6	10	16/16
La-138	10 MGD or less	ND	ND	ND	ND	0/153
	10+ MGD to 50 MGD	ND	ND	ND	0.07	1/91
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	ND	0/19
	NR	ND	ND	ND	ND	0/16
Radionuclide Group: Transuranics						
Am-241	10 MGD or less	ND	ND	ND	0.14	5/153
	10+ MGD to 50 MGD	ND	ND	ND	2.5	5/91
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	ND	0/19
	NR	ND	ND	ND	ND	0/16
Pu-238	10 MGD or less	ND	0.01	0.1	0.19	40/49
	10+ MGD to 50 MGD	ND	0.01	0.02	0.03	19/23
	50+ MGD to 100 MGD	ND	0.02	0.07	0.07	5/6
	More than 100 MGD	ND	0.01	0.07	0.14	10/11
	NR	ND	ND	0	0	1/3
Pu-239	10 MGD or less	ND	0.003	0.05	0.12	35/49
	10+ MGD to 50 MGD	ND	0.002	0.01	0.03	17/23
	50+ MGD to 100 MGD	ND	0	0.01	0.01	4/6
	More than 100 MGD	0	0.005	0.04	0.07	11/11
	NR	ND	ND	0.1	0.1	1/3
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	10 MGD or less	ND	ND	ND	0.09	1/153
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/91
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	0.06	1/19
	NR	ND	ND	ND	ND	0/16

Table A.5 Concentrations of Radionuclides in Sludge Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Rn-219	10 MGD or less	ND	ND	ND	ND	0/153
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/91
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	ND	0/19
	NR	ND	ND	ND	ND	0/16
Th-227	10 MGD or less	ND	ND	0.1	0.5	26/111
	10+ MGD to 50 MGD	ND	ND	0.05	0.15	12/51
	50+ MGD to 100 MGD	ND	ND	0.02	0.04	4/20
	More than 100 MGD	ND	ND	0.1	0.1	6/16
	NR	ND	ND	0.07	0.07	1/9
U-235	10 MGD or less	ND	ND	0.41	3.1	59/153
	10+ MGD to 50 MGD	ND	ND	0.42	1.3	31/91
	50+ MGD to 100 MGD	ND	ND	0.21	0.7	6/32
	More than 100 MGD	ND	0.06	0.58	0.6	11/19
	NR	ND	ND	0.3	0.6	5/16
Radionuclide Group: Fission and Activation Products						
Ce-141	10 MGD or less	ND	ND	ND	ND	0/153
	10+ MGD to 50 MGD	ND	ND	ND	0.016	1/91
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	ND	0/19
	NR	ND	ND	ND	ND	0/16
Co-57	10 MGD or less	ND	ND	ND	0.01	1/153
	10+ MGD to 50 MGD	ND	ND	ND	0.05	1/91
	50+ MGD to 100 MGD	ND	ND	ND	0.06	2/32
	More than 100 MGD	ND	ND	ND	0.04	1/19
	NR	ND	ND	ND	0.26	1/16
Co-60	10 MGD or less	ND	ND	0.016	5.1	9/153
	10+ MGD to 50 MGD	ND	ND	ND	0.1	3/91
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	0.03	1/19
	NR	ND	ND	ND	ND	0/16
Cr-51	10 MGD or less	ND	ND	ND	ND	0/153
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/91
	50+ MGD to 100 MGD	ND	ND	0.6	2.8	5/32
	More than 100 MGD	ND	ND	ND	3.5	1/19
	NR	ND	ND	ND	ND	0/16
Cs-134	10 MGD or less	ND	ND	ND	0.04	1/153
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/91
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	ND	0/19
	NR	ND	ND	ND	ND	0/16

Table A.5 Concentrations of Radionuclides in Sludge Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Cs-137	10 MGD or less	ND	ND	0.11	3.6	66/153
	10+ MGD to 50 MGD	ND	ND	0.06	0.3	32/91
	50+ MGD to 100 MGD	ND	0.01	0.05	0.3	17/32
	More than 100 MGD	ND	0.02	0.14	0.19	13/19
	NR	ND	ND	0.3	0.73	5/16
Eu-154	10 MGD or less	ND	ND	ND	21	1/153
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/91
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	ND	0/19
	NR	ND	ND	ND	ND	0/16
Fe-59	10 MGD or less	ND	ND	ND	0.4	1/153
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/91
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	ND	0/19
	NR	ND	ND	ND	ND	0/16
Sm-153	10 MGD or less	ND	ND	ND	27	1/153
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/91
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	ND	0/19
	NR	ND	ND	ND	ND	0/16
Sr-89	10 MGD or less	ND	1	7	30	32/49
	10+ MGD to 50 MGD	ND	0.2	20	70	14/23
	50+ MGD to 100 MGD	ND	0.5	30	30	8/10
	More than 100 MGD	ND	0.45	5	40	11/12
	NR	ND	0.05	10	10	3/4
Sr-90	10 MGD or less	ND	0.1	2	9.4	31/49
	10+ MGD to 50 MGD	ND	0.2	0.4	1	16/23
	50+ MGD to 100 MGD	ND	0.05	0.5	0.5	6/10
	More than 100 MGD	ND	0.1	0.4	1	7/12
	NR	0.1	0.1	0.1	0.1	4/4
Zn-65	10 MGD or less	ND	ND	ND	0.06	1/153
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/91
	Zn-6550+ MGD to 100 MGD	ND	ND	ND	ND	0/32
	More than 100 MGD	ND	ND	ND	ND	0/19
	NR	ND	ND	ND	ND	0/16
* Indicates concentrations for this radionuclide are expressed in pCi/g wet.						

Table A.6 Concentration of Radionuclides in Ash Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g = 37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	10 MGD or less	ND	2.2	16	16	6/7
	10+ MGD to 50 MGD	0.62	2.8	13.7	14	15/15
	50+ MGD to 100 MGD	0.64	1.7	3.8	3.8	5/5
	More than 100 MGD	2.1	3.1	14.1	14.1	5/5
	NR	0.72	1.7	1.8	1.8	3/3
Pa-234m	10 MGD or less	ND	3	77	77	6/7
	10+ MGD to 50 MGD	ND	2	7	10	11/15
	50+ MGD to 100 MGD	2	5	9	9	5/5
	More than 100 MGD	2	5	6	6	5/5
	NR	3	5	11	11	3/3
Pb-210	10 MGD or less	ND	3.4	8.9	8.9	5/7
	10+ MGD to 50 MGD	ND	ND	5.3	12.3	5/15
	50+ MGD to 100 MGD	ND	ND	5	5	2/5
	More than 100 MGD	ND	ND	6.4	6.4	1/5
	NR	1.8	1.9	8.5	8.5	3/3
Pb-214	10 MGD or less	0.92	2.4	16.4	16.4	7/7
	10+ MGD to 50 MGD	0.61	3.1	14.6	14.8	15/15
	50+ MGD to 100 MGD	0.69	1.9	4.1	4.1	5/5
	More than 100 MGD	2.2	3.4	15.1	15.1	5/5
	NR	0.74	1.9	2	2	3/3
Ra-226	10 MGD or less	1	3.4	15	15	7/7
	10+ MGD to 50 MGD	ND	3.4	18	18	13/15
	50+ MGD to 100 MGD	1.1	2	9	9	5/5
	More than 100 MGD	2.5	4	22	22	5/5
	NR	0	2	2.9	2.9	3/3
Th-230	10 MGD or less	ND	0.64	2.3	2.3	6/7
	10+ MGD to 50 MGD	0.3	0.8	1.5	2.6	13/13
	50+ MGD to 100 MGD	0.4	0.7	1.3	1.3	3/3
	More than 100 MGD	0.9	1	2.2	2.2	3/3
	NR	0.55	0.595	0.64	0.64	2/2
Th-234	10 MGD or less	1.1	2.7	80	80	7/7
	10+ MGD to 50 MGD	ND	1.8	7.3	21	11/15
	50+ MGD to 100 MGD	1.7	5.1	7.5	7.5	5/5
	More than 100 MGD	1.1	3.8	5.1	5.1	5/5
	NR	1.9	3.6	11	11	3/3
U-234	10 MGD or less	1.2	6	91	91	7/7
	10+ MGD to 50 MGD	1.3	2.6	18	49	13/13
	50+ MGD to 100 MGD	2.7	6.9	9	9	3/3
	More than 100 MGD	5	5.8	7	7	3/3
	NR	2.7	10.85	19	19	2/2

Table A.6 Concentration of Radionuclides in Ash Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g = 37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
U-238	10 MGD or less	1.1	4.3	74	74	7/7
	10+ MGD to 50 MGD	0.8	2.4	6.2	35	13/13
	50+ MGD to 100 MGD	2.5	6.2	6.4	6.4	3/3
	More than 100 MGD	3.8	4.7	5.1	5.1	3/3
	NR	2.5	8.75	15	15	2/2
C-14*	10 MGD or less	ND	ND	1	1	2/5
	10+ MGD to 50 MGD	ND	ND	0	0	1/6
	50+ MGD to 100 MGD	ND	ND - 1	1	1	1/2
	More than 100 MGD	ND	ND - 0	0	0	1/2
	NR	ND	ND	ND	ND	0/3
H-3*	10 MGD or less	ND	0.5	4	4	3/5
	10+ MGD to 50 MGD	ND	ND	1	1	2/6
	50+ MGD to 100 MGD	3	5.5	8	8	2/2
	More than 100 MGD	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	10 MGD or less	ND	1.5	15.7	15.7	6/7
	10+ MGD to 50 MGD	ND	1.2	3.5	5.5	10/15
	50+ MGD to 100 MGD	0.3	1.6	1.8	1.8	5/5
	More than 100 MGD	ND	0.9	1.4	1.4	4/5
	NR	ND	ND	ND	ND	0/3
Pb-212	10 MGD or less	1.14	1.7	15	15	7/7
	10+ MGD to 50 MGD	0.74	1.6	3.3	6.6	15/15
	50+ MGD to 100 MGD	0.36	1.5	1.7	1.7	5/5
	More than 100 MGD	0.91	1.42	1.5	1.5	5/5
	NR	0.73	1.1	1.2	1.2	3/3
Ra-224	10 MGD or less	ND	ND	1.8	1.8	2/7
	10+ MGD to 50 MGD	ND	0.4	2.4	4.9	8/15
	50+ MGD to 100 MGD	ND	ND	1.3	1.3	2/5
	More than 100 MGD	ND	0.5	1.3	1.3	3/5
	NR	ND	ND	ND	ND	0/3
Ra-228	10 MGD or less	1.8	3	30	30	7/7
	10+ MGD to 50 MGD	0.68	4.7	17	24	15/15
	50+ MGD to 100 MGD	0.65	2.2	3.4	3.4	5/5
	More than 100 MGD	1.6	2.4	9.9	9.9	5/5
	NR	1.8	1.9	2.9	2.9	3/3
Th-228	10 MGD or less	ND	1.3	14	14	6/7
	10+ MGD to 50 MGD	0.9	2.2	3.7	6.7	13/13
	50+ MGD to 100 MGD	0.4	1.7	1.7	1.7	3/3
	More than 100 MGD	0.9	1.1	2.3	2.3	3/3
	NR	0.68	0.84	1	1	2/2

Table A.6 Concentration of Radionuclides in Ash Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g = 37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Th-232	10 MGD or less	ND	0.49	0.7	0.7	6/7
	10+ MGD to 50 MGD	0.3	0.8	0.9	1.7	13/13
	50+ MGD to 100 MGD	0.22	0.8	0.8	0.8	3/3
	More than 100 MGD	0.5	0.7	1	1	3/3
	NR	0.39	0.425	0.46	0.46	2/2
Tl-208	10 MGD or less	0.36	1.4	13.5	13.5	7/7
	10+ MGD to 50 MGD	ND	0.66	2.3	3.1	13/15
	50+ MGD to 100 MGD	0.11	0.47	1.48	1.48	5/5
	More than 100 MGD	ND	0.34	1.6	1.6	4/5
	NR	0.63	1.03	1.05	1.05	3/3
Radionuclide Group: Medical Isotopes						
I-125	10 MGD or less	ND	ND	1	1	3/7
	10+ MGD to 50 MGD	ND	ND	ND	0.3	1/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
I-131	10 MGD or less	ND	0.13	3.8	3.8	5/7
	10+ MGD to 50 MGD	ND	0.39	20	46	9/15
	50+ MGD to 100 MGD	ND	ND	7.4	7.4	1/5
	More than 100 MGD	0.05	0.17	4.3	4.3	5/5
	NR	0.22	1.2	81	81	3/3
In-111	10 MGD or less	ND	ND	ND	ND	0/7
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
Tl-201	10 MGD or less	ND	3.3	61	61	6/7
	10+ MGD to 50 MGD	ND	ND	93	105	7/15
	50+ MGD to 100 MGD	ND	ND	26	26	1/5
	More than 100 MGD	ND	ND	35	35	2/5
	NR	0.62	1	73	73	3/3
Tl-202	10 MGD or less	ND	ND	0.07	0.07	1/7
	10+ MGD to 50 MGD	ND	ND	1.1	1.53	3/15
	50+ MGD to 100 MGD	ND	ND	0.77	0.77	1/5
	More than 100 MGD	ND	ND	0.99	0.99	2/5
	NR	ND	ND	ND	ND	0/3

Table A.6 Concentration of Radionuclides in Ash Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g = 37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	10 MGD or less	2.2	4.3	8.3	8.3	7/7
	10+ MGD to 50 MGD	ND	5.3	15	15.4	14/15
	50+ MGD to 100 MGD	0.5	0.8	1.9	1.9	5/5
	More than 100 MGD	3.5	12.5	27	27	5/5
	NR	3.6	6.1	30	30	3/3
K-40	10 MGD or less	11.4	13.7	19.8	19.8	7/7
	10+ MGD to 50 MGD	7.4	14	20	22.4	15/15
	50+ MGD to 100 MGD	13	17.4	22	22	5/5
	More than 100 MGD	11	15	16	16	5/5
	NR	7.9	10.8	20.9	20.9	3/3
La-138	10 MGD or less	ND	ND	ND	ND	0/7
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/15
	50+ MGD to 100 MGD	N D	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
Radionuclide Group: Transuranics						
Am-241	10 MGD or less	ND	ND	0.21	0.21	2/7
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
Pu-238	10 MGD or less	ND	ND	0.1	0.1	3/7
	10+ MGD to 50 MGD	ND	0.02	0.08	0.09	10/13
	50+ MGD to 100 MGD	ND	0.03	0.05	0.05	2/3
	More than 100 MGD	0	0.01	0.1	0.1	3/3
	NR	0	0.01	0.02	0.02	2/2
Pu-239	10 MGD or less	ND	ND	0.03	0.03	3/7
	10+ MGD to 50 MGD	ND	0.01	0.06	0.17	11/13
	50+ MGD to 100 MGD	ND	0.01	0.02	0.02	2/3
	More than 100 MGD	0	0.02	0.04	0.04	3/3
	NR	0.01	0.03	0.05	0.05	2/2
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	10 MGD or less	ND	ND	0.2	0.2	1/7
	10+ MGD to 50 MGD	ND	ND	0.5	0.8	2/15
	50+ MGD to 100 MGD	ND	ND	0.1	0.1	1/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3

Table A.6 Concentration of Radionuclides in Ash Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g = 37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Rn-219	10 MGD or less	ND	ND	ND	ND	0/7
	10+ MGD to 50 MGD	ND	ND	0.2	0.4	3/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
Th-227	10 MGD or less	ND	ND	0.2	0.2	2/7
	10+ MGD to 50 MGD	ND	ND-0.02	0.6	1.1	7/14
	50+ MGD to 100 MGD	ND	0.04	0.2	0.2	3/5
	More than 100 MGD	ND	ND- 0.2	0.2	0.2	2/4
	NR	ND	ND	ND	ND	0/3
U-235	10 MGD or less	0.07	0.3	3.4	3.4	7/7
	10+ MGD to 50 MGD	ND	0.11	0.7	1.7	14/15
	50+ MGD to 100 MGD	ND	0.18	0.6	0.6	3/5
	More than 100 MGD	ND	0.18	0.4	0.4	4/5
	NR	ND	0.14	0.7	0.7	2/3
Radionuclide Group: Fission and Activation Products						
Ce-141	10 MGD or less	ND	ND	ND	ND	0/7
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
Co-57	10 MGD or less	ND	ND	ND	ND	0/7
	10+ MGD to 50 MGD	ND	ND	ND	0.17	1/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
Co-60	10 MGD or less	ND	ND	0.038	0.038	1/7
	10+ MGD to 50 MGD	ND	ND	ND	3.46	1/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
Cr-51	10 MGD or less	ND	ND	ND	ND	0/7
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/15
	50+ MGD to 100 MGD	ND	ND	0.3	0.3	2/5
	More than 100 MGD	ND	ND	0.8	0.8	2/5
	NR	ND	ND	35	35	1/3
Cs-134	10 MGD or less	ND	ND	ND	ND	0/7
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3

Table A.6 Concentration of Radionuclides in Ash Summarized by Annual Average Flow Rate Expressed in Million Gallons per Day (MGD)
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g = 37 Bq/kg.)

Radionuclide	Flow Rate	Min	Median	95th P	Max	No. Detects/ No. Analyses
Cs-137	10 MGD or less	0	0.07	0.11	0.11	7/7
	10+ MGD to 50 MGD	ND	0.06	0.18	0.37	14/15
	50+ MGD to 100 MGD	0.02	0.08	0.09	0.09	5/5
	More than 100 MGD	0.04	0.08	0.27	0.27	5/5
	NR	0.04	0.07	0.23	0.23	3/3
Eu-154	10 MGD or less	ND	ND	ND	ND	0/7
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
Fe-59	10 MGD or less	ND	ND	ND	ND	0/7
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
Sm-153	10 MGD or less	ND	ND	ND	ND	0/7
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3
Sr-89	10 MGD or less	ND	ND	2	2	3/7
	10+ MGD to 50 MGD	ND	1.15	20	60	11/14
	50+ MGD to 100 MGD	ND	ND	30	30	1/4
	More than 100 MGD	0.6	3	300	300	3/3
	NR	0.4	2.7	5	5	2/2
Sr-90	10 MGD or less	ND	0	1	1	6/7
	10+ MGD to 50 MGD	ND	0.2	1	1	12/14
	50+ MGD to 100 MGD	ND	0.95	1	1	3/4
	More than 100 MGD	ND	0.1	6	6	2/3
	NR	ND	ND-0.4	0.4	0.4	1/2
Zn-65	10 MGD or less	ND	ND	0.06	0.06	1/7
	10+ MGD to 50 MGD	ND	ND	ND	ND	0/15
	50+ MGD to 100 MGD	ND	ND	ND	ND	0/5
	More than 100 MGD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/3

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	A	ND	0.245	1.1	1.5	79/106
	B	ND	0.485	6.8	16	74/84
	C	ND	0.32	1.6	1.6	2/3
	D	ND	0.26	1	1.4	8/11
	AB	ND	0.39	1.8	4.1	33/48
	AC	ND	0.27	0.8	1.2	10/13
	BC	ND	0.4	7.9	13	14/17
	CD	0.17	0.17	0.17	0.17	1/1
	ABC	ND	0.19	0.8	2.1	10/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	0.17	0.34	1.23	1.23	5/5
	NR	ND	ND	0.2	0.2	2/5
Pa-234m	A	ND	ND	7	16	32/106
	B	ND	ND	5	27	15/84
	C	ND	ND	1	1	1/3
	D	ND	ND	6	17	3/11
	AB	ND	ND	9	20	15/48
	AC	ND	ND	2	6	2/13
	BC	ND	ND	6	17	3/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	6	22	7/17
	BCD	3	3	3	3	1/1
	ABCD	ND	ND	2.6	2.6	1/5
	NR	ND	ND	ND	ND	0/5
Pb-210	A	ND	ND	4	13	48/106
	B	ND	ND	2.5	9	35/84
	C	ND	2.2	3.1	3.1	2/3
	D	ND	1.2	8	11	8/11
	AB	ND	ND	6	12	18/48
	AC	ND	ND	2.5	3	6/13
	BC	ND	ND	1.4	4.7	7/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	2.5	2.7	7/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	1.5	3	3	3/5
	NR	ND	ND	0	0	1/5

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Pb-214	A	ND	0.265	1.3	1.5	79/106
	B	ND	0.545	7.6	17	75/84
	C	0.27	0.33	1.8	1.8	3/3
	D	ND	0.29	1.3	2	9/11
	AB	ND	0.4	2	4.4	36/48
	AC	ND	0.31	0.8	1	11/13
	BC	ND	0.48	8.3	15	14/17
	CD	0.28	0.28	0.28	0.28	1/1
	ABC	ND	0.24	0.9	2.2	15/17
	BCD	0.2	0.2	0.2	0.2	1/1
	ABCD	0.15	0.39	1.4	1.4	5/5
	NR	ND	0.2	0.4	0.4	4/5
Radionuclide Group: Uranium-238 Decay Series						
Ra-226	A	ND	2	10	17	96/106
	B	ND	3	24	47	78/84
	C	0	3	5.6	5.6	3/3
	D	ND	2.2	4	5	9/11
	AB	ND	2	11	15	46/48
	AC	0	1.7	3	4	13/13
	BC	0.3	3	19	30	17/17
	CD	3.2	3.2	3.2	3.2	1/1
	ABC	0	1.5	10	12	17/17
	BCD	5	5	5	5	1/1
	ABCD	ND	1.2	2.2	2.2	4/5
	NR	ND	2	4	4	4/5
Th-230	A	0.1	0.435	1.2	1.6	24/24
	B	0.12	0.31	0.8	1.7	38/38
	C	0.61	0.61	0.61	0.61	1/1
	D	0.21	0.35	1.7	1.7	3/3
	AB	0.09	0.36	0.57	0.62	12/12
	AC	0.49	0.49	0.49	0.49	1/1
	BC	0.11	0.315	0.5	0.5	8/8
	ABC	0.17	0.3	0.38	0.38	5/5

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Th-234	A	ND	0.7	7.8	15	65/106
	B	ND	0.5	5	23	50/84
	C	ND	0.5	1.3	1.3	2/3
	D	ND	1	2.3	11	9/11
	AB	ND	0.9	8	19	32/48
	AC	ND	1	2.3	6.8	8/13
	BC	ND	0.1	3.6	15	9/17
	CD	1.2	1.2	1.2	1.2	1/1
	ABC	ND	0.5	5	16	9/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	0.9	2.7	2.7	4/5
	NR	ND	ND	3	3	2/5
U-234	A	0.43	2.1	14	15.4	24/24
	B	0.39	1.95	14	34	38/38
	C	1	1	1	1	1/1
	D	0.71	2.1	17	17	3/3
	AB	0.8	2.05	15	44	12/12
	AC	2.1	2.1	2.1	2.1	1/1
	BC	0.18	0.85	25	25	8/8
	ABC	0.8	1.3	20	20	5/5
U-238	A	0.37	1.9	10.3	12.5	24/24
	B	0.18	1.35	6.6	26	38/38
	C	1	1	1	1	1/1
	D	0.53	2	12	12	3/3
	AB	0.7	1.6	8	12	12/12
	AC	1.4	1.4	1.4	1.4	1/1
	BC	0.19	0.65	15	15	8/8
	ABC	0.6.	1.3	16	16	5/5
Radionuclide Group: C-14 and H-3						
C-14 *	A	ND	ND	1	2	23/58
	B	ND	ND	1	2	15/40
	C	0	0.5	1	1	2/2
	D	ND	ND	2	2	3/8
	AB	ND	ND	1	3	9/23
	AC	ND	ND	0	0	2/7
	BC	ND	0.5	1	1	5/8
	ABC	ND	ND	2	2	3/8
	ABCD	ND	ND	ND	ND	0/3
	NR	ND	ND	ND	ND	0/1

Table A.7 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
H-3*	A	ND	0.25	4	5	39/58
	B	ND	0.25	4	6	27/40
	C	0	3.5	7	7	2/2
	D	0.1	1	3	3	8/8
	AB	ND	0.5	3	5	18/23
	AC	ND	ND	4	4	3/7
	BC	ND	ND - 1	8	8	4/8
	ABC	ND	0.45	6	6	7/8
	ABCD	0	0.4	4	4	3/3
	NR	ND	ND	ND	ND	0/1
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	A	ND	ND	1	1.3	38/106
	B	ND	ND	3.3	13	29/84
	C	ND	ND	0.7	0.7	1/3
	D	ND	ND	ND	0.4	1/11
	AB	ND	ND	1.4	2.6	12/48
	AC	ND	ND	0.7	0.8	4/13
	BC	ND	ND	1.3	4	6/17
	CD	1	1	1	1	1/1
	ABC	ND	ND	0.9	0.9	5/17
	BCD	0.6	0.6	0.6	0.6	1/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	0.5	1	1	3/5
Pb-212	A	ND	0.435	1	1.55	102/106
	B	ND	0.555	3	15	82/84
	C	0.57	0.8	3.1	3.1	3/3
	D	0.2	0.47	1.4	1.9	11/11
	AB	ND	0.4	1.9	2.9	47/48
	AC	ND	0.49	1.4	1.4	12/13
	BC	0.07	0.47	2.5	3	17/17
	CD	1.2	1.2	1.2	1.2	1/1
	ABC	0.12	0.27	0.58	0.62	17/17
	BCD	0.47	0.47	0.47	0.47	1/1
	ABCD	0.21	0.28	2.5	2.5	5/5
	NR	0.2	0.4	0.6	0.6	5/5

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Ra-224	A	ND	ND	0.7	1.1	16/106
	B	ND	ND	2.3	12	15/84
	C	ND	ND	1	1	1/3
	D	ND	ND	ND	0.4	1/11
	AB	ND	ND	1	2.7	8/48
	AC	ND	ND	ND	0.4	1/13
	BC	ND	ND	0.9	3	3/17
	CD	1.1	1.1	1.1	1.1	1/1
	ABC	ND	ND	ND	0.2	1/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Ra-228	A	ND	0.7	1.9	5	92/106
	B	ND	1.2	12	38	76/84
	C	0.6	0.8	8	8	3/3
	D	ND	0.78	1.6	2.8	9/11
	AB	ND	0.85	3	6	37/48
	AC	ND	0.56	3.1	4.8	11/13
	BC	ND	1.3	12	13	16/17
	CD	4.5	4.5	4.5	4.5	1/1
	ABC	ND	0.84	1.6	2.3	16/17
	BCD	0.9	0.9	0.9	0.9	1/1
	ABCD	0.44	0.6	2.5	2.5	5/5
	NR	ND	0.7	1.1	1.1	4/5
Radionuclide Group: Thorium-232 Decay Series						
Th-228	A	0.23	0.53	1.3	1.4	24/24
	B	0.19	0.8	6.8	9	38/38
	C	2.6	2.6	2.6	2.6	1/1
	D	0.36	0.5	1.8	1.8	3/3
	AB	0.07	0.495	0.8	2.4	12/12
	AC	1.7	1.7	1.7	1.7	1/1
	BC	0.42	1.65	4.1	4.1	8/8
	ABC	0.19	0.27	0.57	0.57	5/5
Th-232	A	0.13	0.315	0.9	1.1	24/24
	B	0.07	0.2	0.46	0.6	38/38
	C	0.37	0.37	0.37	0.37	1/1
	D	0.13	0.24	1.6	1.6	3/3
	AB	0.02	0.205	0.4	0.4	12/12
	AC	0.44	0.44	0.44	0.44	1/1
	BC	0.08	0.105	0.31	0.31	8/8
	ABC	0.09	0.1	0.27	0.27	5/5

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Tl-208	A	ND	0.08	0.69	0.99	62/106
	B	ND	0.09	2.4	4.8	52/84
	C	0.23	0.53	2.7	2.7	3/3
	D	ND	ND	1.4	1.8	5/11
	AB	ND	ND	0.6	1.44	22/48
	AC	ND	ND	0.2	0.23	6/13
	BC	ND	0.07	1.1	1.9	10/17
	CD	0.37	0.37	0.37	0.37	1/1
	ABC	ND	0.05	0.17	0.27	11/17
	BCD	0.11	0.11	0.11	0.11	1/1
	ABCD	ND	0.06	2.3	2.3	3/5
	NR	ND	0.11	0.15	0.15	4/5
Radionuclide Group: Medical Isotopes						
I-125	A	ND	ND	0.8	40	6/106
	B	ND	ND	ND	0.9	1/84
	C	ND	ND	0.3	0.3	1/3
	D	ND	ND	ND	0.5	1/11
	AB	ND	ND	ND	0.7	1/48
	AC	ND	ND	ND	4	1/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
I-131	A	ND	2.35	60.5	280	88/106
	B	ND	1.3	42	220	65/84
	C	ND	0.59	2.2	2.2	2/3
	D	ND	4.1	51	73	9/11
	AB	ND	1.65	105	840	36/48
	AC	ND	0.56	23	106	9/13
	BC	ND	0.2	4.2	39	9/17
	CD	0.11	0.11	0.11	0.11	1/1
	ABC	0.04	4.2	19	36	17/17
	BCD	2	2	2	2	1/1
	ABCD	0.17	11.3	65	65	5/5
	NR	ND	2.2	34	34	4/5

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
In-111	A	ND	ND	0.04	3.6	8/106
	B	ND	ND	ND	0.17	2/84
	C	ND	ND	0.05	0.05	1/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	0.12	1/48
	AC	ND	ND	ND	0.04	1/13
	BC	ND	ND	0.044	0.4	2/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	3	3.5	4/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Tl-201	A	ND	0.9	45	207	59/106
	B	ND	ND	34	138	31/84
	C	ND	0.49	0.7	0.7	2/3
	D	ND	3.5	11.6	16	6/11
	AB	ND	ND	110	241	20/48
	AC	ND	0.34	16	189	7/13
	BC	ND	ND	7.3	19	6/17
	CD	3.7	3.7	3.7	3.7	1/1
	ABC	ND	2.3	19	51	13/17
	BCD	56	56	56	56	1/1
	ABCD	ND	10.2	31	31	4/5
	NR	ND	ND	13	13	1/5
Tl-202	A	ND	ND	0.51	0.92	25/106
	B	ND	ND	0.66	0.95	19/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	0.11	1/11
	AB	ND	ND	0.4	0.85	8/48
	AC	ND	ND	0.19	0.19	3/13
	BC	ND	ND	0.09	0.55	3/17
	CD	0.14	0.14	0.14	0.14	1/1
	ABC	ND	ND	0.54	0.54	8/17
	BCD	1.16	1.16	1.16	1.16	1/1
	ABCD	ND	ND	0.59	0.59	2/5
	NR	ND	ND	0.14	0.14	2/5

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	A	ND	1.8	11	22	95/106
	B	ND	0.57	4	8	64/84
	C	0.7	1.2	2.9	2.9	3/3
	D	0.2	2	8	9	11/11
	AB	ND	0.8	4.9	8.7	38/48
	AC	ND	1.4	14.9	17	12/13
	BC	ND	0.6	5.5	8.6	12/17
	CD	1.5	1.5	1.5	1.5	1/1
	ABC	0.4	1.9	6.6	10.7	17/17
	BCD	1.8	1.8	1.8	1.8	1/1
	ABCD	0.11	1.4	4.1	4.1	5/5
	NR	ND	1.5	1.6	1.6	4/5
K-40	A	ND	4.35	12	15.4	105/106
	B	ND	4	13	22	83/84
	C	3.2	3.6	5.4	5.4	3/3
	D	2.3	4.5	22	26	11/11
	AB	ND	3.25	12	25	47/48
	AC	1.1	5.1	10	10	13/13
	BC	1.4	3.6	6	6	17/17
	CD	3	3	3	3	1/1
	ABC	0.9	3.5	8.7	9	17/17
	BCD	1.9	1.9	1.9	1.9	1/1
	ABCD	2.5	4.8	6.7	6.7	5/5
	NR	2.1	3	4	4	5/5
La-138	A	ND	ND	ND	ND	0/106
	B	ND	ND	ND	ND	0/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	ND	0/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	0.07	0.07	1/5

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Transuranics						
Am-241	A	ND	ND	ND	0.3	3/106
	B	ND	ND	0	2.5	5/84
	C	ND	ND	0.12	0.12	1/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	ND	0/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	0.1	1/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Pu-238	A	ND	0.01	0.07	0.14	22/24
	B	ND	0.01	0.05	0.1	30/38
	C	0.19	0.19	0.19	0.19	1/1
	D	ND	0.01	0.01	0.01	2/3
	AB	ND	0.01	0.03	0.03	10/12
	AC	ND	ND	ND	ND	0/1
	BC	ND	0.01	0.1	0.1	6/8
	ABC	ND	0.01	0.02	0.02	4/5
Pu-239	A	ND	0.0035	0.07	0.1	17/24
	B	ND	0.002	0.03	0.03	26/38
	C	0.11	0.11	0.11	0.11	1/1
	D	ND	0.004	0.009	0.009	2/3
	AB	ND	0.0035	0.04	0.04	11/12
	AC	0.00	0.004	0.004	0.004	1/1
	BC	ND	0.01	0.12	0.12	6/8
	ABC	ND	0.003	0.01	0.01	4/5

Table A.7 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "What are the primary sources of drinking water for your community?"

A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	A	ND	ND	ND	0.09	1/106
	B	ND	ND	ND	ND	0/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	0.06	1/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Rn-219	A	ND	ND	ND	ND	0/106
	B	ND	ND	ND	ND	0/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	ND	0/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Th-227	A	ND	ND	0.07	0.1	7/65
	B	ND	ND	0.1	0.5	22/62
	C	ND	ND	ND	ND	0/2
	D	ND	ND	0.04	0.04	2/10
	AB	ND	ND	0.07	0.1	10/33
	AC	ND	ND	ND	ND	0/7
	BC	ND	ND	0.2	0.2	5/13
	ABC	ND	ND	0.02	0.04	3/11
	ABCD	ND	ND	ND	ND	0/3
	NR	ND	ND	ND	ND	0/1

Table A.7 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
U-235	A	ND	ND	0.42	0.61	31/106
	B	ND	ND - 0	0.5	1.3	42/84
	C	ND	0.06	0.17	0.17	2/3
	D	ND	ND	0.07	1.3	3/11
	AB	ND	ND	0.46	3.1	16/48
	AC	ND	ND	0.15	0.31	3/13
	BC	ND	0.01	0.28	0.7	9/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	0.1	0.7	5/17
	BCD	0.3	0.3	0.3	0.3	1/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Radionuclide Group: Fission and Activation Products						
Ce-141	A	ND	ND	ND	ND	0/106
	B	ND	ND	ND	0.016	1/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	ND	0/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Co-57	A	ND	ND	ND	ND	0/106
	B	ND	ND	ND	0.05	2/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	0.26	1/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	0.06	0.06	3/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Co-60	A	ND	ND	ND	0.1	3/106
	B	ND	ND	ND	1.16	4/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	5.1	2/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	0.07	1/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	0.04	0.08	3/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Cr-51	A	ND	ND	ND	2.8	3/106
	B	ND	ND	ND	ND	0/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	3.5	1/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	0.6	0.8	2/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Radionuclide Group: Fission and Activation Products						
Cs-134	A	ND	ND	ND	ND	0/106
	B	ND	ND	ND	0.04	1/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	ND	0/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Cs-137	A	ND	0.02	0.19	1.5	63/106
	B	ND	ND	0.08	3.6	25/84
	C	ND	0.03	0.07	0.07	2/3
	D	ND	ND	0.1	0.3	4/11
	AB	ND	ND	0.11	1.1	16/48
	AC	ND	ND	0.05	0.07	5/13
	BC	ND	ND	0.1	0.11	6/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	0.014	0.06	0.11	11/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	0.05	0.05	1/5
	NR	ND	ND	ND	ND	0/5
Eu-154	A	ND	ND	ND	21	1/106
	B	ND	ND	ND	ND	0/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	ND	0/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Fe-59	A	ND	ND	ND	ND	0/106
	B	ND	ND	ND	0.4	1/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	ND	0/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Fission and Activation Products						
Sm-153	A	ND	ND	ND	ND	0/106
	B	ND	ND	ND	ND	0/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	27	1/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5
Sr-89	A	ND	0.15	2	10	18/26
	B	ND	1	20	70	25/35
	C	2	2	2	2	1/1
	D	ND	ND - 0	2	2	3/6
	AB	ND	0.3	20	40	11/16
	AC	1	1	1	1	1/1
	BC	ND	1	7	7	4/7
	ABC	ND	3	30	30	5/6
Sr-90	A	ND	0.1	9	9.4	19/26
	B	ND	0.1	0.4	2	23/35
	C	ND	ND	ND	ND	0/1
	D	ND	0.15	0.4	0.4	4/6
	AB	ND	0.05	0.3	0.7	9/16
	AC	1	1	1	1	1/1
	BC	ND	0.1	0.4	0.4	5/7
	ABC	ND	ND - 0.1	0.3	0.3	3/6

Table A.7 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Zn-65	A	ND	ND	ND	ND	0/106
	B	ND	ND	ND	ND	0/84
	C	ND	ND	ND	ND	0/3
	D	ND	ND	ND	ND	0/11
	AB	ND	ND	ND	0.06	1/48
	AC	ND	ND	ND	ND	0/13
	BC	ND	ND	ND	ND	0/17
	CD	ND	ND	ND	ND	0/1
	ABC	ND	ND	ND	ND	0/17
	BCD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/5
	NR	ND	ND	ND	ND	0/5

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.8 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	A	ND	2.15	9	13.7	19/20
	B	1.3	4.65	16	16	4/4
	D	1.06	1.28	2.8	2.8	3/3
	AB	0.72	9.9	14.1	14.1	5/5
	AC	2.8	2.8	2.8	2.8	1/1
	ACD	0.64	0.64	0.64	0.64	1/1
	ABCD	2.2	2.2	2.2	2.2	1/1
Pa-234m	A	ND	4	7	10	17/20
	B	ND	3	77	77	3/4
	D	1.1	7	11	11	3/3
	AB	ND	6	11	11	4/5
	AC	2	2	2	2	1/1
	ACD	2	2	2	2	1/1
	ABCD	2	2	2	2	1/1
Pb-210	A	ND	2.7	8.5	12.3	12/20
	B	ND	4.45	8.9	8.9	3/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	1.8	1.8	1/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1
Pb-214	A	0.61	2.3	10	14.8	20/20
	B	1.32	5.1	16.4	16.4	4/4
	D	1.17	1.35	3	3	3/3
	AB	0.74	11.1	15.1	15.1	5/5
	AC	3.1	3.1	3.1	3.1	1/1
	ACD	0.69	0.69	0.69	0.69	1/1
	ABCD	2.4	2.4	2.4	2.4	1/1
Ra-226	A	ND	2.9	17	18	19/20
	B	ND	4.05	15	15	3/4
	D	2.2	2.5	6.6	6.6	3/3
	AB	0	16.7	22	22	5/5
	AC	9.5	9.5	9.5	9.5	1/1
	ACD	1.1	1.1	1.1	1.1	1/1
	ABCD	4	4	4	4	1/1

Table A.8 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Th-230	A	ND	1	2.3	2.6	14/15
	B	0.64	0.95	1	1	4/4
	D	0.3	0.45	0.6	0.6	2/2
	AB	0.55	0.7	1.3	1.3	5/5
	AC	0.6	0.6	0.6	0.6	1/1
	ACD	0.4	0.4	0.4	0.4	1/1
Radionuclide Group: Uranium-238 Decay Series						
Th-234	A	ND	3.6	7.2	7.3	19/20
	B	1.1	11.4	80	80	4/4
	D	ND	4.9	10	10	2/3
	AB	ND	4.2	11	11	4/5
	AC	ND	ND	ND	ND	0/1
	ACD	1.7	1.7	1.7	1.7	1/1
	ABCD	1.1	1.1	1.1	1.1	1/1
U-234	A	1.3	5.1	18	49	15/15
	B	1.2	1.95	91	91	4/4
	D	12	12.5	13	13	2/2
	AB	6.9	7.3	19	19	5/5
	AC	1.9	1.9	1.9	1.9	1/1
	ACD	2.7	2.7	2.7	2.7	1/1
U-238	A	0.8	3.1	6.4	35	15/15
	B	1.1	1.65	74	74	4/4
	D	6.2	7.6	9	9	2/2
	AB	3.3	5.1	15	15	5/5
	AC	1.7	1.7	1.7	1.7	1/1
	ACD	2.5	2.5	2.5	2.5	1/1
Radionuclide Group: C-14 and H-3						
C-14*	A	ND	ND	0	1	4/13
	B	ND	ND	1	1	1/3
	AB	ND	ND	ND	ND	0/2
H-3*	A	ND	ND	3	8	6/13
	B	ND	ND	4	4	1/3
	AB	ND	ND	ND	ND	0/2

Table A.8 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	A	ND	1.25	2.4	3.5	14/20
	B	ND	3.45	15.7	15.7	3/4
	D	0.6	0.9	1.5	1.5	3/3
	AB	ND	ND	1.6	1.6	2/5
	AC	2.1	2.1	2.1	2.1	1/1
	ACD	0.3	0.3	0.3	0.3	1/1
	ABCD	0.9	0.9	0.9	0.9	1/1
Pb-212	A	0.73	1.5	2.6	3.3	20/20
	B	1.3	4.55	15	15	4/4
	D	0.74	0.99	1.7	1.7	3/3
	AB	1	1.5	1.6	1.6	5/5
	AC	2.4	2.4	2.4	2.4	1/1
	ACD	0.36	0.36	0.36	0.36	1/1
	ABCD	1.14	1.14	1.14	1.14	1/1
Ra-224	A	ND	ND	2	2.4	7/20
	B	ND	ND	4.9	4.9	1/4
	D	0.4	0.8	1.8	1.8	3/3
	AB	ND	ND	1.3	1.3	2/5
	AC	0.4	0.4	0.4	0.4	1/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	0.6	0.6	0.6	0.6	1/1
Ra-228	A	0.68	2.45	9.6	17	20/20
	B	2.2	15.15	30	30	4/4
	D	0.71	1.46	3.2	3.2	3/3
	AB	1.8	7.8	9.9	9.9	5/5
	AC	5.7	5.7	5.7	5.7	1/1
	ACD	0.65	0.65	0.65	0.65	1/1
	ABCD	2.4	2.4	2.4	2.4	1/1
Th-228	A	ND	1.3	3.4	3.7	14/15
	B	0.7	4.1	14	14	4/4
	D	0.9	1.4	1.9	1.9	2/2
	AB	0.68	1.7	2.4	2.4	5/5
	AC	1.7	1.7	1.7	1.7	1/1
	ACD	0.4	0.4	0.4	0.4	1/1

Table A.8 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "What are the primary sources of drinking water for your community?"

A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Th-232	A	ND	0.8	1	1.7	14/15
	B	0.4	0.475	0.9	0.9	4/4
	D	0.5	0.6	0.7	0.7	2/2
	AB	0.39	0.5	0.8	0.8	5/5
	AC	0.5	0.5	0.5	0.5	1/1
	ACD	0.22	0.22	0.22	0.22	1/1
Tl-208	A	ND	0.89	2.3	3.1	19/20
	B	1.16	2	13.5	13.5	4/4
	D	0.23	0.3	0.55	0.55	3/3
	AB	ND	0.47	1.05	1.05	3/5
	AC	0.73	0.73	0.73	0.73	1/1
	ACD	0.11	0.11	0.11	0.11	1/1
	ABCD	0.34	0.34	0.34	0.34	1/1
Radionuclide Group: Medical Isotopes						
I-125	A	ND	ND	ND	0.4	1/20
	B	ND	ND - 0.8	1	1	2/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	0.3	0.3	1/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1
I-131	A	ND	0.22	4.3	20	14/20
	B	ND	0.815	46	46	3/4
	D	ND	ND	ND	ND	0/3
	AB	ND	0.05	81	81	3/5
	AC	1.14	1.14	1.14	1.14	1/1
	ACD	7.4	7.4	7.4	7.4	1/1
	ABCD	0.61	0.61	0.61	0.61	1/1
In-111	A	ND	ND	ND	ND	0/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1

Table A.8 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Tl-201	A	ND	0.49	35	48	11/20
	B	3.3	46	105	105	4/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	73	73	1/5
	AC	93	93	93	93	1/1
	ACD	26	26	26	26	1/1
	ABCD	11	11	11	11	1/1
Tl-202	A	ND	ND	0.14	1.1	3/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	0.1	0.1	1/5
	AC	1.53	1.53	1.53	1.53	1/1
	ACD	0.77	0.77	0.77	0.77	1/1
	ABCD	0.99	0.99	0.99	0.99	1/1
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	A	0.14	7.65	27	30	20/20
	B	2.2	3.3	15	15	4/4
	D	ND	1.2	2.2	2.2	2/3
	AB	0.5	3.6	5.3	5.3	5/5
	AC	4.3	4.3	4.3	4.3	1/1
	ACD	1.9	1.9	1.9	1.9	1/1
	ABCD	12.5	12.5	12.5	12.5	1/1
K-40	A	7.4	15.9	22	22.4	20/20
	B	8.4	14.75	19.8	19.8	4/4
	D	9.7	12	12.7	12.7	3/3
	AB	10.8	13	14.2	14.2	5/5
	AC	9.4	9.4	9.4	9.4	1/1
	ACD	15	15	15	15	1/1
	ABCD	16	16	16	16	1/1
La-138	A	ND	ND	ND	ND	0/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1

Table A.8 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Transuranics						
Am-241	A	ND	ND	ND	0.21	1/20
	B	ND	ND	0.04	0.04	1/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1
Pu-238	A	ND	0.03	0.1	0.1	11/15
	B	ND	0	0.02	0.02	3/4
	D	ND	ND - 0.01	0.01	0.01	1/2
	AB	0	0.02	0.08	0.08	5/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
Pu-239	A	ND	0.01	0.06	0.17	11/15
	B	ND	0.009	0.02	0.02	3/4
	D	0.01	0.02	0.03	0.03	2/2
	AB	0	0.01	0.05	0.05	5/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	A	ND	ND	0.5	0.8	2/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	0.2	0.2	1/3
	AB	ND	ND	0.1	0.1	1/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1
Rn-219	A	ND	ND	0.2	0.4	2/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	0.2	0.2	0.2	0.2	1/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1

Table A.8 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Th-227	A	ND	ND	0.3	1.1	7/20
	B	ND	ND	0.6	0.6	1/4
	D	0.02	0.11	0.2	0.2	2/2
	AB	ND	ND	0.2	0.2	2/5
	AC	0.1	0.1	0.1	0.1	1/1
	ACD	0.04	0.04	0.04	0.04	1/1
U-235	A	ND	0.14	0.7	1.7	15/20
	B	0.06	0.08	3.4	3.4	4/4
	D	0.15	0.4	0.5	0.5	3/3
	AB	0.14	0.4	0.7	0.7	5/5
	AC	0.03	0.03	0.03	0.03	1/1
	ACD	0.18	0.18	0.18	0.18	1/1
	ABCD	0.11	0.11	0.11	0.11	1/1
Radionuclide Group: Fission and Activation Products						
Ce-141	A	ND	ND	ND	ND	0/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1
Co-57	A	ND	ND	ND	0.17	1/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1
Co-60	A	ND	ND	0.038	3.46	2/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1

Table A.8 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Cr-51	A	ND	ND	ND	0.2	1/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	35	35	2/5
	AC	ND	ND	ND	ND	0/1
	ACD	0.3	0.3	0.3	0.3	1/1
	ABCD	0.8	0.8	0.8	0.8	1/1
Cs-134	A	ND	ND	ND	ND	0/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1
Cs-137	A	ND	0.085	0.27	0.37	19/20
	B	0.03	0.05	0.08	0.08	4/4
	D	0.03	0.05	0.11	0.11	3/3
	AB	0.04	0.05	0.08	0.08	5/5
	AC	0.04	0.04	0.04	0.04	1/1
	ACD	0.02	0.02	0.02	0.02	1/1
	ABCD	0.08	0.08	0.08	0.08	1/1
Radionuclide Group: Fission and Activation Products						
Eu-154	A	ND	ND	ND	ND	0/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1
Fe-59	A	ND	ND	ND	ND	0/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1

Table A.8 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"What are the primary sources of drinking water for your community?"
A=Municipal/Surface, B=Municipal/Ground, C=Private Wells, D=Private/Surface
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Sm-153	A	ND	ND	ND	ND	0/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1
Sr-89	A	ND	1	5	60	11/17
	B	ND	ND - 1	2	2	2/4
	D	ND	ND - 20	20	20	1/2
	AB	ND	0.4	300	300	4/5
	AC	12	12	12	12	1/1
	ACD	30	30	30	30	1/1
Sr-90	A	ND	0.1	1	1	15/17
	B	ND	0.2	1	1	3/4
	D	ND	ND - 0.7	0.7	0.7	1/2
	AB	ND	0.3	6	6	4/5
	AC	0.1	0.1	0.1	0.1	1/1
	ACD	ND	ND	ND	ND	0/1
Zn-65	A	ND	ND	ND	0.06	1/20
	B	ND	ND	ND	ND	0/4
	D	ND	ND	ND	ND	0/3
	AB	ND	ND	ND	ND	0/5
	AC	ND	ND	ND	ND	0/1
	ACD	ND	ND	ND	ND	0/1
	ABCD	ND	ND	ND	ND	0/1

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.9 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Does your wastewater collection system receive discharges of drinking water treatment residuals?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Yes	ND	0.3	1.9	16	85/105
	No	ND	0.295	3	16	151/202
	NR	ND	ND - 0.23	0.27	0.27	2/4
Pa-234m	Yes	ND	ND	10	22	29/105
	No	ND	ND	7	27	49/202
	NR	ND	ND - 2	6	6	2/4
Pb-210	Yes	ND	ND	4.2	5.6	41/105
	No	ND	ND	4	13	92/202
	NR	ND	ND - 0.4	0.6	0.6	2/4
Pb-214	Yes	ND	0.33	2	17	93/105
	No	ND	0.3	3.1	17	157/202
	NR	ND	0.2	0.31	0.31	3/4
Ra-226	Yes	ND	2	10	47	100/105
	No	ND	2	15	30	185/202
	NR	0.2	0.5	2.4	2.4	4/4
Th-230	Yes	0.14	0.39	1.6	1.7	30/30
	No	0.09	0.325	0.8	1.7	62/62
Th-234	Yes	ND	0.5	5	16	62/105
	No	ND	0.65	7	23	125/202
	NR	0.1	1.25	6.8	6.8	4/4
U-234	Yes	0.39	1.85	17	20	30/30
	No	0.18	2.1	17	44	62/62
U-238	Yes	0.18	1.4	12.5	16	30/30
	No	0.19	1.4	12	26	62/62
Radionuclide Group: C-14 and H-3						
C-14*	Yes	ND	0	1	2	26/49
	No	ND	ND	1	3	35/107
	NR	ND	ND - 0	0	0	1/2
H-3*	Yes	ND	0.4	3	8	35/49
	No	ND	0.2	5	7	74/107
	NR	1	2	3	3	2/2
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Yes	ND	ND	1.4	13	36/105
	No	ND	ND	1.1	6.8	63/202
	NR	ND	ND - 0.4	0.5	0.5	2/4

Table A.9 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Does your wastewater collection system receive discharges of drinking water treatment residuals?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Pb-212	Yes	ND	0.5	1.9	15	104/105
	No	ND	0.435	1.9	5.4	195/202
	NR	0.09	0.23	0.49	0.49	4/4
Ra-224	Yes	ND	ND	0.9	12	17/105
	No	ND	ND	1	5	30/202
	NR	ND	ND	ND	ND	0/4
Ra-228	Yes	ND	0.9	4	20	97/105
	No	ND	0.81	6.7	38	171/202
	NR	ND	0.275	0.53	0.53	3/4
Th-228	Yes	0.19	0.75	4.6	9	30/30
	No	0.07	0.6	4.1	9	62/62
Th-232	Yes	0.08	0.23	1.1	1.6	30/30
	No	0.02	0.195	0.52	0.7	62/62
Tl-208	Yes	ND	0.09	1.4	4.1	70/105
	No	ND	0.04	0.9	4.8	108/202
	NR	ND	ND - 0.1	0.15	0.15	2/4
Radionuclide Group: Medical Isotopes						
I-125	Yes	ND	ND	ND	0.7	1/105
	No	ND	ND	ND	40	10/202
	NR	ND	ND	ND	ND	0/4
I-131	Yes	ND	2.9	42	840	90/105
	No	ND	1.45	60.5	280	154/202
	NR	ND	ND - 0.56	0.67	0.67	2/4
In-111	Yes	ND	ND	0.044	3.6	7/105
	No	ND	ND	0.03	3.5	11/202
	NR	ND	ND	0.04	0.04	1/4
Tl-201	Yes	ND	0.3	45	176	53/105
	No	ND	ND	48	241	97/202
	NR	ND	ND	3.1	3.1	1/4
Tl-202	Yes	ND	ND	0.4	0.93	24/105
	No	ND	ND	0.56	1.16	48/202
	NR	ND	ND	0.01	0.01	1/4
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Yes	ND	1.2	9.9	22	90/105
	No	ND	1.2	7.2	17	169/202
	NR	0.1	0.48	14.9	14.9	4/4
K-40	Yes	ND	4	12	22	104/105
	No	ND	3.9	13	26	200/202
	NR	2.7	4.1	5.7	5.7	4/4

Table A.9 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Does your wastewater collection system receive discharges of drinking water treatment residuals?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
La-138	Yes	ND	ND	ND	ND	0/105
	No	ND	ND	ND	0.07	1/202
	NR	ND	ND	ND	ND	0/4
Radionuclide Group: Transuranics						
Am-241	Yes	ND	ND	ND	0.1	4/105
	No	ND	ND	ND	2.5	6/202
	NR	ND	ND	ND	ND	0/4
Pu-238	Yes	ND	0.01	0.1	0.14	26/30
	No	ND	0.01	0.05	0.19	49/62
Pu-239	Yes	ND	0.0045	0.05	0.07	24/30
	No	ND	0.002	0.04	0.12	44/62
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Yes	ND	ND	ND	0.09	2/105
	No	ND	ND	ND	ND	0/202
	NR	ND	ND	ND	ND	0/4
Rn-219	Yes	ND	ND	ND	ND	0/105
	No	ND	ND	ND	ND	0/202
	NR	ND	ND	ND	ND	0/4
Th-227	Yes	ND	ND	0.1	0.5	18/67
	No	ND	ND	0.09	0.5	31/138
	NR	ND	ND	ND	ND	0/2
U-235	Yes	ND	ND	0.42	1.1	37/105
	No	ND	ND	0.5	3.1	73/202
	NR	ND	ND - 0.15	0.31	0.31	2/4
Radionuclide Group: Fission and Activation Products						
Ce-141	Yes	ND	ND	ND	0.016	1/105
	No	ND	ND	ND	ND	0/202
	NR	ND	ND	ND	ND	0/4
Co-57	Yes	ND	ND	ND	0.26	1/105
	No	ND	ND	ND	0.06	5/202
	NR	ND	ND	ND	ND	0/4
Co-60	Yes	ND	ND	ND	0.08	5/105
	No	ND	ND	ND	5.1	8/202
	NR	ND	ND	ND	ND	0/4
Cr-51	Yes	ND	ND	ND	3.5	3/105
	No	ND	ND	ND	0.8	3/202
	NR	ND	ND	ND	ND	0/4

Table A.9 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Does your wastewater collection system receive discharges of drinking water treatment residuals?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Cs-134	Yes	ND	ND	ND	ND	0/105
	No	ND	ND	ND	0.04	1/202
	NR	ND	ND	ND	ND	0/4
Cs-137	Yes	ND	ND	0.11	0.4	49/105
	No	ND	ND	0.11	3.6	80/202
	NR	0.01	0.02	0.04	0.04	4/4
Eu-154	Yes	ND	ND	ND	ND	0/105
	No	ND	ND	ND	21	1/202
	NR	ND	ND	ND	ND	0/4
Fe-59	Yes	ND	ND	ND	ND	0/105
	No	ND	ND	ND	0.4	1/202
	NR	ND	ND	ND	ND	0/4
Sm-153	Yes	ND	ND	ND	ND	0/105
	No	ND	ND	ND	27	1/202
	NR	ND	ND	ND	ND	0/4
Sr-89	Yes	ND	0.6	20	70	25/33
	No	ND	0.3	20	30	43/65
Sr-90	Yes	ND	0.1	0.4	2	20/33
	No	ND	0.1	1	9.4	44/65
Zn-65	Yes	ND	ND	ND	ND	0/105
	No	ND	ND	ND	0.06	1/202
	NR	ND	ND	ND	ND	0/4

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.10 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Does your wastewater collection system receive discharges of drinking water treatment residuals?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Yes	0.62	2.15	13.7	14.1	16/16
	No	ND	3	14	16	18/19
Pa-234m	Yes	ND	5	11	77	14/16
	No	ND	3	9	11	16/19
Pb-210	Yes	ND	3.75	8.9	12.3	10/16
	No	ND	ND	4.4	5.3	6/19
Pb-214	Yes	0.61	2.3	14.8	15.1	16/16
	No	0.69	3.2	14.6	16.4	19/19
Ra-226	Yes	ND	2.4	17	22	15/16
	No	ND	3.4	18	18	18/19
Th-230	Yes	0.6	1.1	2.6	2.6	10/10
	No	ND	0.64	1.4	2.2	17/18
Th-234	Yes	1	3.7	10	80	16/16
	No	ND	2.7	11	21	15/19
U-234	Yes	1.3	6.05	91	91	10/10
	No	1.2	5.55	13	19	18/18
U-238	Yes	0.8	3.65	74	74	10/10
	No	1.1	3.3	6.4	15	18/18
Radionuclide Group: C-14 and H-3						
C-14*	Yes	ND	ND	1	1	3/10
	No	ND	ND	0	0	2/8
H-3*	Yes	ND	0.7	8	8	6/10
	No	ND	ND	0.5	0.5	1/8
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Yes	ND	1.4	2.4	3.5	13/16
	No	ND	0.8	5.5	15.7	12/19
Pb-212	Yes	0.85	1.5	2.6	3.3	16/16
	No	0.36	1.42	6.6	15	19/19
Ra-224	Yes	ND	ND	1.8	2.4	6/16
	No	ND	ND	2	4.9	9/19
Ra-228	Yes	0.68	2.45	9.6	9.9	16/16
	No	0.65	2.9	24	30	19/19
Th-228	Yes	0.7	2.05	3.4	3.4	10/10
	No	ND	1.45	6.7	14	17/18
Th-232	Yes	0.49	0.8	1.7	1.7	10/10
	No	ND	0.49	0.9	1	17/18
Tl-208	Yes	0.34	1.095	2.3	3.1	16/16
	No	ND	0.47	2	13.5	16/19

Table A.10 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Does your wastewater collection system receive discharges of drinking water treatment residuals?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Medical Isotopes						
I-125	Yes	ND	ND	ND	1	1/16
	No	ND	ND	0.4	0.8	3/19
I-131	Yes	ND	0.09	1.17	20	10/16
	No	ND	0.37	46	81	13/19
In-111	Yes	ND	ND	ND	ND	0/16
	No	ND	ND	ND	ND	0/19
Tl-201	Yes	ND	ND - 0.36	48	61	8/16
	No	ND	1.3	93	105	11/19
Tl-202	Yes	ND	ND	0.99	1.1	3/16
	No	ND	ND	0.77	1.53	4/19
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Yes	0.14	7.85	27	30	16/16
	No	ND	4.3	13	15	18/19
K-40	Yes	7.4	15.8	20.9	22.4	16/16
	No	7.9	14	19.8	22	19/19
La-138	Yes	ND	ND	ND	ND	0/16
	No	ND	ND	ND	ND	0/19
Radionuclide Group: Transuranics						
Am-241	Yes	ND	ND	ND	ND	0/16
	No	ND	ND	0.04	0.21	2/19
Pu-238	Yes	ND	0.015	0.1	0.1	7/10
	No	ND	0.015	0.09	0.1	13/18
Pu-239	Yes	ND	0.005	0.17	0.17	8/10
	No	ND	0.01	0.04	0.05	13/18
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Yes	ND	ND	0.2	0.8	2/16
	No	ND	ND	0.1	0.5	2/19
Rn-219	Yes	ND	ND	ND	0.4	1/16
	No	ND	ND	0.2	0.2	2/19
Th-227	Yes	ND	ND	0.2	1.1	5/15
	No	ND	ND - 0.02	0.3	0.6	9/18
U-235	Yes	ND	0.11	1.7	3.4	11/16
	No	0.03	0.18	0.6	0.7	19/19
Radionuclide Group: Fission and Activation Products						
Ce-141	Yes	ND	ND	ND	ND	0/16
	No	ND	ND	ND	ND	0/19

Table A.10 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Does your wastewater collection system receive discharges of drinking water treatment residuals?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Co-57	Yes	ND	ND	ND	0.17	1/16
	No	ND	ND	ND	ND	0/19
Co-60	Yes	ND	ND	ND	3.46	1/16
	No	ND	ND	ND	0.038	1/19
Cr-51	Yes	ND	ND	0.3	0.8	2/16
	No	ND	ND	0.3	35	3/19
Cs-134	Yes	ND	ND	ND	ND	0/16
	No	ND	ND	ND	ND	0/19
Cs-137	Yes	ND	0.095	0.27	0.37	15/16
	No	0	0.05	0.08	0.09	19/19
Eu-154	Yes	ND	ND	ND	ND	0/16
	No	ND	ND	ND	ND	0/19
Fe-59	Yes	ND	ND	ND	ND	0/16
	No	ND	ND	ND	ND	0/19
Sm-153	Yes	ND	ND	ND	ND	0/16
	No	ND	ND	ND	ND	0/19
Sr-89	Yes	ND	0.65	60	300	7/12
	No	ND	1	20	30	13/18
Sr-90	Yes	ND	0.1	1	6	10/12
	No	ND	0.3	1	1	14/18
Zn-65	Yes	ND	ND	ND	ND	0/16
	No	ND	ND	ND	0.06	1/19

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.11 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Does your waste water collection system include combined sanitary and storm water sewers?"

(All concentration are expressed in pCi/g dry, unless noted; 1pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Yes	ND	0.31	1.9	16	73/95
	No	ND	0.275	2.9	16	165/216
Pa-234m	Yes	ND	ND	4	22	26/95
	No	ND	ND	9	27	54/216
Pb-210	Yes	ND	ND	5.6	11	43/95
	No	ND	ND	3	13	92/216
Pb-214	Yes	ND	0.37	2	17	80/95
	No	ND	0.3	3	17	173/216
Ra-226	Yes	ND	2.2	10	47	88/95
	No	ND	2	14	30	201/216
Th-230	Yes	0.14	0.415	1.7	1.7	22/22
	No	0.09	0.32	0.8	1.6	70/70
Th-234	Yes	ND	0.6	3	16	57/95
	No	ND	0.75	7.8	23	134/216
U-234	Yes	0.18	1.45	7.3	20	22/22
	No	0.39	2.1	17	44	70/70
U-238	Yes	0.19	1.1	6.6	16	22/22
	No	0.18	1.4	12	26	70/70
Radionuclide Group: C-14 and H-3						
C-14*	Yes	ND	ND	1	3	20/49
	No	ND	ND	1	2	42/109
H-3*	Yes	ND	0.4	6	8	39/49
	No	ND	0.3	4	7	72/109
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Yes	ND	ND	1.3	13	34/95
	No	ND	ND	1.1	6.8	67/216
Pb-212	Yes	ND	0.5	1.9	15	92/95
	No	ND	0.4	1.9	5.4	211/216
Ra-224	Yes	ND	ND	0.7	12	15/95
	No	ND	ND	1	4	32/216
Ra-228	Yes	ND	0.8	4	20	83/95
	No	ND	0.83	7.9	38	188/216
Th-228	Yes	0.19	0.7	6.7	9	22/22
	No	0.07	0.6	4.1	9	70/70
Th-232	Yes	0.08	0.255	0.9	1.6	22/22
	No	0.02	0.185	0.5	1.1	70/70
Tl-208	Yes	ND	0.08	1.8	4.1	57/95
	No	ND	0.06	0.9	4.8	123/216

Table A.11 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Does your waste water collection system include combined sanitary and storm water sewers?"

(All concentration are expressed in pCi/g dry, unless noted; 1pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Medical Isotopes						
I-125	Yes	ND	ND	ND	1.5	2/95
	No	ND	ND	ND	40	9/216
I-131	Yes	ND	2.6	82	280	78/95
	No	ND	1.55	44	840	168/216
In-111	Yes	ND	ND	0.033	1.19	7/95
	No	ND	ND	0.04	3.6	12/216
Tl-201	Yes	ND	1.2	36	241	59/95
	No	ND	ND	48	207	92/216
Tl-202	Yes	ND	ND	0.4	0.82	25/95
	No	ND	ND	0.54	1.16	48/216
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Yes	ND	3.5	13.5	22	88/95
	No	ND	0.9	3	6	175/216
K-40	Yes	1.6	5	13	26	95/95
	No	ND	3.5	12	25	213/216
La-138	Yes	ND	ND	ND	ND	0/95
	No	ND	ND	ND	0.07	1/216
Radionuclide Group: Transuranics						
Am-241	Yes	ND	ND	ND	0.1	1/95
	No	ND	ND	ND	2.5	9/216
Pu-238	Yes	ND	0.01	0.07	0.14	17/22
	No	ND	0.01	0.07	0.19	58/70
Pu-239	Yes	ND	0.004	0.04	0.07	18/22
	No	ND	0.002	0.05	0.12	50/70
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Yes	ND	ND	ND	0.06	1/95
	No	ND	ND	ND	0.09	1/216
Rn-219	Yes	ND	ND	ND	ND	0/95
	No	ND	ND	ND	ND	0/216
Th-227	Yes	ND	ND	0.07	0.5	11/60
	No	ND	ND	0.1	0.5	38/147
U-235	Yes	ND	ND	0.29	0.7	28/95
	No	ND	ND	0.5	3.1	84/216
Radionuclide Group: Fission and Activation Products						
Ce-141	Yes	ND	ND	ND	0.016	1/95
	No	ND	ND	ND	ND	0/216
Co-57	Yes	ND	ND	ND	0.04	1/95
	No	ND	ND	ND	0.26	5/216

Table A.11 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Does your waste water collection system include combined sanitary and storm water sewers?"

(All concentration are expressed in pCi/g dry, unless noted; 1pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Co-60	Yes	ND	ND	ND	0.3	4/95
	No	ND	ND	ND	5.1	9/216
Cr-51	Yes	ND	ND	ND	3.5	3/95
	No	ND	ND	ND	2.8	3/216
Cs-134	Yes	ND	ND	ND	ND	0/95
	No	ND	ND	ND	0.04	1/216
Cs-137	Yes	ND	0.029	0.11	0.3	58/95
	No	ND	ND	0.11	3.6	75/216
Eu-154	Yes	ND	ND	ND	ND	0/95
	No	ND	ND	ND	21	1/216
Fe-59	Yes	ND	ND	ND	0.4	1/95
	No	ND	ND	ND	ND	0/216
Sm-153	Yes	ND	ND	ND	ND	0/95
	No	ND	ND	ND	27	1/216
Sr-89	Yes	ND	0.3	5	70	18/28
	No	ND	0.8	20	40	50/70
Sr-90	Yes	ND	0.1	0.5	0.6	17/28
	No	ND	0.1	1	9.4	47/70
Zn-65	Yes	ND	ND	ND	ND	0/95
	No	ND	ND	ND	0.06	1/216

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.12 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Does your waste water collection system include combined sanitary and storm water sewers?"

(All concentration are expressed in pCi/g dry, unless noted; 1pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Yes	1.06	2.2	3.8	13.7	15/15
	No	ND	2.9	14.1	16	19/20
Pa-234m	Yes	ND	5	10	11	14/15
	No	ND	3	11	77	16/20
Pb-210	Yes	ND	ND	8.5	12.3	6/15
	No	ND	ND - 1.8	5.3	8.9	10/20
Pb-214	Yes	1.17	2.4	4.1	14.8	15/15
	No	0.61	3.15	15.1	16.4	20/20
Ra-226	Yes	ND	2.5	9.4	17	14/15
	No	ND	3.7	18	22	19/20
Th-230	Yes	0.6	1.3	2.6	2.6	9/9
	No	ND	0.64	1.5	2.3	18/19
Th-234	Yes	ND	3.7	7.5	10	14/15
	No	ND	2.15	21	80	17/20
U-234	Yes	2.1	5.3	49	49	9/9
	No	1.2	6	19	91	19/19
U-238	Yes	1.9	4.3	35	35	9/9
	No	0.8	3.1	15	74	19/19
Radionuclide Group: C-14 and H-3						
C-14*	Yes	ND	ND	1	1	2/7
	No	ND	ND	0	1	3/11
H-3*	Yes	ND	0.4	8	8	4/7
	No	ND	ND	2	4	3/11
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Yes	ND	1.3	1.8	2.4	12/15
	No	ND	1.2	5.5	15.7	13/20
Pb-212	Yes	0.74	1.5	2.1	2.6	15/15
	No	0.36	1.55	6.6	15	20/20
Ra-224	Yes	ND	0.4	1.8	2.4	8/15
	No	ND	ND	2	4.9	7/20
Ra-228	Yes	0.71	2.3	3.7	4.7	15/15
	No	0.65	4.45	24	30	20/20
Th-228	Yes	0.9	1.7	3.4	3.4	9/9
	No	ND	1.5	6.7	14	18/19
Th-232	Yes	0.7	0.8	1	1	9/9
	No	ND	0.49	0.9	1.7	18/19
Tl-208	Yes	ND	0.55	1.6	2.3	14/15
	No	ND	0.74	3.1	13.5	18/20

Table A.12 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Does your waste water collection system include combined sanitary and storm water sewers?"

(All concentration are expressed in pCi/g dry, unless noted; 1pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Medical Isotopes						
I-125	Yes	ND	ND	ND	ND	0/15
	No	ND	ND	0.8	1	4/20
I-131	Yes	ND	ND	3.8	4.3	7/15
	No	ND	0.525	46	81	16/20
In-111	Yes	ND	ND	ND	ND	0/15
	No	ND	ND	ND	ND	0/20
Tl-201	Yes	ND	ND	11	35	5/15
	No	ND	5.05	93	105	14/20
Tl-202	Yes	ND	ND	0.07	0.99	2/15
	No	ND	ND	1.1	1.53	5/20
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Yes	0.14	8.2	27	30	15/15
	No	ND	4.3	15	15.4	19/20
K-40	Yes	9.7	16	20.9	22.4	15/15
	No	7.4	13.6	19.8	22	20/20
La-138	Yes	ND	ND	ND	ND	0/15
	No	ND	ND	ND	ND	0/20
Radionuclide Group: Transuranics						
Am-241	Yes	ND	ND	ND	ND	0/15
	No	ND	ND	0.04	0.21	2/20
Pu-238	Yes	ND	0.02	0.1	0.1	6/9
	No	ND	0.01	0.09	0.1	14/19
Pu-239	Yes	ND	0.01	0.06	0.06	7/9
	No	ND	0.009	0.05	0.17	14/19
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Yes	ND	ND	0.2	0.8	3/15
	No	ND	ND	ND	0.5	1/20
Rn-219	Yes	ND	ND	ND	0.4	1/15
	No	ND	ND	0.2	0.2	2/20
Th-227	Yes	ND	ND	0.2	1.1	6/13
	No	ND	ND	0.3	0.6	8/20
U-235	Yes	ND	0.15	0.6	1.7	11/15
	No	ND	0.145	0.7	3.4	19/20

Table A.12 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Does your waste water collection system include
combined sanitary and storm water sewers?"
(All concentration are expressed in pCi/g dry, unless noted; 1pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Fission and Activation Products						
Ce-141	Yes	ND	ND	ND	ND	0/15
	No	ND	ND	ND	ND	0/20
Co-57	Yes	ND	ND	ND	0.17	1/15
	No	ND	ND	ND	ND	0/20
Co-60	Yes	ND	ND	ND	0.038	1/15
	No	ND	ND	ND	3.46	1/20
Cr-51	Yes	ND	ND	ND	0.8	1/15
	No	ND	ND	0.3	35	4/20
Cs-134	Yes	ND	ND	ND	ND	0/15
	No	ND	ND	ND	ND	0/20
Cs-137	Yes	0.03	0.09	0.23	0.27	15/15
	No	ND	0.05	0.1	0.37	19/20
Eu-154	Yes	ND	ND	ND	ND	0/15
	No	ND	ND	ND	ND	0/20
Fe-59	Yes	ND	ND	ND	ND	0/15
	No	ND	ND	ND	ND	0/20
Sm-153	Yes	ND	ND	ND	ND	0/15
	No	ND	ND	ND	ND	0/20
Sr-89	Yes	ND	ND - 0.6	60	60	5/10
	No	ND	1	30	300	15/20
Sr-90	Yes	ND	0.5	1	1	8/10
	No	ND	0.1	1	6	16/20
Zn-65	Yes	ND	ND	ND	0.06	1/15
	No	ND	ND	ND	ND	0/20
* Indicates concentrations for this radionuclide are expressed in pCi/g wet.						

Table A.13 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Do you receive sludge from other wastewater treatment facilities for processing at your facility?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Yes	ND	0.25	1.5	6	59/75
	No	ND	0.3	2.4	16	179/236
Pa-234m	Yes	ND	ND	7	17	15/75
	No	ND	ND	7	27	65/236
Pb-210	Yes	ND	ND	3	4.3	29/75
	No	ND	ND	4.7	13	106/236
Pb-214	Yes	ND	0.29	1.5	5.8	61/75
	No	ND	0.33	3	17	192/236
Ra-226	Yes	ND	2	10.1	26	70/75
	No	ND	2	13	47	219/236
Th-230	Yes	0.09	0.22	0.8	1.6	24/24
	No	0.09	0.4	1.2	1.7	68/68
Th-234	Yes	ND	0.5	5	12	43/75
	No	ND	0.75	6.7	23	148/236
U-234	Yes	0.18	2.1	15.4	17	24/24
	No	0.39	1.9	20	44	68/68
U-238	Yes	0.19	1.25	12	12.5	24/24
	No	0.18	1.4	12	26	68/68
Radionuclide Group: C-14 and H-3						
C-14*	Yes	ND	ND	1	2	15/34
	No	ND	ND	1	3	48/124
H-3*	Yes	ND	0.3	2	6	26/34
	No	ND	0.35	5	8	85/124
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Yes	ND	ND	0.8	3.7	23/75
	No	ND	ND	1.4	13	78/236
Pb-212	Yes	ND	0.38	1.2	4.2	74/75
	No	ND	0.475	2	15	229/236
Ra-224	Yes	ND	ND	0.6	5	11/75
	No	ND	ND	1	12	36/236

Table A.13 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Do you receive sludge from other wastewater treatment facilities for processing at your facility?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Ra-228	Yes	ND	0.7	4	38	68/75
	No	ND	0.9	6.7	24	203/236
Th-228	Yes	0.16	0.39	3.1	9	24/24
	No	0.07	0.685	4.6	9	68/68
Th-232	Yes	0.06	0.17	0.5	1.1	24/24
	No	0.02	0.205	0.65	1.6	68/68
Tl-208	Yes	ND	0.07	0.8	1.9	47/75
	No	ND	0.07	0.99	4.8	133/236
Radionuclide Group: Medical Isotopes						
I-125	Yes	ND	ND	ND	0.9	2/75
	No	ND	ND	ND	40	9/236
I-131	Yes	ND	3.8	60.5	220	65/75
	No	ND	1.35	44	840	181/236
In-111	Yes	ND	ND	0.033	1.19	6/75
	No	ND	ND	0.04	3.6	13/236
Tl-201	Yes	ND	0.6	43	80	43/75
	No	ND	ND	48	241	108/236
Tl-202	Yes	ND	ND	0.7	0.93	24/75
	No	ND	ND	0.45	1.16	49/236
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Yes	ND	1.1	9.1	13.5	65/75
	No	ND	1.2	8.6	22	198/236
K-40	Yes	0.3	3.8	10.5	22	75/75
	No	ND	4	13	26	233/236
La-138	Yes	ND	ND	ND	ND	0/75
	No	ND	ND	ND	0.07	1/236
Radionuclide Group: Transuranics						
Am-241	Yes	ND	ND	ND	2.5	4/75
	No	ND	ND	ND	0.3	6/236
Pu-238	Yes	ND	0.01	0.04	0.05	19/24
	No	ND	0.01	0.1	0.19	56/68
Pu-239	Yes	ND	0.0025	0.04	0.1	20/24
	No	ND	0.004	0.05	0.12	48/68

Table A.13 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Do you receive sludge from other wastewater treatment facilities for processing at your facility?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Yes	ND	ND	ND	ND	0/75
	No	ND	ND	ND	0.09	2/236
Rn-219	Yes	ND	ND	ND	ND	0/75
	No	ND	ND	ND	ND	0/236
Th-227	Yes	ND	ND	0.1	0.5	14/48
	No	ND	ND	0.09	0.5	35/159
U-235	Yes	ND	ND	0.58	1.3	27/75
	No	ND	ND	0.42	3.1	85/236
Radionuclide Group: Fission and Activation Products						
Ce-141	Yes	ND	ND	ND	ND	0/75
	No	ND	ND	ND	0.016	1/236
Co-57	Yes	ND	ND	ND	0.26	1/75
	No	ND	ND	ND	0.06	5/236
Co-60	Yes	ND	ND	0.03	1.16	5/75
	No	ND	ND	ND	5.1	8/236
Cr-51	Yes	ND	ND	ND	0.3	1/75
	No	ND	ND	ND	3.5	5/236
Cs-134	Yes	ND	ND	ND	0.04	1/75
	No	ND	ND	ND	ND	0/236
Cs-137	Yes	ND	ND	0.11	3.6	34/75
	No	ND	ND	0.11	1.5	99/236
Eu-154	Yes	ND	ND	ND	ND	0/75
	No	ND	ND	ND	21	1/236
Fe-59	Yes	ND	ND	ND	ND	0/75
	No	ND	ND	ND	0.4	1/236
Sm-153	Yes	ND	ND	ND	ND	0/75
	No	ND	ND	ND	27	1/236
Sr-89	Yes	ND	0.2	10	40	15/23
	No	ND	0.4	20	70	53/75
Sr-90	Yes	ND	0.1	0.3	0.4	17/23
	No	ND	0.1	1	9.4	47/75
Zn-65	Yes	ND	ND	ND	0.06	1/75
	No	ND	ND	ND	ND	0/236

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.14 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Do you receive sludge from other wastewater treatment facilities for processing at your facility?"

(All concentrations are expressed in pCi/g dry, unless noted; 1pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Yes	0.62	2.7	14	14.1	21/21
	No	ND	2.25	13.7	16	13/14
Pa-234m	Yes	ND	4	9	11	18/21
	No	ND	3	11	77	12/14
Pb-210	Yes	ND	ND	6.4	8.5	7/21
	No	ND	2.2	8.9	12.3	9/14
Pb-214	Yes	0.61	3	14.6	15.1	21/21
	No	0.69	2.55	14.8	16.4	14/14
Ra-226	Yes	ND	2.9	18	22	19/21
	No	0	3.2	17	18	14/14
Th-230	Yes	0.3	0.95	2.2	2.6	14/14
	No	ND	0.64	1.5	2.3	13/14
Th-234	Yes	ND	3.8	10	21	19/21
	No	ND	2.15	11	80	12/14
U-234	Yes	1.5	6.35	12	13	14/14
	No	1.2	3.9	49	91	14/14
U-238	Yes	1.4	4.05	6.4	9	14/14
	No	0.8	2.65	35	74	14/14
Radionuclide Group: C-14 and H-3						
C-14*	Yes	ND	ND	1	1	3/9
	No	ND	ND	1	1	2/9
H-3*	Yes	ND	ND	8	8	3/9
	No	ND	ND	4	4	4/9
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Yes	ND	0.9	1.8	5.5	14/21
	No	ND	1.5	3.5	15.7	11/14
Pb-212	Yes	0.74	1.42	2.5	6.6	21/21
	No	0.36	1.85	3.3	15	14/14
Ra-224	Yes	ND	0.4	1.8	4.9	11/21
	No	ND	ND	2	2.4	4/14
Ra-228	Yes	0.68	2.4	9.9	24	21/21
	No	0.65	3.35	17	30	14/14
Th-228	Yes	0.9	1.7	3.4	6.7	14/14
	No	ND	1.3	3.7	14	13/14
Th-232	Yes	0.4	0.7	0.9	1	14/14
	No	ND	0.475	0.9	1.7	13/14
Tl-208	Yes	ND	0.47	2	2	18/21
	No	0.11	1.105	3.1	13.5	14/14

Table A.14 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Do you receive sludge from other wastewater treatment facilities for processing at your facility?"
(All concentrations are expressed in pCi/g dry, unless noted; 1pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Medical Isotopes						
I-125	Yes	ND	ND	ND	0.3	1/21
	No	ND	ND	0.8	1	3/14
I-131	Yes	ND	0.13	4.3	46	12/21
	No	ND	0.305	20	81	11/14
In-111	Yes	ND	ND	ND	ND	0/21
	No	ND	ND	ND	ND	0/14
Tl-201	Yes	ND	ND	48	105	8/21
	No	ND	5.05	73	93	11/14
Tl-202	Yes	ND	ND	0.1	0.99	3/21
	No	ND	ND	1.1	1.53	4/14
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Yes	ND	4.3	27	30	20/21
	No	0.14	4.3	8.1	8.3	14/14
K-40	Yes	8.4	15	22	22.4	21/21
	No	7.4	13.6	17.9	19.8	14/14
La-138	Yes	ND	ND	ND	ND	0/21
	No	ND	ND	ND	ND	0/14
Radionuclide Group: Transuranics						
Am-241	Yes	ND	ND	ND	ND	0/21
	No	ND	ND	0.04	0.21	2/14
Pu-238	Yes	ND	0.02	0.08	0.1	12/14
	No	ND	0	0.09	0.1	8/14
Pu-239	Yes	ND	0.015	0.04	0.06	12/14
	No	ND	0	0.05	0.17	9/14
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Yes	ND	ND	0.1	0.2	2/21
	No	ND	ND	0.5	0.8	2/14
Rn-219	Yes	ND	ND	ND	ND	0/21
	No	ND	ND	0.2	0.4	3/14
Th-227	Yes	ND	ND	0.2	0.6	9/19
	No	ND	ND	0.3	1.1	5/14
U-235	Yes	ND	0.15	0.5	0.6	16/21
	No	0.03	0.145	1.7	3.4	14/14
Radionuclide Group: Fission and Activation Products						
Ce-141	Yes	ND	ND	ND	ND	0/21
	No	ND	ND	ND	ND	0/14
Co-57	Yes	ND	ND	ND	0.17	1/21
	No	ND	ND	ND	ND	0/14

**Table A.14 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Do you receive sludge from other wastewater treatment facilities for processing at your facility?"**

(All concentrations are expressed in pCi/g dry, unless noted; 1pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Co-60	Yes	ND	ND	ND	0.038	1/21
	No	ND	ND	ND	3.46	1/14
Cr-51	Yes	ND	ND	0.3	0.8	3/21
	No	ND	ND	0.3	35	2/14
Cs-134	Yes	ND	ND	ND	ND	0/21
	No	ND	ND	ND	ND	0/14
Cs-137	Yes	0.03	0.08	0.23	0.27	21/21
	No	ND	0.06	0.18	0.37	13/14
Eu-154	Yes	ND	ND	ND	ND	0/21
	No	ND	ND	ND	ND	0/14
Fe-59	Yes	ND	ND	ND	ND	0/21
	No	ND	ND	ND	ND	0/14
Sm-153	Yes	ND	ND	ND	ND	0/21
	No	ND	ND	ND	ND	0/14
Sr-89	Yes	ND	0.3	20	300	9/16
	No	ND	1.65	30	60	11/14
Sr-90	Yes	ND	0.5	1	6	14/16
	No	ND	0	1	1	10/14
Zn-65	Yes	ND	ND	ND	0.06	1/21
	No	ND	ND	ND	ND	0/14

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.15 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question: Do you receive septage for processing at your facility?

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g= 37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Yes	ND	0.27	2	16	137/177
	No	ND	0.305	3	16	92/124
	NR	ND	0.335	1.37	1.37	9/10
Pa-234m	Yes	ND	ND	6	22	46/177
	No	ND	ND	7	27	28/124
	NR	ND	2	11	11	6/10
Pb-210	Yes	ND	ND	4	12	84/177
	No	ND	ND	4.2	13	50/124
	NR	ND	ND	1	1	1/10
Pb-214	Yes	ND	0.3	2.4	17	146/177
	No	ND	0.35	3.1	17	98/124
	NR	ND	0.32	1.42	1.42	9/10
Ra-226	Yes	ND	2	10.4	47	166/177
	No	ND	2.1	17	30	113/124
	NR	1.8	2.85	10.1	10.1	10/10
Th-230	Yes	0.09	0.31	0.8	1.6	48/48
	No	0.09	0.36	1.2	1.7	35/35
	NR	0.19	0.54	1	1	9/9
Th-234	Yes	ND	0.5	5.7	19	107/177
	No	ND	0.75	5	23	76/124
	NR	ND	1.45	12	12	8/10
U-234	Yes	0.18	2.1	17	20	48/48
	No	0.4	1.6	25	44	35/35
	NR	0.8	1.6	15.4	15.4	9/9
U-238	Yes	0.18	1.4	9	16	48/48
	No	0.37	1.4	12	26	35/35
	NR	0.7	1.4	12.5	12.5	9/9
Radionuclide Group: C-14 and H-3						
C-14*	Yes	ND	ND	1	3	42/94
	No	ND	ND	1	2	16/59
	NR	ND	0.6	1	1	5/5
H-3*	Yes	ND	0.3	5	7	66/94
	No	ND	0.5	4	8	41/59
	NR	ND	1	1.7	1.7	4/5

Table A.15 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question: Do you receive septage for processing at your facility?

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g= 37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Yes	ND	ND	1	13	52/177
	No	ND	ND	2	6.8	44/124
	NR	ND	ND - 0.5	0.8	0.8	5/10
Pb-212	Yes	ND	0.48	1.9	15	174/177
	No	ND	0.4	1.9	5.4	119/124
	NR	0.15	0.615	1.55	1.55	10/10
Ra-224	Yes	ND	ND	1	12	28/177
	No	ND	ND	0.7	3	16/124
	NR	ND	ND	0.7	0.7	3/10
Ra-228	Yes	ND	0.8	5.1	38	155/177
	No	ND	0.9	7.8	24	106/124
	NR	0.6	1	1.9	1.9	10/10
Th-228	Yes	0.07	0.605	3.1	9	48/48
	No	0.2	0.7	4.6	6.8	35/35
	NR	0.2	0.49	1.4	1.4	9/9
Th-232	Yes	0.02	0.23	0.65	1.1	48/48
	No	0.06	0.16	0.52	1.6	35/35
	NR	0.1	0.4	0.9	0.9	9/9
Tl-208	Yes	ND	0.06	0.96	4.1	100/177
	No	ND	0.07	1.1	4.8	75/124
	NR	ND	ND - 0.11	0.26	0.26	5/10
Radionuclide Group: Medical Isotopes						
I-125	Yes	ND	ND	ND	5.9	9/177
	No	ND	ND	ND	40	2/124
	NR	ND	ND	ND	ND	0/10
I-131	Yes	ND	2.6	73	280	146/177
	No	ND	1.29	42	840	93/124
	NR	ND	0.425	39	39	7/10
In-111	Yes	ND	ND	0.03	1.9	10/177
	No	ND	ND	0.09	3.6	9/124
	NR	ND	ND	ND	ND	0/10
Tl-201	Yes	ND	0.45	43	176	93/177
	No	ND	ND	56	241	55/124
	NR	ND	ND	24	24	3/10
Tl-202	Yes	ND	ND	0.32	0.93	41/177

Table A.15 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question: Do you receive septage for processing at your facility?

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g= 37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
	No	ND	ND	0.56	1.16	32/124
	NR	ND	ND	ND	ND	0/10
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Yes	ND	1.2	8.7	15.3	155/177
	No	ND	1.1	8.6	17	100/124
	NR	ND	1.15	22	22	8/10
K-40	Yes	ND	4	13	26	176/177
	No	ND	3.9	10	16	122/124
	NR	2.5	4.05	7.3	7.3	10/10
La-138	Yes	ND	ND	ND	ND	0/177
	No	ND	ND	ND	0.07	1/124
	NR	ND	ND	ND	ND	0/10
Radionuclide Group: Transuranics						
Am-241	Yes	ND	ND	ND	2.5	8/177
	No	ND	ND	ND	0.14	2/124
	NR	ND	ND	ND	ND	0/10
Pu-238	Yes	ND	0.01	0.07	0.19	39/48
	No	ND	0.01	0.03	0.1	28/35
	NR	ND	0.01	0.14	0.14	8/9
Pu-239	Yes	ND	0.002	0.04	0.11	37/48
	No	ND	0.004	0.04	0.12	22/35
	NR	0	0.01	0.07	0.07	9/9
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Yes	ND	ND	ND	0.09	2/177
	No	ND	ND	ND	ND	0/124
	NR	ND	ND	ND	ND	0/10
Rn-219	Yes	ND	ND	ND	ND	0/177
	No	ND	ND	ND	ND	0/124
	NR	ND	ND	ND	ND	0/10
Th-227	Yes	ND	ND	0.09	0.5	22/116
	No	ND	ND	0.1	0.2	22/81
	NR	ND	ND - 0.01	0.1	0.1	5/10
U-235	Yes	ND	ND	0.41	1.3	60/177
	No	ND	ND	0.5	3.1	43/124
	NR	ND	0.16	0.6	0.6	9/10

Table A.15 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question:
Do you receive septage for processing at your facility?
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g= 37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Fission and Activation Products						
Ce-141	Yes	ND	ND	ND	ND	0/177
	No	ND	ND	ND	0.016	1/124
	NR	ND	ND	ND	ND	0/10
Co-57	Yes	ND	ND	ND	0.26	2/177
	No	ND	ND	ND	0.06	4/124
	NR	ND	ND	ND	ND	0/10
Co-60	Yes	ND	ND	ND	1.16	8/177
	No	ND	ND	ND	5.1	5/124
	NR	ND	ND	ND	ND	0/10
Cr-51	Yes	ND	ND	ND	3.5	3/177
	No	ND	ND	ND	2.8	3/124
	NR	ND	ND	ND	ND	0/10
Cs-134	Yes	ND	ND	ND	0.04	1/177
	No	ND	ND	ND	ND	0/124
	NR	ND	ND	ND	ND	0/10
Cs-137	Yes	ND	ND	0.1	3.6	76/177
	No	ND	ND	0.12	1.5	51/124
	NR	ND	0.02	0.19	0.19	6/10
Eu-154	Yes	ND	ND	ND	ND	0/177
	No	ND	ND	ND	21	1/124
	NR	ND	ND	ND	ND	0/10
Fe-59	Yes	ND	ND	ND	ND	0/177
	No	ND	ND	ND	0.4	1/124
	NR	ND	ND	ND	ND	0/10
Sm-153	Yes	ND	ND	ND	27	1/177
	No	ND	ND	ND	ND	0/124
	NR	ND	ND	ND	ND	0/10
Sr-89	Yes	ND	0.4	6	40	37/51
	No	ND	0.15	30	70	24/38
	NR	ND	0.3	10	10	7/9
Sr-90	Yes	ND	0.04	1	9	30/51
	No	ND	0.1	0.6	9.4	28/38
	NR	ND	0.1	0.4	0.4	6/9
Zn-65	Yes	ND	ND	ND	0.06	1/177
	No	ND	ND	ND	ND	0/124
	NR	ND	ND	ND	ND	0/10

** Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.16 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Do you receive septage for processing at your facility?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Yes	0.62	2.4	13.7	14.1	25/25
	No	ND	1.9	16	16	5/6
	NR	2.1	6.5	14	14	4/4
Pa-234m	Yes	ND	4	11	11	22/25
	No	ND	3	77	77	5/6
	NR	ND	3	6	6	3/4
Pb-210	Yes	ND	ND	8.5	12.3	10/25
	No	1.9	3.5	8.9	8.9	6/6
	NR	ND	ND	ND	ND	0/4
Pb-214	Yes	0.61	2.9	14.8	15.1	25/25
	No	0.92	2.05	16.4	16.4	6/6
	NR	2.2	7.25	14.6	14.6	4/4
Ra-226	Yes	ND	2.5	18	22	23/25
	No	1	2.95	15	15	6/6
	NR	2.9	13.05	18	18	4/4
Th-230	Yes	0.3	0.85	1.5	2.6	18/18
	No	ND	0.605	2.3	2.3	5/6
	NR	0.55	0.85	2.2	2.2	4/4
Th-234	Yes	ND	3.6	11	21	22/25
	No	1.1	2.15	80	80	6/6
	NR	ND	3.95	5.1	5.1	3/4
U-234	Yes	1.3	4.1	19	49	18/18
	No	1.2	5.55	91	91	6/6
	NR	5	6.55	7.6	7.6	4/4
U-238	Yes	0.8	3.55	15	35	18/18
	No	1.1	2.95	74	74	6/6
	NR	3.3	3.55	4.7	4.7	4/4
Radionuclide Group: C-14 and H-3						
C-14*	Yes	ND	ND	1	1	2/10
	No	ND	ND	1	1	2/6
	NR	ND	ND - 0	0	0	1/2
H-3*	Yes	ND	ND	8	8	4/10
	No	ND	ND - 0.5	4	4	3/6
	NR	ND	ND	ND	ND	0/2
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Yes	ND	1.3	3.5	5.5	20/25
	No	ND	1.6	15.7	15.7	4/6
	NR	ND	ND	0.8	0.8	1/4

Table A.16 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Do you receive septage for processing at your facility?"
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Pb-212	Yes	0.36	1.5	3.3	6.6	25/25
	No	0.73	1.7	15	15	6/6
	NR	0.91	1.21	1.6	1.6	4/4
Ra-224	Yes	ND	0.4	2.4	4.9	14/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	0.5	0.5	1/4
Ra-228	Yes	0.65	2.4	17	24	25/25
	No	1.8	2.95	30	30	6/6
	NR	1.6	4.8	8.2	8.2	4/4
Th-228	Yes	0.4	1.7	3.7	6.7	18/18
	No	ND	0.9	14	14	5/6
	NR	0.9	1.4	2.4	2.4	4/4
Th-232	Yes	0.22	0.75	0.9	1.7	18/18
	No	ND	0.46	0.51	0.51	5/6
	NR	0.48	0.6	1	1	4/4
Tl-208	Yes	0.11	0.66	2.3	3.1	25/25
	No	0.63	1.5	13.5	13.5	6/6
	NR	ND	ND	0.29	0.29	1/4
Radionuclide Group: Medical Isotopes						
I-125	Yes	ND	ND	ND	ND	0/25
	No	ND	ND - 0.4	1	1	3/6
	NR	ND	ND	0.3	0.3	1/4
I-131	Yes	ND	0.22	46	81	15/25
	No	ND	0.185	1.2	1.2	5/6
	NR	ND	2.185	4.3	4.3	3/4
In-111	Yes	ND	ND	ND	ND	0/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Tl-201	Yes	ND	0.36	93	105	13/25
	No	0.62	7.85	61	61	6/6
	NR	ND	ND	ND	ND	0/4
Tl-202	Yes	ND	ND	1.1	1.53	7/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Yes	ND	3.6	27	30	24/25
	No	2.3	5.2	7.6	7.6	6/6
	NR	4.2	4.8	13	13	4/4

Table A.16 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Do you receive septage for processing at your facility?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
K-40	Yes	7.4	14.1	22	22.4	25/25
	No	7.9	14.95	19.8	19.8	6/6
	NR	14	14.6	15	15	4/4
La-138	Yes	ND	ND	ND	ND	0/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Radionuclide Group: Transuranics						
Am-241	Yes	ND	ND	ND	ND	0/25
	No	ND	ND	0.21	0.21	2/6
	NR	ND	ND	ND	ND	0/4
Pu-238	Yes	ND	0.015	0.06	0.09	13/18
	No	ND	ND - 0	0.1	0.1	3/6
	NR	0.01	0.05	0.1	0.1	4/4
Pu-239	Yes	ND	0.01	0.06	0.17	14/18
	No	ND	ND - 0	0.01	0.01	3/6
	NR	0.00	0.03	0.04	0.04	4/4
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Yes	ND	ND	0.5	0.8	4/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Rn-219	Yes	ND	ND	0.2	0.4	3/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Th-227	Yes	ND	0.04	0.6	1.1	13/23
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	0.2	0.2	1/4
U-235	Yes	ND	0.11	0.7	1.7	20/25
	No	0.07	0.145	3.4	3.4	6/6
	NR	0.14	0.18	0.4	0.4	4/4
Radionuclide Group: Fission and Activation Products						
Ce-141	Yes	ND	ND	ND	ND	0/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Co-57	Yes	ND	ND	ND	0.17	1/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Co-60	Yes	ND	ND	0.038	3.46	2/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4

Table A.16 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"Do you receive septage for processing at your facility?"
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Cr-51	Yes	ND	ND	0.8	35	5/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Cs-134	Yes	ND	ND	ND	ND	0/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Cs-137	Yes	ND	0.08	0.27	0.37	24/25
	No	0	0.06	0.08	0.08	6/6
	NR	0.04	0.045	0.08	0.08	4/4
Eu-154	Yes	ND	ND	ND	ND	0/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Fe-59	Yes	ND	ND	ND	ND	0/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Sm-153	Yes	ND	ND	ND	ND	0/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4
Sr-89	Yes	ND	1	60	300	13/20
	No	ND	ND - 0	5	5	3/6
	NR	0	0.8	3	3	4/4
Sr-90	Yes	ND	0.4	1	6	16/20
	No	ND	0	1	1	5/6
	NR	ND	0.2	0.3	0.3	3/4
Zn-65	Yes	ND	ND	ND	0.06	1/25
	No	ND	ND	ND	ND	0/6
	NR	ND	ND	ND	ND	0/4

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.17 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question,
"What percentage of the annual average daily total flow rate is industrial flow?"
(All concentrations are expressed in pCi/g dry, unless noted;1 pCi/g=37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Less than 50%	ND	0.295	2.9	16	218/284
	50% or More	ND	0.36	0.56	0.75	12/15
	NR	ND	0.22	2	2.3	8/12
Pa-234m	Less than 50%	ND	ND	8	27	75/284
	50% or More	ND	ND	3	4	4/15
	NR	ND	ND	ND	3	1/12
Pb-210	Less than 50%	ND	ND	4.2	13	123/284
	50% or More	ND	ND	0.7	4	5/15
	NR	ND	0.2	3.4	6	7/12
Pb-214	Less than 50%	ND	0.305	3	17	232/284
	50% or More	ND	0.4	0.61	0.8	12/15
	NR	ND	0.245	2.1	2.4	9/12
Ra-226	Less than 50%	ND	2	14	47	265/284
	50% or More	ND	1	3	4.3	14/15
	NR	ND	1.55	4.6	5	10/12
Th-230	Less than 50%	0.09	0.355	1	1.7	86/86
	50% or More	0.32	0.8	1.2	1.2	3/3
	NR	0.12	0.21	0.24	0.24	3/3
Th-234	Less than 50%	ND	0.8	7	23	179/284
	50% or More	ND	ND	0.8	2	4/15
	NR	ND	0.65	4.9	5	8/12
U-234	Less than 50%	0.18	1.95	17	44	86/86
	50% or More	0.9	1	2.3	2.3	3/3
	NR	0.43	3.1	5.1	5.1	3/3
U-238	Less than 50%	0.18	1.4	12	26	86/86
	50% or More	0.7	0.9	2.1	2.1	3/3
	NR	0.37	2.2	3.7	3.7	3/3
Radionuclide Group: C-14 and H-3						
C-14*	Less than 50%	ND	ND	1	3	58/145
	50% or More	ND	0	1	1	3/5
	NR	ND	ND	0	0	2/8
H-3*	Less than 50%	ND	0.3	5	8	102/145
	50% or More	ND	0.5	0.7	0.7	4/5
	NR	ND	0.15	3	3	5/8
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Less than 50%	ND	ND	1.4	13	90/284
	50% or More	ND	0.3	0.8	0.9	8/15
	NR	ND	ND	1	3.3	3/12

Table A.17 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question, "What percentage of the annual average daily total flow rate is industrial flow?"

(All concentrations are expressed in pCi/g dry, unless noted;1 pCi/g=37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Pb-212	Less than 50%	ND	0.435	1.9	15	276/284
	50% or More	0.03	0.4	0.67	0.82	15/15
	NR	0.03	0.515	1.1	3.3	12/12
Ra-224	Less than 50%	ND	ND	1	12	41/284
	50% or More	ND	ND	0.6	0.7	5/15
	NR	ND	ND	ND	1	1/12
Ra-228	Less than 50%	ND	0.9	6.7	38	251/284
	50% or More	ND	0.56	1	1.02	11/15
	NR	ND	0.64	1.7	3.5	9/12
Th-228	Less than 50%	0.07	0.655	4.6	9	86/86
	50% or More	0.16	0.5	0.7	0.7	3/3
	NR	0.38	0.38	0.5	0.5	3/3
Th-232	Less than 50%	0.02	0.2	0.65	1.6	86/86
	50% or More	0.1	0.35	0.52	0.52	3/3
	NR	0.08	0.21	0.28	0.28	3/3
Tl-208	Less than 50%	ND	0.07	0.99	4.8	164/284
	50% or More	ND	0.08	0.28	0.6	11/15
	NR	ND	ND	0.46	3.1	5/12
Radionuclide Group: Medical Isotopes						
I-125	Less than 50%	ND	ND	ND	40	9/284
	50% or More	ND	ND	ND	1.1	1/15
	NR	ND	ND	ND	0.5	1/12
I-131	Less than 50%	ND	2.2	60.5	840	229/284
	50% or More	ND	0.03	0.8	3.6	8/15
	NR	ND	1.45	10.3	98	9/12
In-111	Less than 50%	ND	ND	0.04	3.6	18/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	1.19	1/12
Tl-201	Less than 50%	ND	0.375	48	241	145/284
	50% or More	ND	ND	0.3	34	2/15
	NR	ND	ND	3.5	71	4/12
Tl-202	Less than 50%	ND	ND	0.54	1.16	69/284
	50% or More	ND	ND	0.09	0.49	3/15
	NR	ND	ND	ND	0.88	1/12
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Less than 50%	ND	1.3	8.7	22	244/284
	50% or More	ND	0.5	2.5	10.7	10/15
	NR	ND	1	9.1	9.9	9/12

Table A.17 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question, "What percentage of the annual average daily total flow rate is industrial flow?"

(All concentrations are expressed in pCi/g dry, unless noted;1 pCi/g=37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
K-40	Less than 50%	ND	4	13	26	281/284
	50% or More	0.8	2.8	5.8	8	15/15
	NR	0.3	4	8	9	12/12
La-138	Less than 50%	ND	ND	ND	ND	0/284
	50% or More	ND	ND	ND	0.07	1/15
	NR	ND	ND	ND	ND	0/12
Radionuclide Group: Transuranics						
Am-241	Less than 50%	ND	ND	ND	2.5	10/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12
Pu-238	Less than 50%	ND	0.01	0.07	0.19	69/86
	50% or More	0	0	0.01	0.01	3/3
	NR	0.00	0.006	0.01	0.01	3/3
Pu-239	Less than 50%	ND	0.0035	0.05	0.12	64/86
	50% or More	ND	ND	0.001	0.001	1/3
	NR	0.00	0.003	0.01	0.01	3/3
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Less than 50%	ND	ND	ND	0.09	2/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12
Rn-219	Less than 50%	ND	ND	ND	ND	0/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12
Th-227	Less than 50%	ND	ND	0.1	0.5	46/191
	50% or More	ND	ND	0.07	0.07	2/7
	NR	ND	ND	0.05	0.05	1/9
U-235	Less than 50%	ND	ND	0.5	3.1	104/284
	50% or More	ND	ND	0.18	0.26	5/15
	NR	ND	ND	0.15	0.2	3/12
Radionuclide Group: Fission and Activation Products						
Ce-141	Less than 50%	ND	ND	ND	0.016	1/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12
Co-57	Less than 50%	ND	ND	ND	0.26	6/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12
Co-60	Less than 50%	ND	ND	ND	5.1	13/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12

Table A.17 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question,
"What percentage of the annual average daily total flow rate is industrial flow?"
(All concentrations are expressed in pCi/g dry, unless noted;1 pCi/g=37 Bq/kg)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Cr-51	Less than 50%	ND	ND	ND	3.5	6/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12
Cs-134	Less than 50%	ND	ND	ND	0.04	1/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12
Cs-137	Less than 50%	ND	ND	0.11	3.6	118/284
	50% or More	ND	0.011	0.07	0.11	9/15
	NR	ND	ND - 0.01	0.05	0.12	6/12
Eu-154	Less than 50%	ND	ND	ND	21	1/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12
Fe-59	Less than 50%	ND	ND	ND	0.4	1/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12
Sm-153	Less than 50%	ND	ND	ND	27	1/284
	50% or More	ND	ND	ND	ND	0/15
	NR	ND	ND	ND	ND	0/12
Sr-89	Less than 50%	ND	0.35	20	70	66/94
	50% or More	ND	ND	3	3	1/3
	NR	20	20	20	20	1/1
Sr-90	Less than 50%	ND	0.1	0.7	9.4	61/94
	50% or More	0.2	0.2	1	1	3/3
	NR	ND	ND	ND	ND	0/1
Zn-65	Less than 50%	ND	ND	ND	ND	0/284
	50% or More	ND	ND	ND	0.06	1/15
	NR	ND	ND	ND	ND	0/12

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.18 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "What percentage of the annual average daily total flow rate is industrial flow?"

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g= 37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Less than 50%	ND	2.55	14.1	16	29/30
	50% or More	0.62	2.01	3.4	3.4	2/2
	NR	1.6	1.7	3	3	3/3
Pa-234m	Less than 50%	ND	3	11	77	26/30
	50% or More	ND	ND - 7	7	7	1/2
	NR	5	5	5	5	3/3
Pb-210	Less than 50%	ND	ND	8.9	12.3	12/30
	50% or More	2.9	3.65	4.4	4.4	2/2
	NR	ND	4.1	5	5	2/3
Pb-214	Less than 50%	0.69	2.95	15.1	16.4	30/30
	50% or More	0.61	2.205	3.8	3.8	2/2
	NR	1.7	1.9	3.2	3.2	3/3
Ra-226	Less than 50%	ND	3.4	18	22	28/30
	50% or More	1.1	2.05	3	3	2/2
	NR	1.9	2	5.5	5.5	3/3
Th-230	Less than 50%	0.3	0.85	2.3	2.6	26/26
	50% or More	ND	ND	ND	ND	0/1
	NR	0.7	0.7	0.7	0.7	1/1
Th-234	Less than 50%	ND	3.15	21	80	26/30
	50% or More	1	3.25	5.5	5.5	2/2
	NR	4.7	5.1	7.2	7.2	3/3
U-234	Less than 50%	1.2	5.2	49	91	26/26
	50% or More	7.1	7.1	7.1	7.1	1/1
	NR	9	9	9	9	1/1
U-238	Less than 50%	0.8	3.2	35	74	26/26
	50% or More	6.1	6.1	6.1	6.1	1/1
	NR	6.4	6.4	6.4	6.4	1/1
Radionuclide Group: C-14 and H-3						
C-14*	Less than 50%	ND	ND	0	1	2/14
	50% or More	0	0	0	0	2/2
	NR	ND	ND - 1	1	1	1/2
H-3*	Less than 50%	ND	ND	2	4	5/14
	50% or More	ND	ND	ND	ND	0/2
	NR	3	5.5	8	8	2/2
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Less than 50%	ND	1.05	5.5	15.7	21/30
	50% or More	ND	ND - 1.8	1.8	1.8	1/2
	NR	1.2	1.6	1.8	1.8	3/3

Table A.18 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"What percentage of the annual average daily total flow rate is industrial flow?"
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g= 37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Pb-212	Less than 50%	0.36	1.5	6.6	15	30/30
	50% or More	0.85	1.375	1.9	1.9	2/2
	NR	1.3	1.5	1.7	1.7	3/3
Ra-224	Less than 50%	ND	ND	2.4	4.9	14/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	0.5	0.5	1/3
Ra-228	Less than 50%	0.65	2.8	24	30	30/30
	50% or More	0.68	1.24	1.8	1.8	2/2
	NR	2.2	2.4	3.4	3.4	3/3
Th-228	Less than 50%	0.4	1.6	6.7	14	26/26
	50% or More	ND	ND	ND	ND	0/1
	NR	1.7	1.7	1.7	1.7	1/1
Th-232	Less than 50%	0.22	0.505	1	1.7	26/26
	50% or More	ND	ND	ND	ND	0/1
	NR	0.8	0.8	0.8	0.8	1/1
Tl-208	Less than 50%	ND	0.62	3.1	13.5	27/30
	50% or More	0.75	1.205	1.66	1.66	2/2
	NR	0.4	1.36	1.48	1.48	3/3
Radionuclide Group: Medical Isotopes						
I-125	Less than 50%	ND	ND	0.8	1	4/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
I-131	Less than 50%	ND	0.22	46	81	21/30
	50% or More	0.24	0.705	1.17	1.17	2/2
	NR	ND	ND	ND	ND	0/3
In-111	Less than 50%	ND	ND	ND	ND	0/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Tl-201	Less than 50%	ND	0.795	93	105	17/30
	50% or More	12.4	30.2	48	48	2/2
	NR	ND	ND	ND	ND	0/3
Tl-202	Less than 50%	ND	ND	1.1	1.53	7/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Less than 50%	ND	4.3	27	30	29/30
	50% or More	7.5	11.45	15.4	15.4	2/2
	NR	0.8	0.8	1.2	1.2	3/3

Table A.18 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"What percentage of the annual average daily total flow rate is industrial flow?"
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g= 37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
K-40	Less than 50%	7.4	13.85	20.9	22.4	30/30
	50% or More	14.1	15.15	16.2	16.2	2/2
	NR	17.4	19.3	22	22	3/3
La-138	Less than 50%	ND	ND	ND	ND	0/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Radionuclide Group: Transuranics						
Am-241	Less than 50%	ND	ND	0.04	0.21	2/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Pu-238	Less than 50%	ND	0.015	0.1	0.1	19/26
	50% or More	ND	ND	ND	ND	0/1
	NR	0.05	0.05	0.05	0.05	1/1
Pu-239	Less than 50%	ND	0.01	0.06	0.17	20/26
	50% or More	ND	ND	ND	ND	0/1
	NR	0.02	0.02	0.02	0.02	1/1
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Less than 50%	ND	ND	0.5	0.8	4/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Rn-219	Less than 50%	ND	ND	0.2	0.4	3/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Th-227	Less than 50%	ND	ND	0.6	1.1	13/28
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	0.1	0.1	1/3
U-235	Less than 50%	ND	0.15	1.7	3.4	28/30
	50% or More	ND	ND - 0.31	0.31	0.31	1/2
	NR	ND	ND	0.3	0.3	1/3
Radionuclide Group: Fission and Activation Products						
Ce-141	Less than 50%	ND	ND	ND	ND	0/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Co-57	Less than 50%	ND	ND	ND	0.17	1/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3

Table A.18 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
"What percentage of the annual average daily total flow rate is industrial flow?"
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g= 37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Co-60	Less than 50%	ND	ND	0.038	3.46	2/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Cr-51	Less than 50%	ND	ND	0.8	35	4/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	0.2	0.2	1/3
Cs-134	Less than 50%	ND	ND	ND	ND	0/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Cs-137	Less than 50%	ND	0.07	0.27	0.37	29/30
	50% or More	0.07	0.085	0.1	0.1	2/2
	NR	0.06	0.09	0.09	0.09	3/3
Eu-154	Less than 50%	ND	ND	ND	ND	0/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Fe-59	Less than 50%	ND	ND	ND	ND	0/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Sm-153	Less than 50%	ND	ND	ND	ND	0/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
Sr-89	Less than 50%	ND	1	60	300	19/26
	50% or More	ND	ND - 2	2	2	1/2
	NR	ND	ND	ND	ND	0/2
Sr-90	Less than 50%	ND	0.1	1	6	20/26
	50% or More	0.1	0.55	1	1	2/2
	NR	1	1	1	1	2/2
Zn-65	Less than 50%	ND	ND	ND	0.06	1/30
	50% or More	ND	ND	ND	ND	0/2
	NR	ND	ND	ND	ND	0/3
* Indicates concentrations for this radionuclide are expressed in pCi/g wet.						

Table A.19 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"Do you have more than one final sewage sludge production facility location?"
(All concentrations are expressed in pCi/g dry, unless notes; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Yes	ND	0.21	2	6	24/32
	No	ND	0.3	2.3	16	214/279
Pa-234m	Yes	ND	ND	4	5	6/32
	No	ND	ND	8	27	74/279
Pb-210	Yes	ND	ND	2.2	12	12/32
	No	ND	ND	4	13	123/279
Pb-214	Yes	ND	0.225	2.1	4	26/32
	No	ND	0.31	2.6	17	227/279
Ra-226	Yes	ND	2	10.6	19	31/32
	No	ND	2	13	47	258/279
Th-230	Yes	0.17	0.305	0.5	0.5	6/6
	No	0.09	0.34	1.2	1.7	86/86
Th-234	Yes	ND	0.5	3.1	19	19/32
	No	ND	0.7	6.8	23	172/279
U-234	Yes	0.5	1.45	2.5	2.5	6/6
	No	0.18	2	17	44	86/86
U-238	Yes	0.5	1.05	2	2	6/6
	No	0.18	1.4	12	26	86/86
Radionuclide Group: C-14 and H-3						
C-14*	Yes	ND	ND	2	3	6/14
	No	ND	ND	1	2	57/144
H-3*	Yes	ND	0.1	1	2	10/14
	No	ND	0.35	5	8	101/144
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Yes	ND	ND	0.9	2	10/32
	No	ND	ND	1.4	13	91/279
Pb-212	Yes	ND	0.365	1.1	1.9	31/32
	No	ND	0.47	2	15	272/279
Ra-224	Yes	ND	ND	0.5	1	3/32
	No	ND	ND	0.9	12	44/279
Ra-228	Yes	ND	0.79	3	6	28/32
	No	ND	0.84	6.7	38	243/279
Th-228	Yes	0.19	0.645	1.6	1.6	6/6
	No	0.07	0.605	4.6	9	86/86
Th-232	Yes	0.07	0.15	0.31	0.31	6/6
	No	0.02	0.2	0.65	1.6	86/86
Tl-208	Yes	ND	0.055	0.36	1.1	18/32
	No	ND	0.08	0.99	4.8	162/279

Table A.19 Concentrations of Radionuclides in Sludge
Summarized by Response to the POTW Questionnaire Question
"Do you have more than one final sewage sludge production facility location?"
(All concentrations are expressed in pCi/g dry, unless notes; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Medical Isotopes						
I-125	Yes	ND	ND	ND	5.9	1/32
	No	ND	ND	ND	40	10/279
I-131	Yes	ND	3.25	82	153	27/32
	No	ND	1.5	44	840	219/279
In-111	Yes	ND	ND	0.18	3.6	6/32
	No	ND	ND	ND	3.5	13/279
Tl-201	Yes	ND	0.595	40	80	18/32
	No	ND	ND	48	241	133/279
Tl-202	Yes	ND	ND	0.4	0.92	10/32
	No	ND	ND	0.54	1.16	63/279
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Yes	ND	1.45	4	9.9	27/32
	No	ND	1.1	9.1	22	236/279
K-40	Yes	1.4	3.6	8.3	25	32/32
	No	ND	4	12	26	276/279
La-138	Yes	ND	ND	ND	ND	0/32
	No	ND	ND	ND	0.07	1/279
Radionuclide Group: Transuranics						
Am-241	Yes	ND	ND	ND	2.5	2/32
	No	ND	ND	ND	0.14	8/279
Pu-238	Yes	ND	0.01	0.04	0.04	5/6
	No	ND	0.01	0.07	0.19	70/86
Pu-239	Yes	ND	0.0035	0.12	0.12	5/6
	No	ND	0.003	0.04	0.11	63/86
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Yes	ND	ND	ND	ND	0/32
	No	ND	ND	ND	0.09	2/279
Rn-219	Yes	ND	ND	ND	ND	0/32
	No	ND	ND	ND	ND	0/279
Th-227	Yes	ND	ND	0.04	0.05	3/17
	No	ND	ND	0.1	0.5	46/190
U-235	Yes	ND	ND	0.13	0.3	9/32
	No	ND	ND	0.5	3.1	103/279
Radionuclide Group: Fission and Activation Products						
Ce-141	Yes	ND	ND	ND	ND	0/32
	No	ND	ND	ND	0.016	1/279
Co-57	Yes	ND	ND	ND	0.26	1/32
	No	ND	ND	ND	0.06	5/279

Table A.19 Concentrations of Radionuclides in Sludge Summarized by Response to the POTW Questionnaire Question "Do you have more than one final sewage sludge production facility location?"

(All concentrations are expressed in pCi/g dry, unless notes; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Co-60	Yes	ND	ND	ND	0.07	1/32
	No	ND	ND	ND	5.1	12/279
Cr-51	Yes	ND	ND	ND	ND	0/32
	No	ND	ND	ND	3.5	6/279
Cs-134	Yes	ND	ND	ND	ND	0/32
	No	ND	ND	ND	0.04	1/279
Cs-137	Yes	ND	ND	0.06	0.11	7/32
	No	ND	ND	0.11	3.6	126/279
Eu-154	Yes	ND	ND	ND	ND	0/32
	No	ND	ND	ND	21	1/279
Fe-59	Yes	ND	ND	ND	ND	0/32
	No	ND	ND	ND	0.4	1/279
Sm-153	Yes	ND	ND	ND	ND	0/32
	No	ND	ND	ND	27	1/279
Sr-89	Yes	0	5	40	40	7/7
	No	ND	0.3	20	70	61/91
Sr-90	Yes	ND	ND	0.2	0.2	2/7
	No	ND	0.1	1	9.4	62/91
Zn-65	Yes	ND	ND	ND	ND	0/32
	No	ND	ND	ND	0.06	1/279

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

Table A.20 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Do you have more than one final sewage sludge production facility location?

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Uranium-238 Decay Series						
Bi-214	Yes	1.4	3.25	14.1	14.1	4/4
	No	ND	2.2	13.7	16	30/31
Pa-234m	Yes	ND	5	9	9	3/4
	No	ND	3	11	77	27/31
Pb-210	Yes	ND	ND	5	5	1/4
	No	ND	ND	8.5	12.3	15/31
Pb-214	Yes	1.6	3.6	15.1	15.1	4/4
	No	0.61	2.4	14.6	16.4	31/31
Ra-226	Yes	ND	5.5	22	22	3/4
	No	ND	3	17	18	30/31
Th-230	Yes	0.7	1.1	2.6	2.6	4/4
	No	ND	0.7	2.2	2.3	23/24
Th-234	Yes	1.7	3.7	7.5	7.5	4/4
	No	ND	3.6	11	80	27/31
U-234	Yes	2.1	4.9	7	7	4/4
	No	1.2	5.55	49	91	24/24
U-238	Yes	1.9	4	6.2	6.2	4/4
	No	0.8	3.3	35	74	24/24
Radionuclide Group: C-14 and H-3						
C-14*	Yes	ND	ND	ND	ND	0/1
	No	ND	ND	1	1	5/17
H-3*	Yes	1	1	1	1	1/1
	No	ND	ND	4	8	6/17
Radionuclide Group: Thorium-232 Decay Series						
Bi-212	Yes	ND	1.3	1.6	1.6	3/4
	No	ND	1.2	3.5	15.7	22/31
Pb-212	Yes	1.3	1.5	1.6	1.6	4/4
	No	0.36	1.5	3.3	15	31/31
Ra-224	Yes	ND	1.1	1.3	1.3	3/4
	No	ND	ND	2	4.9	12/31
Ra-228	Yes	1.7	2.25	9.9	9.9	4/4
	No	0.65	2.7	17	30	31/31
Th-228	Yes	1.1	2	3.4	3.4	4/4
	No	ND	1.45	6.7	14	23/24
Th-232	Yes	0.5	0.8	0.9	0.9	4/4
	No	ND	0.5	1	1.7	23/24
Tl-208	Yes	0.38	0.475	1.38	1.38	4/4
	No	ND	0.73	2.3	13.5	28/31

Table A.20 Concentrations of Radionuclides in Ash Summarized by Response to the POTW Questionnaire Question "Do you have more than one final sewage sludge production facility location?

(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Radionuclide Group: Medical Isotopes						
I-125	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	0.4	1	4/31
I-131	Yes	ND	ND - 0.05	0.39	0.39	2/4
	No	ND	0.22	20	81	21/31
In-111	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	ND	ND	0/31
Tl-201	Yes	ND	ND	0.36	0.36	1/4
	No	ND	1	73	105	18/31
Tl-202	Yes	ND	ND	0.1	0.1	1/4
	No	ND	ND	0.99	1.53	6/31
Radionuclide Group: NORM other than Thorium/Uranium						
Be-7	Yes	0.5	5.85	11.3	11.3	4/4
	No	ND	4.3	15.4	30	30/31
K-40	Yes	11	16.5	22.4	22.4	4/4
	No	7.4	14.2	19.8	22	31/31
La-138	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	ND	ND	0/31
Radionuclide Group: Transuranics						
Am-241	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	ND	0.21	2/31
Pu-238	Yes	ND	0.015	0.06	0.06	3/4
	No	ND	0.015	0.1	0.1	17/24
Pu-239	Yes	ND	0.005	0.06	0.06	3/4
	No	ND	0.01	0.05	0.17	18/24
Radionuclide Group: Actinium (U-235) Decay Series						
Ra-223	Yes	ND	ND	0.1	0.1	1/4
	No	ND	ND	0.2	0.8	3/31
Rn-219	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	0.2	0.4	3/31
Th-227	Yes	ND	0.135	0.2	0.2	3/4
	No	ND	ND	0.6	1.1	11/29
U-235	Yes	0.11	0.275	0.6	0.6	4/4
	No	ND	0.14	0.7	3.4	26/31
Radionuclide Group: Fission and Activation Products						
Ce-141	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	ND	ND	0/31
Co-57	Yes	ND	ND	0.17	0.17	1/4
	No	ND	ND	ND	ND	0/31

Table A.20 Concentrations of Radionuclides in Ash
Summarized by Response to the POTW Questionnaire Question
“Do you have more than one final sewage sludge production facility location?
(All concentrations are expressed in pCi/g dry, unless noted; 1 pCi/g=37 Bq/kg.)

Radionuclide	Response	Min	Median	95th P	Max	No. Detects/ No. Analyses
Co-60	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	ND	3.46	2/31
Cr-51	Yes	ND	ND	0.3	0.3	1/4
	No	ND	ND	0.3	35	4/31
Cs-134	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	ND	ND	0/31
Cs-137	Yes	0.06	0.075	0.11	0.11	4/4
	No	ND	0.07	0.23	0.37	30/31
Eu-154	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	ND	ND	0/31
Fe-59	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	ND	ND	0/31
Sm-153	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	ND	ND	0/31
Sr-89	Yes	ND	ND	300	300	1/4
	No	ND	1	30	60	19/26
Sr-90	Yes	0	0.95	6	6	4/4
	No	ND	0.1	1	1	20/26
Zn-65	Yes	ND	ND	ND	ND	0/4
	No	ND	ND	ND	0.06	1/31

* Indicates concentrations for this radionuclide are expressed in pCi/g wet.

APPENDIX B
OMB SUPPORTING STATEMENT
FOR
JOINT NRC/EPA SURVEY OF SEWAGE SLUDGE/ASH

APPENDIX B

DECEMBER 2, 1997
OMB SUPPORTING STATEMENT
FOR
JOINT NRC/EPA SURVEY OF SEWAGE SLUDGE/ASH

Description of the Information Collection

The U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency (EPA) are sponsoring a joint effort to characterize radioactive materials in sewage sludge and ash from publicly owned treatment works (POTWs). Sanitary sewer disposal of radioactive material and sludge reconcentration became issues in the 1980s with the discovery of elevated levels in sewage sludge or incinerator ash at several POTWs. Although the NRC expected that compliance with revisions in its sewer disposal criteria would prevent future reconcentration problems, NRC and EPA have continued to work together to ensure a coordinated regulatory review effort concerning sewage treatment with respect to radioactive material. EPA had planned to include analysis of radioactivity in sewage sludge and incinerator ash in its second National Sewage Sludge Survey during 1996-97. (The first national survey conducted in the late 1980s did not include analysis of radioactive material.) Based on the current budget situation, EPA did not move forward with a second national survey. As a result, NRC and EPA will perform a joint survey of radioactivity in sewage sludge and ash at POTWs.

Because existing information is not adequate, NRC is requesting Office of Management and Budget (OMB) approval to conduct the survey to obtain this information. The survey will sample radioactive materials in sewage sludge and ash at POTWs in all regions of the country. For the planned NRC/EPA survey, we will send questionnaires to the POTWs associated with types of NRC licensees that have the highest potential to discharge radioactive material to the sewer system and POTWs in all geographic areas of the United States. Using the information from the questionnaires, NRC and EPA will identify approximately 300 POTWs to be sampled. NRC and EPA tested the survey methods and procedures on nine POTWs. The results of the full survey will be published as a joint NRC/EPA report for use by Federal agencies, States, POTWs, local POTW officials, and other interested parties.

A. JUSTIFICATION

1. Need for and Practical Utility of the Collection of Information

The objectives of this joint NRC/EPA sewage sludge/incinerator ash survey are to (1) obtain national estimates of high probability occurrences of elevated levels of radioactive materials in sludge and ash at POTWs, (2) estimate the extent to which radioactive contamination comes from either NRC/Agreement State licensees or naturally occurring radioactivity, and (3) support rulemaking decisions by NRC and EPA.

Specific amounts and concentrations of radioactive material are legally authorized to be disposed into the sanitary sewer system by Federal or State law. In 1994 NRC revised its sewer disposal criteria partially in response to evidence that certain radioactive materials were reconcentrating in sewage sludge or incinerator ash. Regulations in 10 CFR 20.2003 currently permit disposal into a sanitary sewer of specific quantities of soluble material. The EPA standard for the use and disposal of sewage sludge in 40 CFR Part 503 does not include radionuclides.

This survey also responds to a recommendation in the General Accounting Office (GAO) report, "Actions Needed to Control Radioactive Contamination at Sewage Treatment Plants," published in May 1994. That report recommended that NRC determine the extent of elevated levels of radionuclides at POTWs and establish acceptable limits for radioactive materials in sewage sludge and ash.

2. Agency Use of Information

This is a new collection of information.

The information could lead to additional NRC rulemaking for licensees disposing material into sanitary sewer systems or to EPA rulemaking for the use or disposal of sewage sludge. EPA will determine, based on the results of this survey, whether additional random sampling will be necessary to support its own rulemaking, if warranted.

This information will be used in developing joint NRC/EPA guidance for POTWs. This guidance would provide information to help POTW operators determine sources of radioactive materials at POTWs, describe sampling and analysis procedures, and advise whether a response is needed to the presence of radioactive material in sludge. POTWs, local sewer district officials, and EPA have requested this guidance.

3. Reduction of Burden through Information Technology

POTWs will respond to a short questionnaire and send sewage samples to an NRC or EPA lab for analysis. There will not be an electronic collection of information because the information will be collected on a one-time-basis. Two letters co-signed by NRC and EPA will be mailed to each POTW - the first letter with the questionnaire and the second with the sample collection package. The questionnaire is attached.

4. Effort to Identify Duplication and Use Similar Information

There is no similar information available. The only previous national sewage survey, the 1988-1989 National Sewage Sludge Survey, did not include analysis of radionuclides.

Recently, the Association of Metropolitan Sewerage Agencies (AMSA) conducted a voluntary survey of radionuclide concentrations in some of its members' POTW sewage sludge and ash. However, the AMSA survey did not identify the facilities tested, and thus it is not possible to assess regional background levels of radionuclides or the effects of licensees that dispose of radioactive material into sanitary sewers. (See further discussion of the AMSA survey in Item 8.)

5. Effort to Reduce Small Business Burden

This survey does not directly involve small entities. However, because the information needs are the same for both large and small POTWs, it is not possible to reduce the burden on small entities.

6. Consequences to Federal Program or Policy Activities if the Collection is Not Conducted or is Conducted Less Frequently

If the collection is not conducted at all, NRC and EPA will not be responsive to the recommendation in the GAO report to determine the extent of elevated levels of radionuclides at POTWs. NRC and EPA will also not be able to obtain information providing a basis for developing potential future rulemakings and quantitative guidance for the proposed joint NRC/EPA guidance for POTWs. This is a one-time collection.

There are no technical or legal obstacles to conducting this data collection.

7. Circumstances Which Justify Variation from OMB Guidelines

There is no variation from OMB guidelines. The POTWs will have 30 days to respond.

8. Consultations Outside the NRC

In an October 11, 1994 letter, NRC and EPA notified the water and radiological officials of all States of the potential for reconcentration of radioisotopes in sanitary sewer systems. This letter mentioned the planned EPA national survey and the guidance document.

On March 6, 1996, EPA and NRC staff were briefed by AMSA and the Water Environment Federation (WEF) on the preliminary results of a voluntary (but anonymous) AMSA survey of radionuclide concentrations in sewage sludge and ash at POTWs (see also discussion in Item 4). To date, sewage sludge and ash samples from 55 wastewater plants in 17 states have been analyzed. These plants were distributed across the country and range in size from small to among the largest POTWs in the United States. Because of limitations in the AMSA survey, including the fact that the POTWs were anonymous, the possibility of a more extensive NRC/EPA jointly funded survey of sludge and ash to assess the need for NRC rulemaking was considered. The industry representatives stated their continued interest in a joint NRC/EPA guidance document addressing reconcentration of radioactive material at POTWs. NRC and EPA have met with the WEF Radioactivity Task Force to discuss the status of the NRC/EPA survey and the contents of the joint guidance. During the survey, NRC and EPA will continue to meet with representatives of industry.

The sewage sludge/ash survey is being coordinated by a subcommittee of the Interagency Steering Committee on Radiation Standards (ISCORS). ISCORS was formed in 1995 to coordinate resolution of interagency issues. The ISCORS Sewage Subcommittee is assisting NRC and EPA in the development of the survey, including sample collection and analysis procedures and the selection of facilities to sample.

The NRC contractor, the U.S. Department of Energy's Oak Ridge Institute for Science and Education (ORISE), in Oak Ridge, Tennessee and EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama will analyze the sewage sludge and ash samples. These labs have also provided input on the survey design. For example, ORISE and NAREL collaborated to ensure that the analytical laboratory procedures and quality assurance programs that both labs will use will produce consistent, accurate, and reliable measurements.

An opportunity to comment on the information collection requirements in this survey was provided in the January 6, 1997 Federal Register notice on this clearance request. NRC received comments from five members of the public. The only change to the survey that resulted from the public comments was that one question was added to the questionnaire to determine if a previous analysis of radioactive materials was performed. If there is a question about the survey results at a specific POTW and an earlier analysis is available, we may compare the earlier analysis to the survey results. There were no changes in the cost or hourly burden as a result of the public comments.

Some of the public comments did not address the survey, and therefore, their resolution will have no impact on it. For example, some commenters asked the NRC to survey and sample its licensees, not POTWs. Several commenters noted the nearly complete absence of data in the NRC's possession regarding the licensees' discharges to the sewers. Some commenters also asked what the NRC would do for POTWs if they are found to have a contamination problem.

Some of the commenters objected to the survey. All the comments have been analyzed, and an analysis of the comments is attached.

9. Payment or Gift to Respondents

The POTWs will not receive payments or gifts; however, they will receive the results of the NRC/EPA analysis of sewage sludge and ash samples from their POTWs. Assuming an average of two samples analyzed per POTW, the analysis for each POTW is worth about two thousand dollars. The results will be provided to the POTWs in a joint NRC/EPA report.

10. Confidentiality of the Information

Each POTW will be assigned a code number to ensure confidentiality. Only NRC individuals with a need to know will be given access to the identity of a POTW if an NRC or Agreement State licensee is likely responsible for elevated levels of radioactive materials at a POTW and follow-up testing becomes desirable. At the conclusion of the survey, an industry organization such as AMSA will receive the code book with the identity of the POTW code numbers.

11. Justification for Sensitive Questions

There will be no survey questions of a sensitive nature.

12. Estimated Burden and Burden Hour Cost

About 600 POTWs will be asked to complete the survey questionnaire. Because the survey is voluntary (and thus not all POTWs will respond to the questionnaire), additional POTWs may have to be surveyed to find enough appropriate facilities to be sent sample collection packages. The estimated time to complete the questionnaire is hour. For 600 POTWs, the estimated burden would be 600 hours.

The survey was tested at nine POTWs to assess the questionnaire and sampling and analysis procedures. The test cases also gave a better basis for estimating the actual burden cost. Most of the POTW test cases took 20 minutes or less to complete the questionnaire; larger facilities required two hours to develop a list of zip codes for their collection system. Our original estimate of the time needed to complete the questionnaire was 2 hours; however, based on the results of the test cases, the revised estimated time to complete the questionnaire is 1 hour. For 600 POTWs, the estimated burden to respond to the questionnaire is 600 hours.

The questionnaire to the POTWs will ask for the zip codes for its collection system so that we can identify the licensees associated with each POTW. NRC will request from each Agreement State (depending on its information retrieval capabilities) (a) a list of licensees by zip code or (2) the list of all licensees (so that NRC can determine the licensees in the zip codes for the POTW collection systems). For 30 Agreement States at 8 hours per State, the estimated burden would be 240 hours.

Based on the method discussed in Items B.1 and B.2, about 300 POTWs will be sent sample collection packages. Each POTW will collect an average of two samples (one for each disposal practice). The estimated time for each POTW to collect and return the two samples is 6 hours. For 300 POTWs, the estimated burden is 1800 hours.

Total estimated burden = 600 + 240 + 1800 hours = 2640 hours

Estimated cost = 2640 hours x $120/hour = $316,800

13. Estimate of Other Additional Costs

There will be no additional cost burdens (beyond the cost of the hour burden discussed above) to the POTWs. There is no need to purchase additional equipment or laboratory support. For respondents to this survey, it is most likely that purchases of equipment and services were made (1) prior to October 1, 1995, (2) to achieve regulatory compliance with requirements not associated with the information collection, (3) for reasons other than to provide information or keep records for the government, or (4) as part of customary and usual business or private practices.

14. Estimated Cost to the Federal and State Governments

The cost to the Federal Government for this one-time-only survey includes costs for contractor support for the radioanalytical analysis, NRC and EPA Headquarters staffs, and Agreement State support.

Cost for Radioanalytical Support

Radioanalytical support will be provided by NRC's contractor, ORISE and EPA's NAREL. ORISE will assemble and distribute sample collection packages to about 300 POTWs. ORISE and NAREL will each analyze half the samples to determine the activity of radionuclides. No purchase of computers, software, or monitoring or testing equipment is needed. Monthly letter reports will be prepared containing the results of the analysis.

Tasks	ORISE Cost	EPA/NAREL Cost
Assist NRC and EPA in development of the survey, including test cases	50,000	12,000
Phone calls to POTWs, mailing sample collection packages, and providing return postage	25,500	0
Analyze samples	146,400	110,550
Report preparation	16,100	9,750
Sample disposition	0	5,000
Subtotal	238,000	137,300

Federal Government Cost

NRC Headquarters staff will coordinate the development of the survey and analyze the survey results. NRC, EPA, ORISE, and NAREL staff will write and publish the results as a joint NRC/EPA report. There will also be costs incurred by NRC and EPA for contract management and general oversight of the work scope.

2 FTE x 2080 hours x $120/hour = $499,200

The cost for a statistical consultant to support the analysis is about $100,000.

Total estimated survey cost for the Federal government

Lab costs + Federal costs + statistical consultant =

$238,000 + $137,300 + $499,200 + $100,000 = $974,500

Agreement State Cost

See Item 12, Estimated Burden and Burden Hour Cost, above.

15. Reasons for Changes in Burden or Cost

This is a new collection. There are no changes in burden or cost.

16. Publication for Statistical Use

NRC, EPA, ORISE, and NAREL will jointly write a report summarizing the survey results. The database in the report will include, at a minimum, lists of radionuclide concentrations for each POTW (coded to disguise the names of the facilities), geographic region, and disposal practice.

The project is to be completed within two years of approval by OMB. Questionnaires will be sent to the POTWs within two months of OMB approval, sample collection will take place over a one-year period, from 6 to 18 months after OMB approval, and the final report will be published two years after OMB approval.

17. Reason for Not Displaying the Expiration Date

Not applicable. The expiration date will be displayed.

18. Exceptions to the Certification Statement

There are no exceptions.

B. COLLECTIONS OF INFORMATION EMPLOYING STATISTICAL METHODS

The desire is to provide a national survey of high probability occurrences of elevated levels of radioactive materials in sewage sludge and ash. Even though this is a voluntary survey and may lack the number of samples needed to generate a comprehensive national profile, the survey will sample POTWs in all regions of the country and for a variety of NRC/Agreement State licensees. The collection of information will employ statistical methods.

1. There are approximately 11,000 POTWs in the United States that use at least secondary waste water treatment and are not simple pond treatment systems with only periodic solids cleanout. For the 1980s national survey, EPA developed categories based on flow rate and sewage sludge use and disposal practice. For the planned NRC/EPA survey, questionnaires will be sent to (1) POTWs associated with types of NRC licensees that have the highest potential to discharge radioactive material into the sewer system, (2) many of the POTWs with incinerators (these will be more heavily sampled because concentrations of radioactive material are expected to be higher in ash than in sludge), (3) POTWs in all geographic areas of the contiguous United States, and (4) POTWs requested by States and ISCORS agencies.

The survey questionnaire will ask the POTW operator to list the zip codes served by its collection system. Using this information, NRC will identify those licensees associated with each POTW that have the potential to dispose of radioactive material into its collection system.

There are currently approximately 7,000 NRC licensees and 15,000 Agreement State licensees in the United States (including Alaska and Hawaii, the District of Columbia and Puerto Rico). About half of these facilities use radioactive materials in the form of sealed sources (i.e., contained within a metal or other material casing); radioactive material in sealed sources cannot be disposed into the sewer system. Facilities that use material in unsealed form are predominantly hospitals, clinics, radiopharmacies, research and academic facilities, fuel cycle facilities, and research reactors. Nuclear power plants are not allowed to discharge to sewer systems.

2. The selection of the 300 POTWs to sample will be based on the results of the questionnaire survey. The questionnaire responses will be grouped into several categories and a random sample will be selected from each category. The categories we expect are:

- Types of NRC licensees (e.g., industrial, academic, medical)
- Geographic area, especially areas of high background radioactive material
- Sludge use or disposal practice (e.g., incinerator ash, landfill)

Potential problems include a low response rate because the survey is voluntary and difficulty in finding sufficient sample respondents for each category.

3. The following actions should lead to improved response rates:

- A short and easy to complete questionnaire
- A cover letter clearly stating the objectives of the data collection effort
- Development of a program to follow up on non-respondents

4. A pilot survey of nine POTWs was executed to test the questionnaire and the sampling and laboratory analysis procedures. As a result of the pilot survey, several changes were made to the questionnaire. For example, a question was added on whether the POTW had previously sampled for radioactive material. If there is a question about the survey results at a specific POTW, and an earlier analysis is available, it may be advisable to compare the two analyses.

As a result of the pilot survey, several changes were made to the sample analysis. For example, the list of radionuclides to be analyzed was refined, and the need for analysis of some samples by both labs was dropped due to the similarity of the test site results at the two labs.

5. Statistician consulted for the statistical aspects of the survey design:

Lee Abramson
U.S. Nuclear Regulatory Commission
301-415-6180

APPENDIX C
SEWAGE SLUDGE QUESTIONNAIRE

APPENDIX C

SEWAGE SLUDGE QUESTIONNAIRE

1. GENERAL INSTRUCTIONS

1.1 Introduction

The U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA) request your participation in a joint national survey of the concentrations of radioactive material in sewage sludge (biosolids), ash, and related byproducts.

NRC regulations in 10 CFR 20.2003 currently permit licensee disposal of certain specific quantities of soluble or readily dispersible biological radioactive material into a sanitary sewer system. The EPA regulation that addresses the use or disposal of sewage sludge (40 CFR Part 503) currently does not address radionuclides.

This survey will help determine the adequacy of the present NRC and EPA regulations addressing the discharge of radioactive material to the sanitary sewer system. It will also respond to a recommendation from the General Accounting Office (GAO) to determine the extent to which radioactive contamination in sewage sludge, ash, and related byproducts is occurring (GAO report, "Actions Needed to Control Radioactive Contamination at Sewage Treatment Plants," May 1994).

1.2 When and Where to File

Please return the completed questionnaire within 30 days of date of receipt to the address below:

U.S. Nuclear Regulatory Commission
Attn: Mary Thomas
Mail Stop T-9C24
Washington, DC 20555

1.3 Reporting Period

Please report information for the last 12 months or the last calendar year.

1.4 Further Information

If you require assistance in completing this questionnaire, call Robert Bastian, EPA, at 202-260-7378, (email: bastian.robert@epa.gov) or Mary Thomas, NRC, at 1-800-368-5642-extension 6230 (email: mlt1@nrc.gov).

2. GLOSSARY OF TERMS

End-products are the materials that leave the sewage treatment facility or are disposed of onsite after all
processing is completed (e.g., ash from incineration, digested liquid or dewatered cake, dried pellets, compost).

Incineration is the combustion of matter in sewage sludge by high temperatures in an enclosed device.

Land application is the application of sewage sludge to land to either condition the soil or fertilize crops or other vegetation.

Monofills are landfills where only sewage sludge is disposed. Monofills include trenches and area fills.

Municipal solid waste landfill is a landfill that receives household waste, and that is not a land application unit, surface impoundment, injection well, or waste pile. Such a landfill may be publicly or privately owned.

Sewage sludge is solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in a treatment works. Sewage sludge includes, but is not limited to: domestic septage; scum or solids removed in primary, secondary, or advanced wastewater treatment processes; and material derived from sewage sludge. Sewage sludge does not include ash generated during the incineration of sewage sludge or grit and screenings generated during preliminary treatment of domestic sewage in a treatment works.

Surface disposal is the placement of sewage sludge on an area of land for final disposal. It includes monofills, surface impoundments, lagoons, waste piles, and dedicated disposal sites. It does not include treatment and storage of sewage sludge, although placement on land for longer than 2 years is considered surface disposal unless the site owner/operator retains written records demonstrating that the operation constitutes a treatment or temporary storage site.

Treatment works is either a Federally-owned, publicly-owned, or privately-owned device or system used to treat (including recycle and reclaim) either domestic sewage or a combination of domestic sewage and industrial waste of a liquid nature.

Use or disposal includes: land application of bulk sewage sludge, land application of sewage sludge sold or given away in a bag or other container, surface disposal, disposal in a municipal solid waste landfill unit, incineration, or any other use or disposal practice (e.g., vitrification, use in asphalt or brick production).

SECTION I. TREATMENT WORKS IDENTIFICATION INFORMATION

Mailing Label
Name of the treatment works and physical location (which may differ from the mailing address):

Mailing address of the treatment works (if different):

Name, title, and telephone number of the person who should be contacted regarding information on this questionnaire:

Name, title, address, and telephone number of the person who should be sent the sample collection package:

SECTION II. GENERAL TREATMENT WORKS INFORMATION

1. Indicate below the level(s) of wastewater treatment achieved by this treatment works. (Mark X for all that apply.

   ☐ a. Primary treatment
   ☐ b. Secondary treatment
   ☐ c. Advanced treatment

2. Provide the annual average daily total flow rate for the last 12 months or the last calendar year (the total volume of wastewater treated by the treatment works in one year divided by 365). Use Gallons per Day (GPD) if your total daily flow rate is less than 10,000 GPD, *or* use Million Gallons per Day (MGD), but not both.

   __________________ GPD or MGD
   (Circle one) over the last 12 months <u>or</u> last calendar year (circle one)

3. List the zip codes served by the collection system for this treatment works. This information is needed so NRC can identify licensees that can potentially discharge to your collection system. A list of these licensees will be sent to you in return for providing this information.

4. Identify the *sewage sludge* treatment process(es) used at your treatment works. (Mark X for all that apply.)

   ☐ a. Treatment works did not process sewage sludge in the last 12 months or the last calendar year. Explain:_________________

   ☐ b. Thickening

   ☐ c. Mechanical dewatering by_________________
   (Please fill in process(es) used.

   ☐ d. Heat treatment/wet air oxidation

   ☐ e. Aerobic digestion

☐ f. Anaerobic digestion

☐ g. Composting

☐ h. Lime stabilization (Class B)

☐ i. Alkaline Stabilization (Class A)

☐ j. Air drying beds

☐ k. Heat drying/Pelletizing

☐ l. Sewage sludge treatment/storage lagoon(s)

☐ m. Sewage sludge storage bins or piles

☐ n. Incineration

☐ o. Other sewage sludge treatment processes
(Please specify.)
____

5. Check the boxes below to indicate the sewage sludge use or disposal practice employed at your facility or by others using/disposing of your sewage sludge or ash. Also describe the product as one of the following: slurry, dewatered cake, compost, pellets, ash, effluent, grit, or other. Note if the product is stored onsite before ultimately being disposed offsite; and if the product is stored onsite, the time stored onsite.

☐ a. Land application. Product description:

☐ b. Surface disposal (permanent piles, lagoons, sludge or ash monofills).
Product description: ___________________

☐ c. Disposal in municipal solid waste landfill.
Product description: ___________________

☐ d. Transfer of your sewage sludge or ash to another facility for use or disposal.
Product description: ___________________

Identify the facility (type, location): ___________________

☐ e. Other use or disposal practice.
Product description: ___________________

Describe practice: ___________________

6. What are the primary sources of drinking water for your community? Check more than one, if applicable.

   ☐ a. Municipal water supply from surface water source(s)

   ☐ b. Municipal water supply from groundwater well(s)

   ☐ c. Private wells

   ☐ d. Private water supply from surface water source(s)

7. Does your wastewater collection system receive discharges of drinking water treatment residuals?

   Yes _____ No _____

8. Does your wastewater collection system include combined sanitary and storm water sewers?

   Yes _____ No _____

9. Do you receive sludge from other wastewater treatment facilities for processing at your facility?

   Yes _____ No _____

10. Do you receive septage for processing at your facility?

   Yes _____ No _____

11. What percentage of the annual average daily total flow rate (response to question 3) is industrial flow?

   __________ Percent

12. Have you ever tested for radioactive materials in your sewage sludge?

   Yes _____ No _____

13. Do you have more than one final sewage sludge production facility location?

   Yes _____ No _____

APPENDIX D

QUALITY ASSURANCE PROJECT PLAN

EPA/NRC SEWAGE SLUDGE SURVEY

IAG/QAPP-2

Revision 1
October 2001

Prepared by:

U.S. Environmental Protection Agency
Office of Radiation and Indoor Air
National Air and Radiation Environmental Laboratory
540 South Morris Avenue
Montgomery, AL 36115-2601

This Quality Assurance Project Plan has been prepared in accordance with requirements described in EPA QA/R-5, ?EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations," United States Environmental Protection Agency, Quality Assurance Management Staff (now Quality Assurance Division), Draft Interim Final, August 1994.

Quality Assurance Project Plan
EPA/NRC Sewage Survey

Revision History

Rev.	Responsible Official	Date
0	Mary Wisdom	10/27/99
1	Andrea R. Jones	10/31/01

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1.0 PROJECT DESCRIPTION

This Plan applies to the joint survey sponsored by the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA) to collect information concerning radioactivity in sewage sludge and ash from sewage treatment plants (referred to in the industry as publicly owned treatment works (POTWs) which was conducted from 1998 through 2000. The U.S. Department of Energy's Oak Ridge Institute for Science and Education (ORISE), in Oak Ridge, Tennessee and EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama analyzed the sewage sludge and ash samples. NAREL and ORISE will each analyzed half the samples. Samples were collected over a 12-month period to ensure an even flow of samples into the laboratories and to allow adjustments to the analyses as needed.

<u>Pilot Study</u>

In order to evaluate sampling procedures, laboratory procedures, and laboratory comparability, nine POTWs were selected as test cases. The samples from the test cases were collected, shipped, analyzed, and reported under current requirements of the *Quality Assurance Manual for the Energy/Environment Systems Division, Environmental Survey and Site Assessment Program (EESAP)* of ORISE, and *The Quality Assurance Plan for the National Air and Radiation Environmental Laboratory* and written NAREL and ORISE QA/QC policies for radionuclide analysis. Split samples from the nine test POTWs were analyzed by both ORISE and NAREL. Results were studied to ensure comparability, consistency in sample handling, and validity of analytical methods. The results of this study indicated that in general the laboratories had good agreement between gamma analyses. Thus, the final survey did not require that split samples be analyzed by both laboratories. The gross alpha and beta analyses did not provide as good agreement due to differences in calibration and/or analysis procedures at the two laboratories. Although gross alpha and beta measurements are useful as screening tools, their accuracy should not be assumed to be better than about one order of magnitude. Therefore, the general magnitude of the results should be evaluated rather than detailed comparisons between individual measurements.

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

At ORISE, the Program Director and Assistant Program Director have overall responsibility for ESSAP quality assurance. Specifically, they establish program policies and procedures; monitor training operations; monitor data collection, development, and management; host and, if necessary, initiate external audits; review final survey reports and approve for release; and authorize exceptions to the requirements of the ESSAP Manual. The Quality Assurance Manager provides independent oversight for QA/QC pertaining to projects and laboratory activities and provides input directly to the Program Director; maintains the tracking system of audit findings and nonconformances, and then follows their resolution and closure; reviews all final reports prior to release; oversees maintenance of ESSAP training and certification records; oversees ESSAP performance evaluation activities; and coordinates vendor/provider assessments as deemed necessary by the Program Director.

According to the NAREL Quality Management Plan, the Director of the Office of Radiation and Indoor Air (ORIA) is responsible for ensuring that measurements performed within ORIA meet established Data Quality Objectives (DQOs). The Office Director has delegated the responsibility for overseeing quality assurance to the ORIA Quality Assurance Manager and has further delegated to the NAREL Director the primary responsibility for quality assurance on measurements in that facility. The NAREL Director has appointed a Quality Assurance Coordinator (QAC) to direct and oversee the laboratory's Quality Assurance Program. In addition, the Quality Assurance Forum (QAF) has been formed to focus on all pertinent QA issues. The QAF meets quarterly, includes all interested laboratory personnel, and uses open forums and work groups to recommend procedures that will effectively and efficiently resolve an identified problem.

The two laboratories will provide the analytical work, quality control and quality assurance, and data review and internal evaluation for the project. NAREL and ORISE will cooperate fully toward reaching agreement and closure on any issues which arise.

NAREL and ORISE staff are knowledgeable, well-trained, and experienced. Staff are trained, qualified, and certified according to requirements in the two laboratories' QA plans. Laboratory staffs routinely perform radiochemical analysis and data evaluation and interpretation. Laboratory analysts must be trained and certified for the analytical procedures they conduct.

At ORISE, staff receives appropriate training in health and safety, first aid, and CPR as deemed necessary by program management. The Quality Assurance manager ensures completion of training. The Office of Human Resources schedules and tracks ORISE mandatory training and assists with developmental training. The Office of Safety and Environmental Assurance provides training for radiation workers as required by federal regulations, and other safety related training as needs are identified. At NAREL, the Safety, Health, and Environmental Manager (SHEM) and the Radiation Safety Officer (RSO) with assistance from the Branch Chiefs and the Laboratory Director, annually assess individual needs for training in health and safety and in radiological safety for each employee. Specific job responsibilities dictate the type, complexity, and frequency of such training. Once an employee is identified as requiring health and safety training, whether initial or refresher training, attendance at, and completion of, the training are mandatory.

3.0 PROJECT QUALITY OBJECTIVES

Data quality objectives for the laboratory analysis of project samples are the normal analytical procedures and quality control acceptance criteria routinely followed by each of the laboratories. Section 11 of this QAPP provides a complete description of the analytical DQOs, their acceptance criteria, and corrective action required if criteria are not met.

ORISE will supply the sample collection packages to the POTWs. Samples will be collected, preserved, packaged, and shipped to the ORISE or NAREL laboratory by regular POTW workers using information and sampling supplies furnished by the laboratories. See Appendix A for sampling instructions and lists of sampling materials to be sent to POTWs.

Samples collected each month will be screened by the laboratories using their standard procedures for gross alpha and beta analysis and gamma scanning. A decision tree will be used for the alpha, beta, and gamma screening analyses to determine if, and what, nuclide specific analyses are indicated. Figures 1, 2, and 3 show the three decision trees. These trees will be used to identify samples for nuclide-specific analyses from the samples sent to the laboratories by the POTWs.

Figure D.1

Alpha Analysis Decision Tree

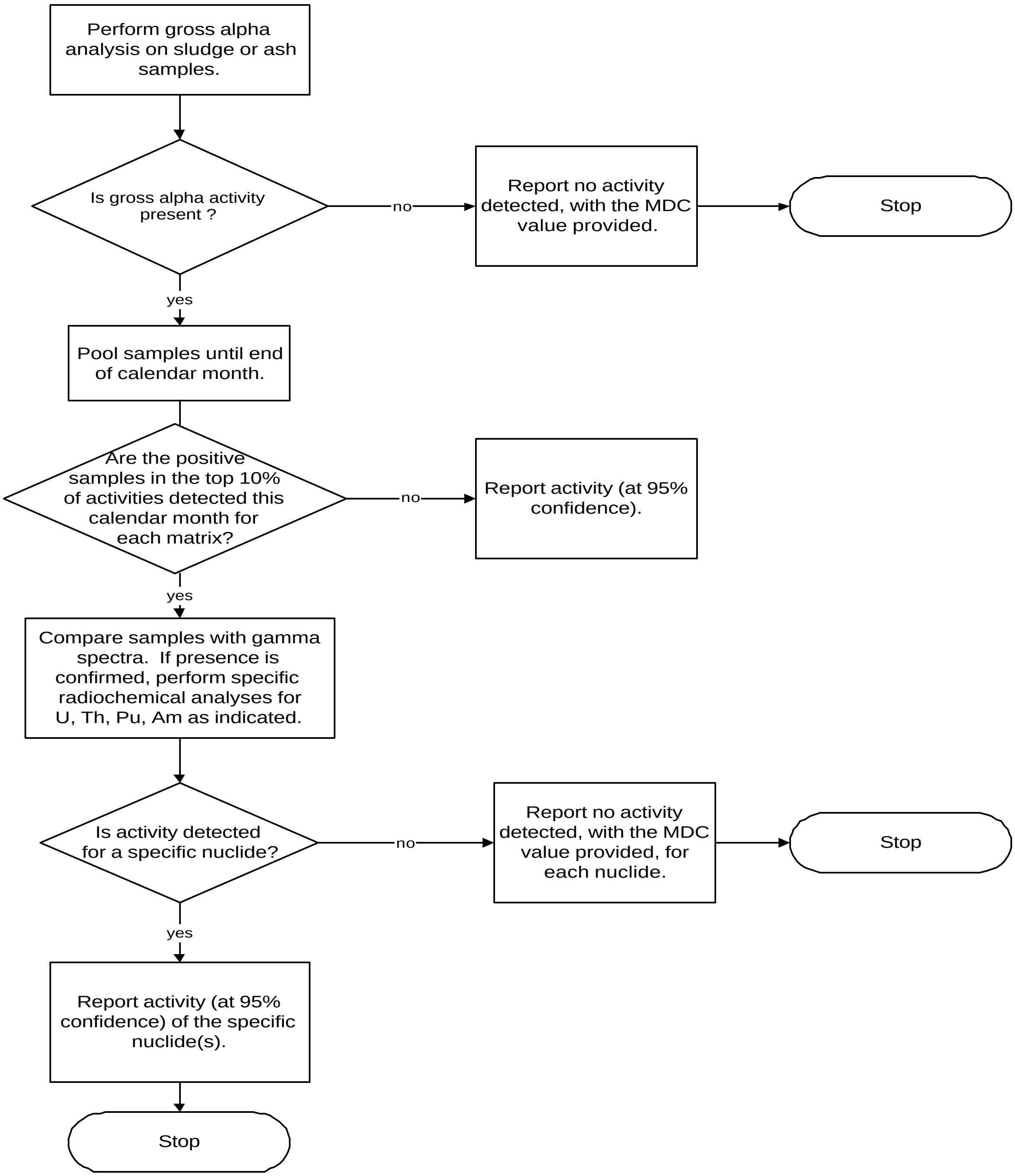


Figure D.2

Beta Analysis Decision Tree

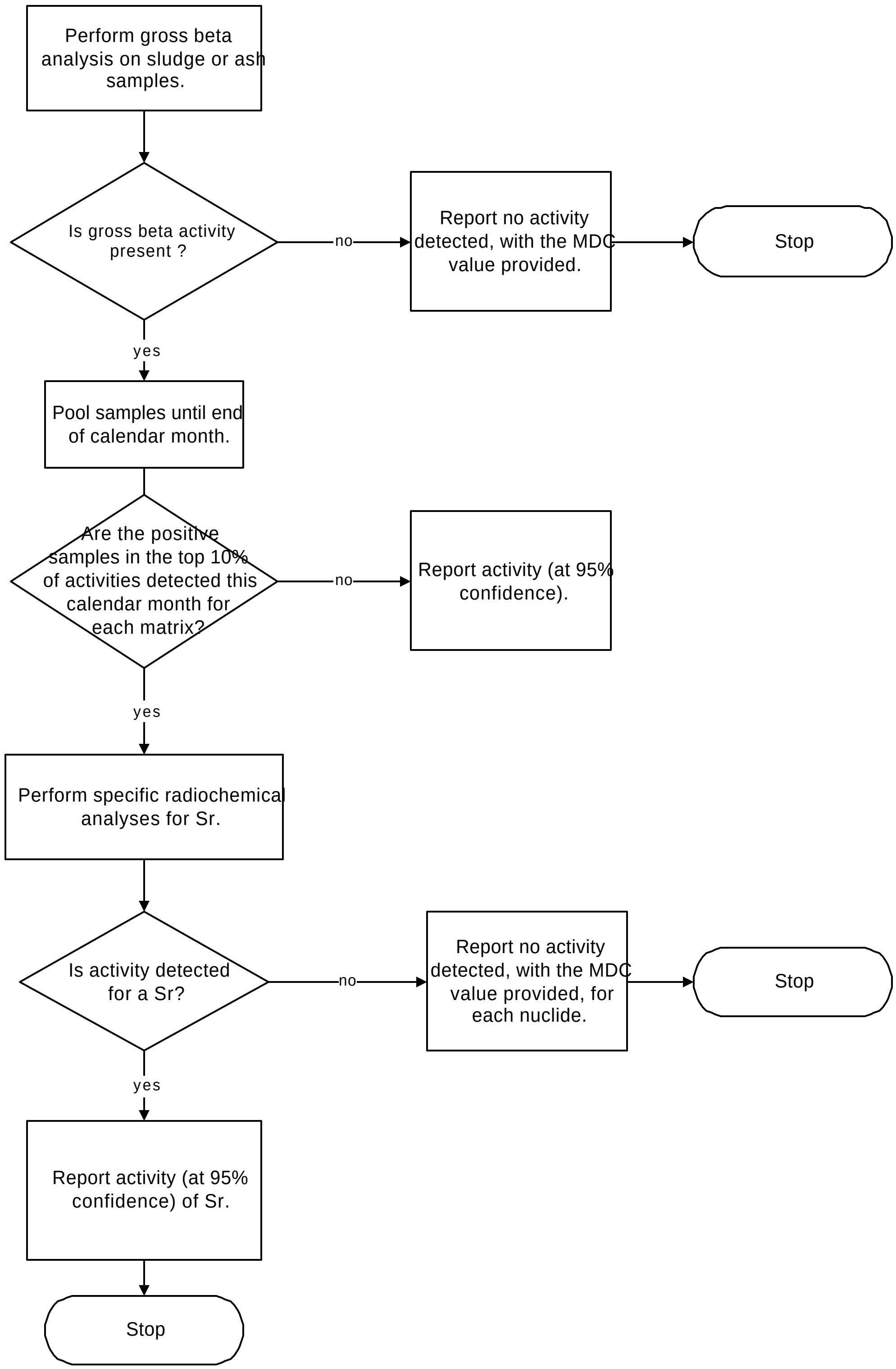
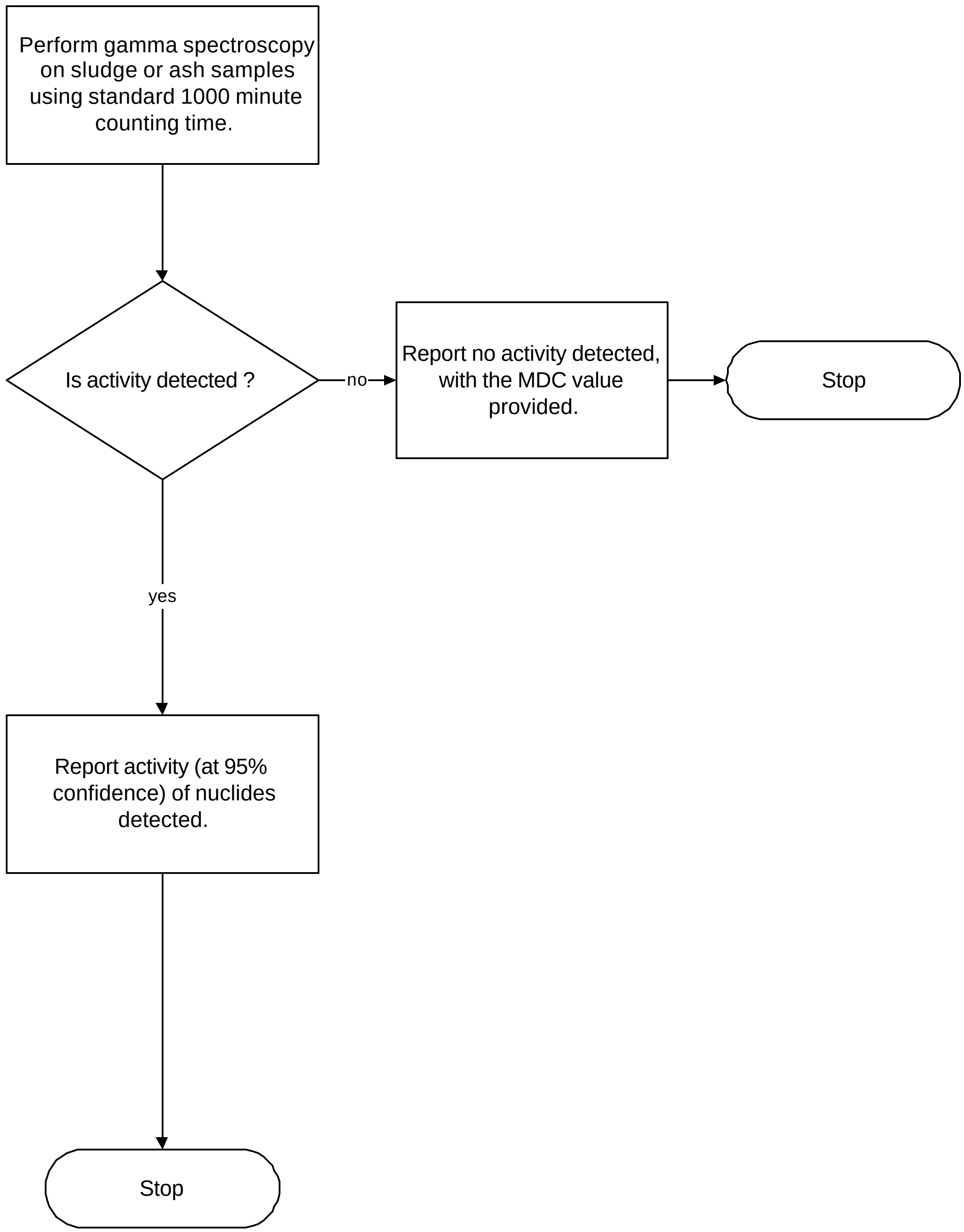


Figure D.3

Gamma Analysis Decision Tree



Each laboratory will report the minimum detectable concentration (MDC) for all nuclides of interest which are not detected in a sample. The instrument signal is compared to a critical level (Lc) which is the value of the net signal (e.g., count rate) that has a 5% probability of being exceeded when a blank sample is analyzed. It is used as a threshold value for deciding whether a sample contains the analyte of interest.

The minimum detectable concentration in a sample (MDC) is the smallest concentration of analyte (expressed in this study as pCi/g of sludge or ash) that has a 95% probability of producing a net detection-level signal (Ld) greater than the critical-level signal (Lc). It is thus the statistically smallest concentration with a 95% probability of being detected. Figure D.4 illustrates this concept.

Figure D.4 Comparison of Critical Level to Detection Limit

File Contains Data for PostScript Printers Only

Analytical results will be reported as activity ± 2s uncertainty. At NAREL, the uncertainty for all alpha spec results includes counting error, nonzero uncertainties for the sample volume, tracer concentration, and tracer volume, and an uncertainty in the counting efficiency, although this uncertainty affects only thorium results and yields for other analyses. For Ra-226 analyses, NAREL uses counting uncertainty and an uncertainty in the counting efficiency. For all other analyses, only counting uncertainty is computed. NAREL made an administrative decision to change the uncertainty reported for all of its gamma analyses in April 2000. The decision was to change from reporting only counting uncertainty, to reporting an uncertainty number which represents our best estimate of total uncertainty. The contractor who maintained the sewage survey database applied this total uncertainty correction algorithm retroactively to the counting uncertainties previously reported by NAREL. This makes all uncertainty numbers in the sewage survey database (for both NAREL and ORISE) nominally equivalent ?total uncertainty".

At ORISE, uncertainties for alpha and gamma spec include anything that has an uncertainty associated with it, including balances, pipettes, volumes, standards, tracers, and counting error. Uncertainty does not include any uncertainty related to the field sampling procedure.

NAREL reports uncertainty to two significant figures. Associated activity numbers are reported with their least significant digit being the same as the least significant digit of the uncertainty, e.g., if the least significant digit of the uncertainty is the tenths digit, that of the activity will also be tenths.

Of all the sludge/ash samples in which gross alpha or gross beta activity is detected, 10% will be chosen each calendar month from both ash and sludge matrices, and submitted for nuclide-specific analysis. They constitute a population, or sample pool, from which special samples will be selected for nuclide-specific analyses. The number of monthly samples should not exceed, for routine analyses, about 35 samples per month for each laboratory (400 samples/lab/12 months for routine analyses consisting of gross beta, gross alpha and gamma analyses). For nuclide-specific analyses, no more than 3 to 4 samples per month per laboratory (10% special samples from the 400 samples/lab/12 months) should be analyzed; and for quality control samples, about 5 per laboratory per month (60 QC samples/12 months in addition to the 300 routine samples).

It should be understood that samples which are received in a calendar month during the survey will be analyzed in batches as soon as is practicable. All samples for which gross alpha, gross beta, and gamma analyses are performed during a calendar month will be stored until the end of the month at which time decisions will be made about which samples of that month's pool will be subjected to nuclide-specific analyses. These nuclide-specific analyses will be conducted during the following 60 days.

Except for preparation of tritium samples at ORISE, no special or extraordinary sample concentration or analytical procedures will be employed for analysis of the sludge samples. For tritium analysis, ORISE will add two steps to its routine preparation procedure:

1. All samples will be double distilled to reduce or eliminate as many interferences as possible.

2. The chemiluminescence monitor for the instrument will be turned on and monitored.

Both laboratories will use currently approved analytical procedures for routine environmental samples. MDCs for samples will be those usually cited by each laboratory for environmental samples.

There are no established guidelines or regulations, in the ranges of results expected in these studies, which would dictate distinct actions at certain levels. Thus, any actions which might be recommended, or any indication of the need for further regulatory decisions, cannot be established until the results of the survey are complete. In the absence of applicable guidelines or regulations, recommended actions will be based on professional judgement.

The Data Quality Objectives (DQOs) for these studies have been developed using a process outlined in the guidance document EPA QA/G-4, *Guidelines for the Data Quality Objective Process*. Generally, DQOs for such specific criteria as accuracy, precision, comparability, and completeness will correspond to those routinely cited by the two laboratory quality assurance manuals as part of the laboratories' overall quality assurance and quality control program. Specific quantitative criteria for laboratory procedures are discussed within Section 11 of this QAPP.

4.0 PROCUREMENT AND ACCEPTANCE REQUIREMENTS

For ORISE, the *Quality Assurance Manual for the Energy/Environment Systems Division, Environmental Survey and Site Assessment Program (ESSAP)* identifies items or services to be procured by description of the item or service required along with all specifications, health and safety considerations, and quality requirements. The ORISE Financial Operations Division is responsible for procurement processing and compliance with all applicable regulations. ESSAP is responsible for assessment/inspection of items or services and payment approval.

The authority to commit and/or obligate funds by purchasing and contracting has been delegated to the NAREL Program Management Officer (PMO) and the NAREL Support Services Specialist. These persons and the bank card holders are the only employees authorized to handle procurement transactions with vendors. The technical or analytical staff is responsible for requesting supplies, reagents, and materials of adequate purity and reliability to ensure that there will be no adverse effect on the technical or analytical data produced. Procurement officials must not change orders for reagents or for technical supplies or services without approval from the original requestor. Upon receipt of purchased items, it is the responsibility of the requestor to verify that the correct items, of the expected grade and quality have been received.

5.0 INSTRUMENTS AND EQUIPMENT

5.1 FIELD AND SAMPLING INSTRUMENTS AND EQUIPMENT

For sample collection, only new containers are to be used.

No laboratory-supplied field sampling equipment or instruments, other than sample containers, will be used as part of this survey. Each POTW will use its own system and equipment to collect the appropriate samples. POTW workers are experienced in collecting samples for various analyses.

5.2 LABORATORY INSTRUMENTS AND EQUIPMENT

Laboratory instruments and equipment at each laboratory are used, calibrated, and maintained according to accepted good laboratory practices, each laboratory's written policies, and each laboratory's SOPs.

Regular efficiency checks (NAREL) and instrument reproducibility checks (ORISE) are performed on every detector in use at the laboratory according to each laboratory's standard operating procedures and written policies. Criteria and corrective actions are in place in both laboratories which dictate procedures when checks fail.

Regular background measurements are required for all detectors by both labs. At NAREL, backgrounds are measured daily for proportional counters, twice a month for alpha spectrometers, monthly for germanium detectors, and immediately before a sample is counted on a scintillation counter. ORISE measures backgrounds daily for proportional counters and a scintillation counter. Weekly background counts are performed for the alpha and gamma detectors.

Each gross radiation detector has an acceptable range for background levels. Background measurements are evaluated statistically to determine whether the true level is outside the acceptable range. There are warning limits and rejection limits for the test. If the most recent background level is outside the rejection limit, the detector is not used to analyze samples.

All radioactive standard solutions used for calibrations at NAREL and ORISE are NIST traceable whenever possible. Standard reference materials are purchased directly from NIST when they are available. If NIST traceable solutions are not available, industry accepted standards are used.

6.0 DOCUMENTATION AND RECORDS

6.1 DOCUMENT CONTROL SYSTEM

At ORISE, the Quality Assurance Manual and procedures manuals are controlled documents. They are distributed to all ESSAP personnel who must use the information to perform or review work. Agency representatives may also receive controlled documents on request. The QA Manager ensures document control is maintained according to QA Manual procedures.

NAREL operates under a formal document control system, described in the *NAREL SOP for Document Control,* which presents the policies and procedures for the production, review, revision, storage, and distribution of documents. Document control policies apply to all printed internal documents that are maintained by or for NAREL personnel on a continuing basis for a period longer than one year. Controlled documents include, but are not limited to, the NAREL Quality Management Plan (QMP), Quality Assurance Manuals (QAMs), Quality Assurance Project Plans (QAPPs), SOPs, technical documentation, and forms. The Document Control Officer maintains the NAREL Document Control Logbook, maintains current copies of all controlled documents in hard copy and electronic forms, approves any new or revised documents in the system, and has primary responsibility for the *NAREL SOP for Document Control.*

6.2 LABORATORY OPERATING DOCUMENTS

At ORISE, procedures used in the ESSAP activities are documented in the following manuals prepared specifically for ESSAP applications: *Laboratory Procedures Manual*, which presents the procedures used in handling, preparation, and analysis of samples for radioactive constituents; *Survey Procedures Manual*, which presents the procedures used for radiation measurements and sampling; and the *Quality Assurance Manual*. These manuals are controlled documents.

The *NAREL Quality Management Plan* (QMP) describes the Quality System at NAREL in terms of the organizational structure, functional responsibilities of management and staff, lines of authority, and processes for planning, implementing, documenting, and assessing activities. The QMP is the umbrella document for management policies, goals, and processes which incorporate quality assurance and quality control into all aspects of work. The QMP describes how NAREL implements its quality system and educates its staff about QA and QC processes.

A Quality Assurance Manual (QAM), formerly called a Quality Assurance Plan (QAP), presents technical criteria for analytical and administrative tasks to ensure that all data produced will be of known and desired quality, and that all measurements performed at NAREL are valid, scientifically defensible, and of known precision and accuracy. The QAM addresses all phases of the quality control, quality assurance, and quality assessment processes. A Quality Assurance Project Plan (QAPP) describes in detail the necessary QA, QC, and other technical activities that must be implemented to ensure that the work performed on a specific project will satisfy the required performance criteria. Each project conducted by or for NAREL requires a QAPP. This includes projects supported by contract, interagency agreement, or grant.

Standard Operating Procedures (SOPs) contain specific details and procedures which ensure that data generated by their use will be of known and adequate quality. An SOP details the method for an operation, analysis, or action, with thoroughly described techniques and steps.

6.3 PROJECT DOCUMENTATION

This QAPP describes the necessary QA, QC, and other technical activities that will be implemented during the Sewer Sludge Survey project. The QAPP is written in accordance with requirements described in EPA QA/R-5, ?EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations," United States Environmental Protection Agency, Quality Assurance Management Staff (now Quality Assurance Division), Draft Interim Final, August 1994. The QAPP also incorporates specific points of agreement between EPA, NRC, ORISE, and NAREL. It references specific documents, including SOPs, which will guide the procedures used during this survey.

6.3.1 GAMMA ANALYSIS

The activity and 2-sigma uncertainty for radionuclides measured by gamma spectrometry are reported only if the nuclide is detected. Nuclides that are not detected do not appear in the report, with the exception of Co-60, Cs-137, I-131, K-40, Ra-226 and Ra-228. If one of these six nuclides is undetected, it is reported as ?Not Detected" or ?ND", and a sample-specific estimate of the MDC is provided.

Due to potential spectral interferences and other possible problems associated with the determination of the activity of certain radionuclides, the activities for Th-234, Pa-234m, Ra-226, and U-235 are subject to greater possible uncertainty than other commonly reported radionuclides. It should be noted that this potential uncertainty is not included in the two-sigma counting uncertainty which is reported with each activity. Although the calculated activities for these radionuclides are reported, it is recommended that the results be used only as a qualitative means of indicating the presence of these radionuclides and not as a quantitative measure of their concentration. The results for these nuclides are not used in the evaluation of quality control samples. Furthermore, because of mutual interference between Ra-226 and U-235, NAREL's gamma analysis software tends to overestimate the amounts of these nuclides whenever both are present in a sample. Lower estimates for Ra-226 activities can be obtained from the reported activities of its decay products, Pb-214 and Bi-214, which are likely to be somewhat less than the Ra-226 activity because of the potential escape of radon gas.

NAREL's gamma spectrometry software corrects activities and MDCs for decay between collection and analysis, but only up to a limit of ten half-lives. So, if the decay time for a sample is more than ten half-lives of a radionuclide, that nuclide will almost always be undetected and the reported MDC will be meaningless. This is usually a problem only for short-lived radionuclides, such as I-131, when there is a long delay between collection and analysis. ORISE uses extrapolated efficiencies for radionuclides with energies below 59 keV, e.g., I-125 and Pb-210. The reported concentrations and MDCs for any radionuclide below 59 keV are approximations and are reported as qualified data. At both laboratories, all preparation, survey, sampling, analytical, reporting, and disposal activities are completely documented throughout the life of a project.

6.3.2 GROSS ALPHA AND BETA ANALYSIS

In comparison to the methods employed to determine radionuclide-specific activities, the method employed by NAREL to determine gross alpha and beta activity has the potential for greater analytical bias. This is especially true for solid samples. It should be noted that this potential analytical uncertainty is not included in the two-sigma counting uncertainty term. Therefore, gross alpha and beta results should be used as gross approximations of the alpha and beta activity present.

6.4 PROJECT DATA PACKAGE DELIVERABLES

Each month, the laboratories will prepare data packages for each batch of samples which has been completed during that calendar month. The data for each completed analysis batch will be correlated on sample summary sheets. See Table 6.1 for an example of the format and content of the data summary sheet. Copies of the data packages and summary sheet will be sent to project managers for EPA and NRC by the 10th day of the month following the end of the month being summarized. Review of the monthly reports will provide a continuing input of information about nuclides and activities seen at the POTWs in the survey and, most importantly, will allow the reviewers and the project team to note problems and unusual results. Monthly data reports will allow the project team to correct any problems noted, change action limits for nuclide-specific analyses if necessary, and add data to the databases to be used for analysis of survey results.

Table D.1

Monthly Data Report for EPA/NRC National Radiological Sewage Survey
Data Summary Sheets

Laboratory: _____________ Page __ of __

Sample ID: _____________ Other ID: __________

Collection Date and Time: _______________ Matrix: ____________

Analysis	Nuclide	Activity	2s Uncertainty	Units	% solids	MDC
Gamma	Pb-212					
Gamma	Pb-214					
Gamma	Bi-214					
Gamma	I-131					
Gamma	Ra-226					
Gamma	Ra-228					
Gamma	Bi-212					
Gamma	Be-7					
Gamma	Tl-208					
Gamma	K-40					
Gamma	Cs-137					

Analysis	Nuclide	Activity	2s Uncertainty	Units	% solids	MDC
Gamma	Co-60					
Gamma	I-125					
Alpha	Gross					
Beta	Gross					
LSC	C-14					
LSC	H-3					
a Spec	U-234					
a Spec	U-235					
a Spec	U-238					
a Spec	Th-227					
a Spec	Th-228					
a Spec	Th-230					
a Spec	Th-232					
a Spec	Pu-238					
a Spec	Pu-239					
a Spec	Pu-242					
a Spec	Am-241					
Prop. Ctr.	Sr-89					
Prop. Ctr.	Sr-90					

Both labs analyze samples in analytical batches; no information will be reported about a sample or an analysis until the entire batch data package has been completed, reviewed, verified, and approved for release from the lab according to the lab's quality assurance and data review policies.

For each analytical batch of samples analyzed at the laboratory, a data package will be provided for each type of analysis. This package will include:

- tabulated sample information for the analytical batch: sample ID, client sample ID, matrix, date collected, date received, and date analyzed.
- documentation exceptions
- holding time information if applicable
- sample preparation exceptions
- sample analytical exceptions
- general information unique to the sample batch, the analytical method, or reporting conventions
- individual report forms for each sample which provide

- sample identification information
- analytical method
- detector identification
- sample weight information
- activity units
- nuclides, activity, 2s uncertainty, and MDC

Instrument printouts including spectra and other raw data, calibration data, and quality control results are compiled and maintained in the laboratory for each sample batch. Raw data will not be included in the monthly data reports, but will be maintained by the labs and will be available to reviewers on request.

6.5 RECORDS ARCHIVING AND RETENTION POLICIES

All records pertaining to environmentally related measurements will be archived, retained, and disposed of according to the pertinent EPA records schedule, with concurrence of EPA and NRC. No documents at either laboratory are disposed of without specific approval from the client or data-user for the project.

7.0 SAMPLING PROCESS DESIGN

Owners and operators of the selected POTWs will collect and ship the samples following guidelines provided by ORISE and NAREL.

All samples collected will be analyzed for gross alpha and beta emissions and gamma-emitting nuclides and, if indicated by the decision tree process, (See Figures 1, 2, and 3) for uranium, thorium, plutonium, radium-226, americium, and strontium. All samples received at ORISE will be analyzed for carbon-14 and tritium. The NAREL and ORISE Minimum Detectable Concentrations (MDC) for these nuclides are listed in Tables 7.1. and 7.2.

8.0 SAMPLING PROCEDURES

8.1 SAMPLING PROCEDURES AND EQUIPMENT

Procedures and equipment for field collection of samples are described in the instructions for collection found in Appendix A of this QAPP.

8.2 COLLECTION OF SAMPLES

Container identification labels will be filled out completely in indelible ink. Labels are glued to containers and then covered with clear waterproof tape for protection. Containers will be filled, closed, and rinsed with water to minimize cross-contamination. Samples will be described and identified on the appropriate Sampling Data Form and are packed for shipment to the laboratory. Samples must be collected and returned to the laboratory within one week of receipt of the sampling kit at the POTW.

8.3 SAMPLE CUSTODY, SHIPPING, AND NOTIFICATION

ORISE will send appropriate sampling containers, chain-of-custody forms (COCs), and sample collection and handling instructions to each POTW in the survey and will notify NAREL when kits are sent and to which facilities. Copies of the COC and the collection instructions are found in Appendix A of this QAPP. POTW operators will collect the samples, ensure that the samples are properly labeled with the name of the facility, type of material sampled, location or source of the sample, the name of the person taking the sample, and the date and time of sample collection. The COC form will then be completed to include the name of the facility, the location or source of the sample, the name of the person taking the sample, and the date and time of sample collection.

The samples will be placed in a shipping container and security seals placed across the top and bottom of the shipping container. Samples will be shipped priority overnight by Federal Express for next-morning delivery to the designated laboratory. No samples should be shipped to laboratories on Friday or the day before a holiday. ORISE will track delivery of all samples shipped by the POTWs. NAREL will notify ORISE of shipments received.

Table D.2 Minimum Detectable Concentration (MDC) for Selected Gamma Emitters Using Gamma Spectrometry with Ge Detector				
Selected Gamma Emitters	NAREL MDC (pCi/L) for 1 L of Water Counted for 1000 min	NAREL MDC (pCi/gwet) for 100 g of Sediment Counted for 1000 min	ORISE MDC (pCi/L) for 1 L of Water Counted for 1000 min	ORISE MDC (pCi/gwet) for 100 g of Sediment Counted for 1000 min
Am-241	17.7	0.0842	4.88	0.01
Cd-109	83.0	0.424	64	0.6
Th-234	52.5	0.270	68.7	0.10
U-235	56.7	0.294	14.4	0.02
Ra-226	86.1	0.446	61.0	0.6
Th-229	65.6	0.340	38.0	0.05
Pb-212	8.45	0.0439	5.41	0.01
Ra-224	91.0	0.473	59.8	0.08
Ra-223	26.7	0.139	16.0	0.01
Pb-214	11.4	0.0601	8.02	0.01
I-131	5.84	0.0307	3.04	0.01
Rn-219	69.6	0.367	39	0.3
I-125	100	0.15	10	0.2
Be-7	45.4	0.241	26.6	0.04
Ba-140	22.2	0.119	11.4	0.02
Tl-208	6.42	0.0344	3.95	0.01
Cs-134	6.67	0.0357	4.11	0.01
Bi-214	13.1	0.0704	8.29	0.01
Cs-137	7.26	0.0391	4.18	0.01
Bi-212	89.4	0.483	28.7	0.04
Pb-211	188	1.02	117	0.17
Mn-54	7.03	0.0382	3.52	0.01
Ra-228	24.4	0.133	21	0.2
Pa-234m	950	5.20	687	0.67
Co-60	10.3	0.0566	4.33	0.01
Na-22	9.38	0.0519	4.17	0.01
K-40	99.3	0.552	59.4	0.10

NOTE: MDCs will vary depending on activity in the sample, density of sample matrix, efficiency of detector, and other counting parameters. The above MDCs were calculated based on a 1000-min count of a 1.0-L Marinelli of deionized water.

Table D.3 Minimum Detectable Concentration (MDC) for Selected Radionuclides Using Various Radiochemical Analyses

Radionuclide	Matrix	NAREL				ORISE			
		Typical Aliquot Size	Count Time (min)	Method	MDC	Typical Aliquot Size	Count Time (min)	Method	MDC
Gross Alpha	Water	250 mL	100	GFP	6 pCi/L	250 mL	200	GFP	3 pCi/L
	Solids								
Gross Beta	Water	250 mL	100	GFP	3 pCi/L	250 mL	200	GFP	2 pCi/L
	Solids								
Radium-226	Water	1 L	1000	SC	0.02 pCi/L	1 L	240	AS	0.1 pCi/L
	Solids	0.5 g	1000	SC	0.04 pCi/g	700g	60	GS	1.0 pCi/g
Radium-228	Water	1 L	100	GFP	1 pCi/L	1 L	60	GFP	2 pCi/L
	Solids	0.5 g	100	GFP	2 pCi/g	700 g	60	GS	1 pCi/g
Iodine-131	Water	2 L	1000	GFP	0.7pCi/L	1 L	1000	GS	3.2 pCi/L
Uranium-234, 235, 238 Thorium-230, 232 Plutonium-238, 239	Water	1L	1000	AS	0.1 pCi/L	0.25L	1000	AS	0.4 pCi/L
	Solids	0.5 g	1000	AS	0.2 pCi/g	1 g	1000	AS	0.1 pCi/g
Sr-89	Water	2 L	100x3	CS-PC	1	0.25 L	60	GFP	5.0
	Solids	0.5 g	100x3	CS-PC	4	5 g.	60	GFP	0.5
Sr-90	Water	2 L	100x3	CS-PC	1	0.25 L	60	GFP	5.0
	Solids	0.5 g	100x3	CS-PC	4	5 g.	60	GFP	0.5
Thorium-227	Water	1L	1000	AS	0.2 pCi/L	0.25 L	1000	AS	0.4 pCi/L
	Solids	0.5 g	1000	AS	0.35 pCi/g	1.0 g	1000	AS	0.1 pCi/g
Thorium-228	Water	1L	1000	AS	0.15 pCi/L	0.25 L	1000	AS	0.4 pCi/L
	Solids	0.5 g	1000	AS	0.3 pCi/g	1.0 g	1000	AS	0.1 pCi/g
H-3	Wet	N/A	N/A	N/A	N/A	60 g wet	60	LSC	1.0 pCi/g
C-14	N/A	N/A	N/A	N/A	N/A	0.5 g wet	60	LSC	3.0 pCi/g

AS Alpha Spectrometry
GFP Gas-Flow Proportional Counting
GS Gamma Spectrometry
LS Liquid Scintillation Counting
SC Scintillation Counting

8.4 CORRECTIVE ACTIONS

Each laboratory will receive and survey samples according to approved laboratory procedures and policies. Discrepancies in labeling, COC information, or other documentation will be noted on the COC for the samples and, when the discrepancy has the potential to affect sample integrity, it will be reported to the POTW samplers and the EPA and NRC project managers. All discrepancies and their resolution must be fully documented. Additional information about corrective action is provided in Section 14.3 of this QAPP. Specific information regarding corrective actions and the personnel responsible for them are documented in the QA manuals for each laboratory.

9.0 LABORATORY SAMPLE RECEIPT

Similar procedures are used at both NAREL and ORISE to ensure complete control of samples and clear, concise documentation of the steps in the sample chain-of-custody form.

The POTW staff initiates the chain-of-custody form for survey samples. When sample custody is transferred (relinquished) to the laboratory, the container and its contents are inspected by the individual accepting custody to assure that tampering has not occurred and custody has therefore been maintained.

Samples received at ORISE will be surveyed for radioactive contamination and recorded in the electronic sample database according to *Laboratory Procedures Manual* requirements. The Laboratory Supervisor will maintain sample custody until the sample is disposed of, consumed, transferred, or destroyed. Sample disposal must be authorized by the Program Director or Assistant Program Director at the direction of the customer. During analysis, the samples will remain in a locked building during working hours and in a locked room in the building during non-working hours. Disposition information is entered into the electronic database. Archived samples are sealed and stored in a locked building.

Environmental samples received at NAREL are surveyed for radioactive contamination, logged-in, and stored in accordance with the *NAREL SOP for Sample Receipt, Log-in, and Storage*. All samples are received by the Sample Preparation Manager (SPM) or her designee. Sample packages are stored in a secure area until they are surveyed for radioactive contamination. The results of the survey are recorded on the chain-of-custody. The SPM compares the samples received to the chain-of-custody. Any discrepancies must be resolved and documented on the COC before sample analysis begins. The samples are then logged-in to the Sample Preparation Logbook and into the NAREL Radioanalytical Database.

After samples are logged-in and numbered, and all documentation is complete, samples are stored at various locations at NAREL, depending on the matrix, analyses requested, and project, until the analyses are performed. Samples are always stored in a secure area to which only laboratory personnel have access. Access to NAREL is restricted. Outside entrances, laboratories, the counting room, and the sample preparation area require a key-card for entry. Visitors must sign in at the reception area and are escorted while in the laboratory.

10.0 LABORATORY SAMPLE PREPARATION PROCEDURES

Sample preparation procedures and required documentation are described in the specific NAREL SOPs and the ORISE procedures manuals for each analytical method. Exceptions to an approved procedure must be documented and explained fully in accordance with the laboratories' QA manuals. Corrective actions must be initiated and documented when required. Appendix B of this QAPP lists specific references to methods and procedures.

11.0 ANALYTICAL PROCEDURES

11.1 ANALYTICAL METHODS

All analytical methods used for this survey at either the NAREL or ORISE laboratories have been approved internally and are based on industry standard procedures with proven precision and accuracy. Methods are described and techniques outlined in the individual method SOPs and procedures manuals for the two laboratories. Appendix B of this QAPP provides a list of methods and procedures for each laboratory.

11.2 ANALYTICAL QUALITY ASSURANCE

Quality control testing is performed for laboratory activities to provide an ongoing assessment of equipment and procedures. Quality control samples are prepared using standards traceable to NIST or to industry accepted reference materials if NIST traceability is not possible. Chemicals used for reagent preparation are reagent grade or higher depending on specific method requirements.

11.3 QUALITY CONTROL SAMPLES

Laboratory quality control (QC) samples will be included in the analytical scheme in accordance with the *Quality Assurance Manual for the Energy/Environment Systems Division, Environmental Survey and Site Assessment Program (ESSAP)* of ORISE, and *The Quality Assurance Plan for the National Air and Radiation Environmental Laboratory* and written ORISE and NAREL QA/QC policies for radionuclide analysis. Four types of internal quality control samples are analyzed routinely in the NAREL and ORISE radiochemistry QA programs. The QC analyses and their frequency are:

- duplicate analyses (NAREL - one per analysis batch, ORISE - based on client request.);
- matrix spikes, containing a known quantity of each analyte of interest added to an existing sample (NAREL - one per analysis batch, ORISE based on client request);
- performance evaluation (PE) samples consisting of the radionuclide of interest in either an interference free matrix (usually deionized water) or standard reference material (SRM) that will simulate soil or ashed samples; and

- reagent blanks, which contain only the radioactive tracer, if appropriate, and reagents used in the analysis (one per analysis batch).

For both labs, a batch can contain 20 samples plus appropriate QC samples.

The batch QC requirements listed above do not apply to gamma analyses. Duplicate gamma analyses are performed on every twentieth sample through the laboratory, and performance evaluation samples consisting of a variety of gamma emitters and matrices are submitted to the radioanalysis laboratory at least once a month.

The result of a quality control check is a quality indicator, whose numerical value must be judged either acceptable or unacceptable. The acceptance criteria for a quality indicator must be based on sound statistical principles and should be formulated in terms of the estimated uncertainties and analytical errors (standard deviations) of the quantities used to compute the value of the indicator.

A quality indicator may have both control limits and warning limits. When an indicator value falls in the warning region, the Project Coordinator must initiate an investigation. When the value is outside the control limits, the Project Coordinator must report the problem to the Quality Assurance Coordinator, who will issue a corrective action memorandum .

11.3.1 Duplicate Analyses

Duplicates are two aliquots taken from the same homogenized sample.

When precision is assessed by duplicate analyses, including matrix spike duplicates, the quality indicator is given by

$$Z_d = \frac{|S_2 - S_1|}{\sqrt{U_1^2 + U_2^2}},$$

where

S_1	=	First of two measurements
S_2	=	Second of two measurements
U_1	=	Estimated 1-sigma total random error associated with S_1
U_2	=	Estimated 1-sigma total random error associated with S_2

When requested by the Subcommittee, NAREL will compute and report the “relative percent difference,” or *RPD*, of the two measurements, which is defined by the equation

$$RPD = \frac{|S_2 - S_1|}{(S_1 + S_2)/2} \times 100\%.$$

Acceptance criteria based on the *RPD* generally require spiked activities significantly above environmental levels and therefore are usually applicable only to matrix spike duplicates.

If the total uncertainties U_i for the measured concentrations S_i are unknown, they may be estimated. When duplicate analyses are performed, the total uncertainties may be estimated as follows:

$$U_i^2 \ ' \ E_i^{\,2} \% ?^2 \left(\frac{S_1 \% S_2}{2} \right)^2$$

where

E_i	=	Estimated 1-sigma counting error
?	=	Maximum acceptable 1-sigma total random error, excluding counting error, expressed as a fraction of the concentration

The result of a duplicate analysis is acceptable if $|Z_d|$ # 2. An investigation is necessary if 2 < $|Z_d|$ # 3. Corrective action is required whenever $|Z_d|$ > 3.

11.3.2 Spiked Samples

An aliquot of a sample is spiked (fortified) with known quantities of specific compounds and subjected to the entire analytical procedure.

In the case of a matrix spike, the accuracy indicator is defined as

$$Z_r \ ' \ \frac{S \& B \& K}{\sqrt{U_s^{\,2} \% U_b^{\,2} \% U_k^{\,2}}},$$

where

S	=	Measured concentration in spiked aliquot
B	=	Measured concentration in unspiked aliquot
K	=	Known concentration of spike added
U_s	=	Estimated 1-sigma total random error associated with S
U_b	=	Estimated 1-sigma total random error associated with B
U_k	=	Estimated 1-sigma total uncertainty associated with K

The total random uncertainties U_s and U_b may be estimated as follows:

$$U_s^{\,2} \ ' \ E_s^{\,2} \% ?^2 S^2,$$
$$U_b^{\,2} \ ' \ E_b^{\,2} \% ?^2 B^2,$$

where

E_s = Estimated 1-sigma counting error for S
E_b = Estimated 1-sigma counting error for B
? = Maximum acceptable 1-sigma total random error, excluding counting error, expressed as a fraction of the concentration

The accuracy indicator for performance spikes and standard reference materials is defined as

$$Z_r = \frac{S - K}{\sqrt{U_s^2 + U_k^2}},$$

where
S = Measured concentration of reference material
K = Known concentration of reference material
U_s = Estimated 1-sigma total error associated with S
U_k = Estimated 1-sigma total uncertainty associated with K

The total random uncertainty U_s may be estimated as follows:

$$U_s^2 = E_s^2 + ?^2 K^2,$$

where
E_s = Estimated 1-sigma counting error for S
? = Maximum acceptable 1-sigma total random error, excluding counting error, expressed as a fraction of the concentration

It is permissible to use a fixed percentage of K, not to exceed 5%, for U_k. If the uncertainty in K is assumed to be negligible, then U_k may be set equal to zero.

The indicator is acceptable if $|Z_r| \le 2$. An investigation is necessary if $2 < |Z_r| \le 3$. Corrective action is required if $|Z_r| > 3$.

When requested by the Subcommittee, NAREL will compute and report the "percent recovery," or $\%R$, which is given by

$$\%R = \frac{S - B}{K} \times 100\%$$

for matrix spikes and by

$$\%R = \frac{S}{K} \times 100\%$$

for performance spikes and standard reference materials. Meaningful acceptance criteria for $\%R$ generally require spiked activities significantly higher than environmental levels.

11.3.3 Reagent Blanks

A reagent blank, or method blank, is an analytical control, consisting of all reagents and internal standards or tracers, that is carried through the entire analytical procedure. The blank is used to define the level of laboratory background and reagent contamination.

Control charts are maintained for each analysis type. The initial set-up and all subsequent updates of a control chart should be based on a sample of at least 20 reagent blank results, which are used to determine a sample mean $\bar{x}$ and standard deviation s.

The blank values used to compute the mean and standard deviation must first be judged acceptable. For this purpose, any reagent blank measurement whose value differs from zero by less than the 2-sigma counting error of the measurement is acceptable. Professional judgment is required to accept any value that differs from zero by more than the 2-sigma counting error.

The mean and standard deviation are computed as follows:

$$\bar{x} = \frac{1}{n} \sum x_i \,,$$

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{\sum x_i^2 - n\bar{x}^2}{n-1}} \,.$$

where n denotes the number of measurements.

A reagent blank value is judged acceptable if it lies within two standard deviations of the mean. An investigation is required if the blank value is more than two but no more than three standard deviations from the mean. The value is unacceptable if it is more than three standard deviations from the mean.

When a reagent blank is unacceptable, the samples in the batch may have to be reanalyzed. Any sample whose measured activity is greater than the associated 2-sigma counting error and whose total activity is less than a predetermined multiple k (generally 5) of the total blank activity must be reanalyzed.

11.3.4 Completeness (statistical)

Completeness is assessed by the following indicator:

$$\%C = 100\% \left(\frac{V}{n} \right)$$

where

$\%C$	=	Percent completeness
V	=	Number of measurements judged valid
n	=	Total number of measurements performed.

The requirements for judging measurements as valid and the total number of measurements necessary to achieve the desired statistical level of confidence depend on the study objectives and, thus, are specified by the QAPP. For this project, designed as a survey study, statistical completeness is not an indicator of concern.

11.4 SAMPLE BATCHING

Analytical batches consist of a number of samples of the same matrix to be analyzed by the same procedure for a common set of parameters. Batches may range in size from 1 to 20 samples. At NAREL and at ORISE, a batch may contain 20 samples plus the additional QC samples. For this survey, reports and data packages will reference analytical batches of samples as defined by each laboratory.

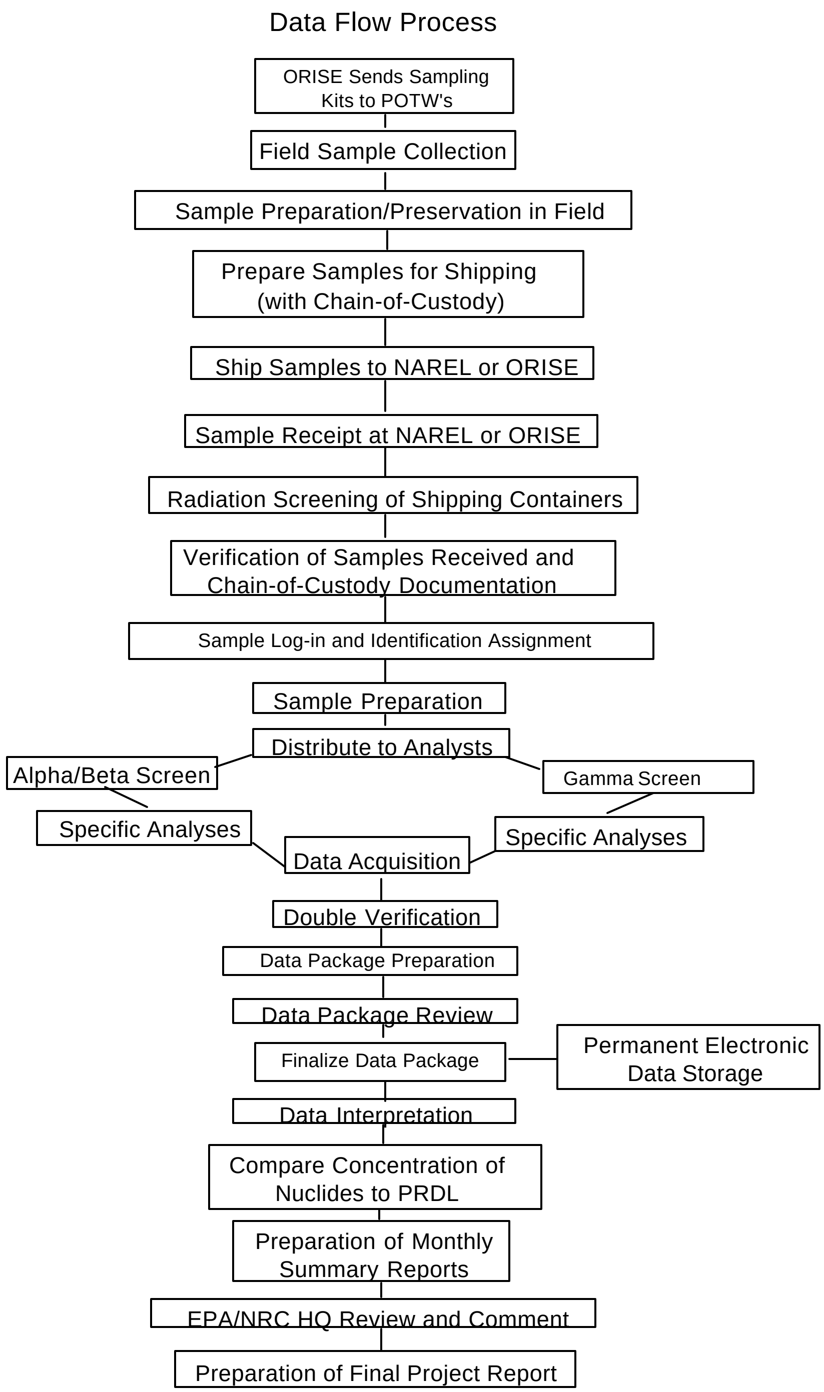
11.5 WASTE DISPOSAL

All radioactive and chemical wastes from samples and reagents are properly characterized, stored, and disposed of in full compliance with all applicable federal and state regulations and with internal NAREL and ORISE policies. Storage and disposal of hazardous and radioactive waste is fully documented. No samples are disposed of without specific concurrence of the laboratory client.

12.0 DATA MANAGEMENT

A flow diagram of the general data management scheme is shown in Figure D.5. The data collection is initiated when ORISE sends sampling kits to POTW operators. Complete documentation is required for each step in the sampling, shipping, receipt, storage, analysis, data production and review, and sample disposal processes.

Figure D.5


Data Flow Process
ORISE Sends Sampling Kits to POTW's
Field Sample Collection
Sample Preparation/Preservation in Field
Prepare Samples for Shipping (with Chain-of-Custody)
Ship Samples to NAREL or ORISE
Sample Receipt at NAREL or ORISE
Radiation Screening of Shipping Containers
Verification of Samples Received and Chain-of-Custody Documentation
Sample Log-in and Identification Assignment
Sample Preparation
Distribute to Analysts
Alpha/Beta Screen
Gamma Screen
Specific Analyses
Specific Analyses
Data Acquisition
Double Verification
Data Package Preparation
Data Package Review
Finalize Data Package
Permanent Electronic Data Storage
Data Interpretation
Compare Concentration of Nuclides to PRDL
Preparation of Monthly Summary Reports
EPA/NRC HQ Review and Comment
Preparation of Final Project Report

A sample identification code is assigned to each sample. Sample preparation activities are performed and the samples are distributed to analysts. Samples are subjected to appropriate analyses (alpha/beta screening, gamma spectrometry, radiochemistry/ specific nuclides analysis), and the resulting data are subjected to review and verification. NAREL analytical data will be reviewed according to the *NAREL Standard Operating Procedure for the Review of Radioanalysis Data* (Draft, June 14, 1996). ORISE analytical data will be reviewed according to the *ESSAP QA Manual.* Following verification, the data are available for inclusion in a data package or other report formats. All data packages and reports are peer-reviewed internally and reviewed by the laboratory's QA staff before being sent to the data-user.

Review of the prepared reports includes verification of documentation for the following:

- sample receipt and preparation,
- laboratory data handling (using the Laboratory Information Management System (LIMS), or other electronic systems,
- instrumentation calibrations and efficiency checks,
- types of sample analyses performed (individual detailed procedures are available for each type),
- data review, error detection and other problem determinations, including requirements for recounting or reanalysis of samples,
- involvement of the project quality assurance officers for the two labs.

Record keeping will be in the form of laboratory logbooks and information and data storage in the laboratory LIMS system (which includes a large database of storage of all data produced in the radioanalytical laboratory). Both NAREL and ORISE have formal document control systems which allow for documents to be either controlled or uncontrolled. Data storage and retrieval is via the LIMS system for NAREL and the relational database for ORISE.

Methods used by the laboratories in data management activities including verification of samples with chain-of-custody records, instrument calibration and background checks, and extensive review of counting room data including checks by at least four persons before release. Systems backups are performed on a routine basis. For NAREL, the backups are daily, with archival to optical disks. ORISE performs incremental backups every 2 days with a monthly full system backup to tape. Any calculations requiring the data extract a copy from the database, leaving the original electronic record intact. The only chance for temporary data loss is in case of a power failure during sample counting or hardware failure. In those instances, the sample is still available and is simply recounted.

Data handling equipment includes radioanalytical instrumentation, PCs dedicated to counting room applications, and the local area network or other database systems. All of this equipment has been thoroughly tested for these applications and proven to be stable and reliable. Commercial software programs used by the two radioanalytical laboratories are listed in Table D.4 and D.5.

Table D.4 NAREL Data Handling Equipment

Program	Analysis System
LB4000	Tennelec LB4000 Gas-Flow Proportional Counters (raw data)
GDR	High-purity Germanium Detectors (raw and reduced data)
OASIS	Alpha Spectrometers (raw and reduced data)
G3000	Gamma Products G3000 Automatic Germanium Counting System (control software)
G5000	Gamma Products G5000 Automatic Alpha/Beta Counting System (control software)

In-house software includes the following:

Data Entry and Instrument Control

Program	Analysis System
I131	Tennelec LB4000 Iodine-131
GROSS	Tennelec LB4000 Gross alpha and beta
SR	Tennelec LB4000 Strontium-89 and 90
RA228	Tennelec LB4000 Radium-228
TH234	Tennelec LB4000 Thorium beta tracer
GET4, GET12	Germanium counters

Calculation and Data Review

Program	Analysis System
GAMMARVW	Gamma spectrometry
ALPHARVW	Alpha spectrometry (Am,U,Pu,Th)
I131RVW	LB4000 Iodine-131
GROSSRVW	LB4000 Gross alpha and beta
SRRVW	LB4000 strontium-89 and 90
RA226	Radium-226 by the radon emanation method

Data Management

CAA	NAREL database system
RPT	Interactive database queries
NARSS	Counting Room analysis scheduling
DATAPKG	Data package production

The calculations performed by all in-house analysis software are documented in the software user manuals. Only one NAREL employee is authorized to modify in-house analysis software and electronic and written records of software modifications are maintained. After each modification of an analysis software system, the calculations are checked using a calculator program, which reads equations from a text file in a form similar to that shown in the user's manual. The results generated by the analysis software are checked against the results given by the calculator.

Table D.5 ORISE Data Handling Equipment

Program	Analysis Program
Alpha spectrometry	Alpha Management System by Canberra
Gamma spectrometry	Genie Spectroscopy by Canberra
Gross alpha/beta	In-house Excel spreadsheet
GAMMA	High Purity Germanium Detectors (raw and reduced data)
AMS	Alpha Spectrometers (raw and reduced data)
ECLIPSE	Tennelec LB5100W (control software)

In-house software includes the following:

Data Entry, Calculation, and Data Review

Program	Analysis Program
GROSS	GAB EXCEL SPREADSHEET
SR	SRB EXCEL SPREADSHEET
GAMTAB	GAMMA TABLES EXCEL SPREADSHEET
AMS	VAX REDUCED DATA
Strontium-90	In-house Excel spreadsheet
Strontium-89,90	In-house Excel spreadsheet
Radium-228	In-house Excel spreadsheet
Carbon-14	In-house Excel spreadsheet
Tritium	In-house Excel spreadsheet
Technetium	In-house Excel spreadsheet

13.0 REPORTS TO MANAGEMENT

13.1 FREQUENCY AND DISTRIBUTION OF REPORTS

The QA staffs at NAREL and ORISE make routine reports to management on the status of the QA program, results of evaluations, and problems. In addition, project-specific reports may be required.

13.2 DIRECT REPORTS TO MANAGEMENT

The NAREL QAC and the ORISE QM report to staff and management on QA or QC issues routinely. Reports on audits and results of audits, performance evaluation results, and other QA and QC issues which need to be brought to the attention of managers are performed in a timely manner to ensure issue resolution.

13.3 REPORTS OF AUDIT FINDINGS

Written reports of the audit findings and recommendations from internal and external audits are submitted to the Laboratory Director, the Associate Director, and the Branch Chiefs as applicable to each lab, by the NAREL QAC or ORISE QM. Responsible parties are expected to investigate and correct deficiencies noted, and to submit a written audit response to the QAC or QM.

13.4 PERFORMANCE EVALUATION RESULTS

QA staff distributes results of performance evaluation studies to the Branch Chief, the Laboratory Director, the Associate Director, and the analysts, as the results are evaluated. At NAREL, unacceptable results require that the Branch Chief or a designee investigate, initiate corrective action, and submit a written Corrective Action Report (CAR) to the QAC. At ORISE, unacceptable results require that a nonconformance report (NCR) be initiated, including a corrective action plan. The QM tracks the NCR through completion.

13.5 PROJECT REPORTS FOR THE SLUDGE SURVEY

Each month, a report will be submitted by each of the laboratories to the NRC and EPA. Reports will include results from sample analyses and information on problems and corrective actions for that month. See Section 6.4 for a complete list of what a report will contain.

14.0 ASSESSMENTS AND RESPONSES

Technical assessments, audits, and inspections are part of the overall quality system and are intended to provide guidance for quality improvement, to identify problems and deficiencies, and to acknowledge what is being done well. Audits are management tools for assessment and improvement, and are not to be viewed as punitive. The technical assessments help staff evaluate how well expectations are being met and offer recognition for good practices and effective work.

14.1 PERFORMANCE EVALUATION AND CROSS-CHECK SAMPLES

A performance evaluation (PE) or cross-check sample examines the ability of the laboratory to perform analytical procedures and obtain data of known and required precision and accuracy. Performance evaluation and cross-check samples are analyzed throughout the year as continual checks on accuracy and precision for all analyses. The NAREL QA staff is also expected to provide internally prepared single-blind PE samples on a regular schedule for analytes and matrices of interest. Successful analysis of known reference materials is required annually for analysts by both labs for the analytes for which he or she is certified to perform analyses.

PE and cross-check samples must be analyzed and reviewed in the same manner as regular analytical samples. PE or cross-check programs conducted by external agencies must be coordinated through the QAC and the appropriate Branch Chief for NAREL and the QM for ORISE. All results must be reviewed and approved by the QA staff before submitting data to any outside PE program. Results and scores received from an outside program must be reported by the outside program directly to the QA staff at NAREL. The QAC or a designee compiles the results, conducts a statistical test for acceptability, and reports the results to the analysts, the Branch Chief, the Associate Director, and the Laboratory Director. Unacceptable results require an investigation, and written documentation of findings and corrective actions must be submitted to the QAC. The QA staff monitors trends in PE and cross-check results and provides a quarterly graphical summary of PE results to management. The ORISE QAM compiles PE results, enters them into a database, and reports results to laboratory staff, other managers, and Program Directors. Results found to be outside the defined PE Program criteria are entered into the nonconformance system and tracked through resolution by the QAM.

14.2 QAC LABORATORY AUDITS

The NAREL QAC conducts at least one complete systems audit during each fiscal year. The audit must cover all aspects of NAREL's mission. The audit allows the QA staff to assess and document facilities, equipment, systems, procurement, record keeping, data validation, operations, maintenance, calibration procedures, software control, reporting requirements, and QC procedures. The audit must assess adherence to the QMP, QAM, and SOPs, generally accepted Good Laboratory Practices (GLP), and written policies for NAREL operations.

An audit of data quality should be performed each year either in conjunction with the systems audit or at a different time. This audit will assess the methods used to collect, interpret, and report the information required to characterize data quality. Such an audit requires detailed review of recording and transfer of raw data, calculations, documentation procedures, and data quality indicators. Audits may be either announced or unannounced.

The QAC or a designee is required to provide documentation of the audit findings, deficiencies, and recommendations to management within one month after completion of an audit. Findings and deficiencies require investigation and implementation of corrective actions by the appropriate personnel, and require a written response to the QAC within one month of the audit report.

The ORISE QM performs assessments of 25% of all projects. Assessments evaluate all critical activities pertinent to the particular project for procedural compliance as well as good laboratory practice. Results are documented and provided to the management team. The appropriate manager ensures that corrective actions are successfully carried out. At ORISE, biennial audits providing an external independent evaluation of all systems and work practices are also required.

14.3 CORRECTIVE ACTIONS AND NONCONFORMANCE REPORTS

Corrective action is required whenever the results of a quality assessment are unacceptable, as when quality indicators fall outside predetermined rejection limits, or when an audit reveals deficiencies in any portion of the QA program.

The primary responsibility for corrective action belongs to management. A Branch Chief or Supervisor who delegates responsibilities to subordinates is still responsible for monitoring the actions of those subordinates and for ensuring that the results are satisfactory. The Quality Assurance Coordinator and Quality Manager also take active roles in resolving serious problems and all problems affecting more than one branch. He or she has the authority to require corrective action and to halt operations in the event of a serious circumstance.

14.3.1 Initiation of Corrective Actions

The first person who discovers a problem should initiate the corrective action process by reporting the problem to the laboratory's quality assurance staff. Corrective actions must be initiated when:

- There is a variation to or a deviation from an SOP, QAPP, QAM, or the QMP

- There is a method, protocol, or work plan violation.

- When samples or extracts are lost or otherwise cannot be handled by the usual procedure or protocol.

- When quality control criteria are exceeded and control cannot be re-established by means defined in an SOP.

- When there is suspect data for any reason.

- When data are found to be flawed, of questionable validity, or in violation of good laboratory practices.

- In any other circumstances when an analyst, manager, or other staff deems it appropriate to request investigation of a circumstance impacting on data quality.

14.3.2 Corrective Action Initiated by the QAC and QAM

At NAREL, the QAC may initiate corrective action by issuing a *corrective action memorandum*, addressed to the appropriate Branch Chief, the Laboratory Director, and other concerned parties, which describes the problem and provides a deadline for a formal response. The Branch Chief, or a subordinate with delegated responsibility, investigates the problem, identifies probable causes, and takes corrective action. The responsible party must report to the QAC the steps taken to solve the problem. The QAC evaluates this corrective action report and may accept it or require testing to prove that the problem has been solved. The QAC tracks the progress of the corrective action until the problem has been resolved. The QAC must maintain documentation of each corrective action. The file includes all related memoranda, paper copies of electronic mail messages, and any computer printouts of related data.

Corrective action should generally be taken immediately. When immediate action is not possible or required, the responsible party must issue a corrective action request, in the form of a memorandum, to facilitate the tracking of the progress of the corrective action. The memorandum will include:

- description of the problem;
- date of detection/identification;
- name of the person identifying the problem;

- name of the person assigned to the corrective action;
- target date for the solution;
- periodic reporting status;
- nature and date of solution; and
- documented feedback to the initiator.

When the QAC performs an audit, he or she must summarize the results in a memorandum addressed to the Laboratory Director and the key staff members involved in the audit. If the QAC finds that corrective action is required, the audit report has the effect of a corrective action memorandum and requires formal written responses.

At ORISE, the QAM discusses formal audit findings with the Program Directors and Manager and assists with the determination of corrective action plans. The cognizant Manager performs an investigation, identifies probable cause, and recommends corrective action to the Program Directors and the QAM. Once the corrective action plan is approved, status of the item is tracked by the QAM through completion. Quarterly nonconformance reports are submitted to Directors and Managers.

15.0 RADIONUCLIDES IN SEWAGE SLUDGE AND ASH DATABASE (RISSAD) DATA MANAGEMENT QUALITY ASSURANCE PROJECT PLAN

15.1 ENVIRONMENTAL HEALTH ASSOCIATES (EHA)

Personnel working on the database have received a copy of the RISSAD Data Quality Management Plan. This section outlines EHA team member responsibilities and the interactions required to implement evaluation of data quality, corrective actions, and reporting activities that ensure data quality.

15.2 DATA ACCEPTANCE CRITERIA

Dual electronic and hard copy versions of the same data sent by ORISE or NAREL will be compared for sameness. If the data points on both copies are the same, data will be accepted. If not the same, the sender will be contacted for corrective action (See Figure D.6).

15.3 COMPUTER AND COMPUTER SOFTWARE

Software is obtained through purchase of commercial packages. Computer hardware is obtained through purchase of commercial brands.

- Acceptability of hardware/software configuration: The RISSADatabase is designed, because of intents and purposes, to be portable and compatible with the most commonly used and easily accessible computer operating systems, database and data analysis software and computer hardware.

- Original development of the database is in Microsoft Access 1997. Updates to newer versions will be at the request of the subcommittee with agreement of NRC to support such efforts.

15.4 RECORD KEEPING

Quality assurance documentation is made at critical control points in the form of e-mail communication and dated logs kept by each EHA team member. All stages of the RISSAD Data Handling Process (see flow chart) are logged for completion. Task descriptions, task delegations, task completion details, data/file transfers, data integrity issues, error determinations and error correction measures implemented, resource needs, and data/database alterations are logged. The logs are consolidated by the database manager for compilation.

Figure D.6

RISSAD Data Handling Process

ORISE or NAERL e-mail an electronic copy of laboratory analytical data and send at the same time, by U.S. Postal Service, a duplicate copy of the paper (hard) copy of the same data.

Both data set versions (electronic and hard) are compared for sameness, data point by data point.

If the two data versions are the same, the laboratory is notified that data integrity is fine and this fact is recorded. If the two data versions are different (errors), the laboratory is notified of the disparity, the process for correcting errors is initiated and logged.

When data integrity is established, the electronic version is re-arranged in form to allow importation into RISSAD. No content modifications are made to any data points.

Data are imported into RISSAD.

The data are compared for sameness, data point by data point, with the original hard copy version. Source of any errors is determined. Errors are corrected. Errors and error correction process is logged.

Data are merged.

Data are compared with original import, data point by data point. Errors are corrected. Errors and error correction process is logged.

Version tracking numbers are updated. Duplicate (backup) copies of RISSAD are regularly made and any changes to the data base are logged.

Database and raw data are stored on removable media (Zip disks/CD-RW) and paper and are locked up when not in use.

15.5 DATA MANAGEMENT PATH

- Task delegation: Database manager will contact EHA team members with descriptions of assigned tasks and transfer the appropriate data/materials to each team member. Each EHA team member will acknowledge receipt of data/materials and understanding of task. Team member will provide completed task product to database manager and database manager will acknowledge receipt of task product. Database manager will quality check product and then provide feedback to team member as to task product quality. Any potential improvements will be discussed, decided on, and implemented. EHA team members will quality check any products developed by the database manager, and any potential improvements will be discussed, decided on, and implemented.

- Error correction and reporting: Each EHA team member will report any errors and problems with data integrity, data/file transfer, database function and structure, and task assignment to the database manager. Database manager and team member(s) will then discuss problems, resolve as necessary, and implement corrective actions. Each team member will enter each issue and subsequent solution implemented into his/her project log.

- Task completion resources: Each EHA team members will notify the database manager of any questions and resources needed to complete task at any time.

15.6 DOCUMENT AND FILE TRACKING SYSTEMS AND CHANGE CONTROL SYSTEMS

Paper documents are filed and kept in a locked metal storage cabinet. Electronic files are named clearly with the most recent date of alteration, alterations/changes are logged, and each file is backed up. All electronic files are stored on and accessed from removable media (Zip disks/CD-RW). Removable media are locked in a metal storage cabinet when not in use.

15.7 DATA SECURITY: TRANSFERENCE, STORAGE, RECOVERY AND RETRIEVAL

- Transference: All electronic files that have data considered 'sensitive' or potentially sensitive and that are transferred by Internet or sent by regular mail are encrypted.

- Storage: All documents and electronic files that have data considered 'sensitive' or potentially sensitive are kept under lock and key when not in use.

- Supervision, Recovery and Retrieval: All documents and electronic files that have data considered 'sensitive' or potentially sensitive are always under the active supervision of the EHA team members using the data. EHA team members are responsible for locking up all data after use. All 'sensitive' electronic files are stored on, accessed and manipulated from removable media (Zip disks/CD-RW).

- Security: Database manager will make decisions on sensitivity of data and on security protocols for use within EHA, Inc. Security decisions will be based on Los Alamos National Laboratory security protocols and any additional protocols required by EHA, Inc.

EHA team members will follow all data management/security protocols. EHA team members will discuss data management/security issues with database manager before implementing any self-generated alterations of data management/security protocols.

15.8 FINAL QUALITY ASSURANCE OF DATABASE

When all data sets have been entered into the RISSAD database and point comparisons with laboratory data sets have been completed, completeness of data against the original sample selection list is performed. Discrepancies in sample numbers, duplicate data, and missing data will be addressed by comparing laboratory codes with POTW IDs and resolving discrepancies with appropriate subcommittee or laboratory personnel.

Finally, summary statistics will be calculated and reviewed for any suspicious data points (outliers) which will then be followed up to ensure they represent valid data.

16.0 IMPLEMENTATION OF QAPP

16.1 IMPLEMENTATION SCHEDULE

Under EPA policy, no environmental data operations may begin to collect data before the QAPP has been approved by authorized EPA personnel or other persons to whom this authority has been specifically delegated. This applies to work performed intramurally by EPA staff and extramurally by contractors and assistance agreement holders. For the purposes of this survey, analytical data acquired from the original nine test sites may be used as part of the project data since these data were acquired, reviewed, and reported under requirements of the quality manuals for each laboratory.

16.2 FLEXIBILITY

The approved QAPP must be implemented as approved. However, when conditions or requirements change during environmental data operations, the QAPP must be revised and then reviewed and approved in the same manner as the original QAPP.

16.3 REVIEW AND APPROVAL FOR THE SLUDGE PROJECT

The signature page of this QAPP lists the required approvals from the two laboratories for the original QAPP and for any subsequent revisions to this document. In addition, Revision 0 of the QAPP was formally agreed to by all members of the ISCORS Subcommittee during its conference call on November 9, 1999.

Appendix A
Sampling Kit and Sample Collection Information Sent to POTWs in the Survey

ORISE/ESSAP
P.O. BOX 117
OAK RIDGE, TN 37830

CHAIN-OF-CUSTODY RECORD

EMERGENCY CONTACTS
(423) 576-3561
(423) 241-3242

Site ***(Name of plant & city)*** ______ **Sample Type** ***(List type of samples)*** ______

Samplers ***(List personnel who took samples)*** ______
Note: If more than one name is listed, circle the sample custodian.

ESSAP SAMPLE NUMBER	Sample Information	Collected		Remarks
		Date	Time	
(Leave this column blank)	*(List specific sample identification, i.e. digestor #, tank #, filter press cake, etc. This must correlate to information on the sample container)*	*Date and time of sample collection*		*(Leave this column blank unless conditions existed which may compromise sample integrity)*

Transport Method ***(Federal Express)*** **Seal No.** ***(Shipping container seal numbers)***			
1. Relinquished by: ***(Initial custody relinquished by sampler)***	***(Date and time of sample transfer)***		***Received in good condition by:** ***(Note custody transfer until received by courier)***
2. Relinquished by:	**Date**	**Time**	***Received in good condition by:**
3. Relinquished by:	**Date**	**Time**	***Received in good condition by:**
4. Relinquished by:	**Date**	**Time**	***Received in good condition by:**

***For sample received in unacceptable condition explain in ?Remarks" column.**

Distribution: Original to individual having custody
Copy filed in field data

COLLECTION OF SEWAGE TREATMENT PLANT SAMPLES

Following is a list of the equipment and supplies, in the attached sample collection package, needed to collect your sample(s):

- For liquid samples, one 1-liter translucent plastic bottle for each sample
- For de-watered or dried samples, one wide-mouth white plastic jar per sample
- One Chain-of-Custody form (for all samples)
- One return shipping container
- Return shipping labels with pre-paid shipping
- Two security seals for the shipping container closure

Collect one sample from each solids waste stream produced at your facility. This may include sludge, dewatered sludge, filter press cake, ash compost, etc. See ?Sampling Instructions" on next page.

Instructions for return shipment of samples:

1. Ensure that the sample(s) are properly labeled with the type of material sampled, location or source of the sample, the name of the person taking the sample, and the sample date and time. **Your facility code, for confidentiality purposes, is already on the sample label(s).**

2. Complete the enclosed Chain-of-Custody form with the location or source of the sample, the name of the person taking the sample, and the sample date and time. **Your facility has been given a code which already appears on the Chain-of-Custody**

3. Place the sample(s) in the shipping container. The person taking the sample must sign the completed Chain-of-Custody form as ?Relinquished by" and enclose the form with the sample(s).

4. Reseal the shipping container and place the security seals across the top and bottom of the shipping container.

5. Place the enclosed return shipping labels on the shipping container. **The return shipping label has your facility code and ORISE's mailing address or NAREL's mailing address to help maintain confidentially.**

6. Please return the sample(s) as quickly as possible after collection. **Do not ship for Saturday delivery.**

If you have any questions or need assistance, please contact Dale Condra at ORISE (423) 241-3242 or Susan Baker at NAREL (334) 270-7052.

Sampling Instructions

If a sample is well-mixed, then a representative sample can be easily obtained. If a sample is not well-mixed, then incremental aliquots must be collected and composited, to obtain a representative sample. The collection date and time should be close to the date that the sewage treatment stream leaves the plant for transport to a landfill or for land application.

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. 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.

A large-mouth plastic jug is sufficient for liquid and slurry samples. 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. If the sample is collected from a tank, the tank should be well-mixed; and the line should be flushed before collecting the sample. If the sample is a slurry, the sampling procedure could involve obtaining a representative sample from a lagoon, pond, tank, or other vessel. The sample should be representative of the typical amount of solids and liquids in the material being sampled. If not collected from a liquid or slurry stream, incremental aliquots should be collected that are representative of the solids and liquid present. For some sampling, such as from lagoons, ponds, tanks, and other vessels, grab samples of the liquid and solids may have to be collected as separate samples (not composited).

Appendix B
Method and Reference SOPs for the Suvery

Method and SOP References for NAREL

The Quality Assurance Plan for the National Air and Radiation Environmental Laboratory.
NAREL Radiochemistry Quality Assurance Manual

QA/SOP-1 NAREL *Standard Operating Procedure for Document Control*
QA/SOP-2 NAREL *Standard Operating Procedure for Writing Standard Operating Procedures*

MAS/SOP-1 NAREL *SOP for Chain of Custody*
MAS/SOP-2 NAREL *SOP for Calibration of Balances*
MAS/SOP-3 NAREL *SOP for Cleaning Laboratory Glassware and Planchets*
MAS/SOP-4 NAREL *SOP for Operating and Maintaining Fume Hoods*
MAS/SOP-5 NAREL *SOP for Use and Maintenance of Laboratory Logbooks*
MAS/SOP-6 NAREL *SOP for Standardization of pH Meters*
MAS/SOP-7 NAREL *SOP for Labeling Chemical Containers*
MAS/SOP-8 NAREL *SOP for Storing Chemicals and Solutions*
MAS/SOP-9 NAREL *SOP for Transporting Chemicals*
MAS/SOP-10 NAREL *SOP for Training and Certification of Laboratory Personnel*
MAS/SOP-11 NAREL *SOP for Preparing Alpha Spectrometry Efficiency Standards*
MAS/SOP-12 NAREL *SOP for Preparing Thorium-234 Tracer Solution*
MAS/SOP-13 NAREL *SOP for Preparing Uranium-232 Tracer Solution*
MAS/SOP-14 NAREL *SOP for Receipt, Log-in, and Storage of Environmental Samples*
MAS/SOP-15 NAREL *SOP for the Preparation of Environmental Samples for Radiochemical Analysis*
MAS/SOP-16 NAREL *SOP for Calibration, Use, and Maintenance of Pipets*
MAS/SOP-17 NAREL *SOP for the Use of Control Charts*
MAS/SOP-18 NAREL *SOP for the Review of Radiochemistry Data*

RAL/SOP-1 NAREL SOP for Calibration and Use of High-purity Germanium Gamma Detectors
RAL/SOP-2 NAREL SOP for the Handling of P-10 Gas
RAL/SOP-3 NAREL SOP for the Use of the Tennelec LB4000 Multi-detector Counting System
RAL/SOP-4 NAREL SOP for Use of the OASIS Alpha Spectrometry System
RAL/SOP-5 NAREL SOP for the Handling of Liquid Nitrogen
RAL/SOP-6 NAREL SOP for Calibration and Use of the Random SC-5 Scintillation Counter
RAL/SOP-7 NAREL SOP for the Calibration and Use of the Gamma Products G-3000 Automatic Gamma Counting System
RAL/SOP-8 NAREL SOP for Automated Gross Beta Analysis Using the G5000 Series Alpha/Beta/Gamma Counting System
RAL/SOP-9 NAREL SOP for Calibration and Use of the G5400 Auto-Quad Alpha/Beta Counting System
RAL/SOP-10 NAREL SOP for Calibration and Use of the G542 Alpha/Beta Counting System

Method and SOP References for ORISE

Quality Assurance Manual for the Environmental Survey and Site Assessment Program
Laboratory Manual for the Environmental Survey and Site Assessment Program

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GLOSSARY

Acceptance criteria - Specified limits placed on characteristics of an item, process, or service defined in requirements documents. (ASQC definitions.)

Accuracy - A measure of the closeness of an individual measurement or the average of a number of measurements to the true value. Accuracy includes a combination of random error (precision) and systematic error (bias) components which are due to sampling and analytical operations.

Agreement state - A state which has signed an agreement with the NRC allowing the state to regulate the use of radioactive material within that state.

AMSA - Association of Metropolitan Sewerage Agencies.

Assessment - The evaluation process used to measure the performance or effectiveness of a system and its elements. Assessment is an all-inclusive term used to denote audit, performance evaluation, management systems review, peer review, inspection, or surveillance.

Audit (quality) - A systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

Bias - Systematic or persistent distortion of a measurement process which causes errors in one direction.

Blank (reagent blank) - A sample which is used to monitor contamination during sampling, transport, storage, or analysis. The blank is subjected to the complete analytical or measurement process to establish a zero baseline or background value.

Calibration - Comparison of a measurement standard, instrument, or item with a standard or instrument of higher accuracy to detect and quantify inaccuracies and to report or eliminate those inaccuracies by adjustments.

Chain of custody - An unbroken trail of accountability that ensures the physical security of samples, data, and records.

Comparability - A measure of the confidence with which one data set or method can be compared to another.

Completeness - A measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct, normal conditions.

Corrective action - Measures taken to rectify conditions adverse to quality and, where possible, to preclude their recurrence.

Data of known quality - Data that have the qualitative and quantitative components associated with their derivation documented appropriately for their intended use, and when such documentation is verifiable and defensible.

Data quality indicators - Quantitative statistics and qualitative descriptors that are used to interpret the degree of acceptability or utility of data to the user. The principal data quality indicators are bias, precision, accuracy (bias and precision are preferred), comparability, completeness, representativeness, and statistical confidence.

Data Quality Objectives (DQO's) - Qualitative and quantitative statements derived from the DQO process that clarify study technical and quality objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.

Duplicate samples - Two samples taken from and representative of the same population and carried through all steps of the sampling and analytical procedure in an identical manner. Duplicate samples are used to assess variance of the total method including sampling and analysis.

Environmental data - Any parameters or pieces of information collected or produced from measurements, analyses, or models of environmental processes, conditions, and effects of pollutants on human health and the ecology, including results from laboratory analyses or from experimental systems representing such processes and conditions.

Holding time - The period a sample may be stored prior to its required analysis. While exceeding the holding time does not necessarily negate the veracity of analytical results, it causes the qualifying or ?flagging" of the data for not meeting all of the specified acceptance criteria.

Incineration - the combustion of organic matter and inorganic matter in sewage sludge by high temperatures in an enclosed devise.

ISCORS - Interagency Steering Committee on Radiation Standards. NRC and WPA formed ISCORS to expedite the resolution and coordination of regulatory issues associated with radiation standards. This committee was formed in response to October 27, 1994, letters from Senator John Glenn to NRC, EPA and the Office of Science and Technology Policy (OSTP). 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 in 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 (OMB), OSTP and the States are observers at meetings. The ISCORS Sewage Subcommittee is assisting in the development of an NRC/EPA sewage survey and a sewage guidance document.

Laboratory split sample - Two or more representative portions taken from the same sample and analyzed by different laboratories to estimate the interlaboratory precision or variability and data comparability.

Land application - spraying or spreading of sewage sludge onto the land surface; the injection of sewage sludge below the land surface; the incorporation of sewage sludge into the land so that the sewage sludge can either condition the soil or fertilize crops or vegetation grown in the soil.

Matrix spike - A sample prepared by adding a known mass of target analyte to a specified amount of matrix sample for which an independent estimate of target analyte concentration is available.
Spiked samples are used, for example, to determine the effect of the matrix on a method's recovery efficiency.

Municipal solid waste landfill - a land or excavation that receives household waste, and that is not a land application unit, surface impoundment, injection well, or waste pile. Such a landfill may be publicly or privately owned.

Peer review - A documented critical review of work generally beyond the state of the art or characterized by the existence of potential uncertainty. The peer review is conducted by qualified individuals (or organization) who are independent of those who performed the work, but are collectively equivalent in technical expertise (i.e., peers) to those who performed the original work. The peer review is conducted to ensure that activities are technically adequate, competently performed, properly documented, and satisfy established technical and quality requirements. The peer review is an in-depth assessment of the assumptions, calculations, extrapolations, alternate interpretations, methodology, acceptance criteria, and conclusions pertaining to specific work and of the documentation that supports them. Peer reviews provide an evaluation of a subject where quantitative methods of analysis or measures of success are unavailable or undefined, such as in research and development.

Performance evaluation (PE) - A type of audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data to evaluate the proficiency of an analyst or laboratory.

POTW - Publicly owned treatment works.

Precision - A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions expressed generally in terms of variance.

Quality - The totality of features and characteristics of a product or service that bear on its ability to meet the stated or implied needs and expectations of the user.

Quality assurance (QA) - An integrated system of management activities involving planning, implementation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the client.

Quality control (QC) - The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer; operational techniques and activities that are used to fulfill requirements for quality.

Reporting limit - The lowest concentration or amount of the target analyte required to be reported from a data collection project. Reporting limits are generally greater than detection limits and are usually not associated with a probability level.

Representativeness - A measure of the degree to which data accurately ad precisely represent a characteristic of a population, parameter variation at a sampling point, a process condition, or an environmental condition.

Reproducibility - The precision, usually expressed as variance, that measures the variability among the results of measurements of the same sample at different laboratories.

Sewage sludge - solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in a treatment works. Sewage sludge includes, but is not limited to, domestic septage; scum or solids removed in primary, secondary, or advanced wastewater treatment processes; and material derived from sewage sludge. Sewage sludge does not include ash generated during the incineration of sewage sludge or grit and screenings generated during preliminary treatment of domestic sewage in a treatment works.

Spike - A known quantity of a chemical that is added to a sample for the purpose of determining (1) the concentration of an analyte by the method of standard additions, or (2) analytical recovery efficiency, based on sample matrix effects and analytical methodology.

Standard operating procedure (SOP) - A written document that details the method for an operation, analysis, or action with thoroughly prescribed techniques and steps, and that is officially approved as the method for performing certain routine or repetitive tasks.

Traceability - The ability to trace the history, application, or location of an entity by means of recorded identifications. In a calibration sense, traceability relates measuring equipment to national or international standards, primary standards, basic physical constants or properties, or reference materials. In a data collection sense, it relates calculations and data generated throughout the project back to the requirements for the quality of the project.

Treatment works - either a federally owned, publicly owned, or privately owned device or system used to treat (including recycle and reclaim) either domestic sewage or a combination of domestic sewage and industrial waste of a liquid nature.

Use or disposal - includes land application of bulk sewage sludge, land application of sewage sludge sold or given away in a bag or other container, surface disposal, disposal in a municipal solid waste landfill unit, incineration, or any other use or disposal practice.