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United States
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Commission

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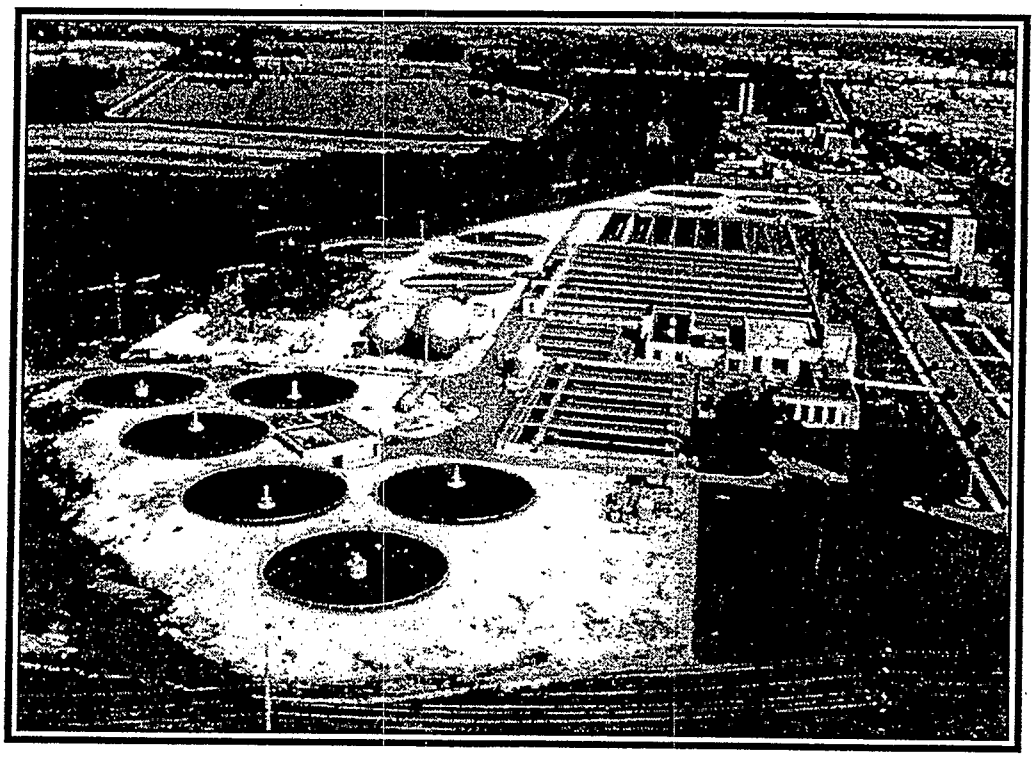
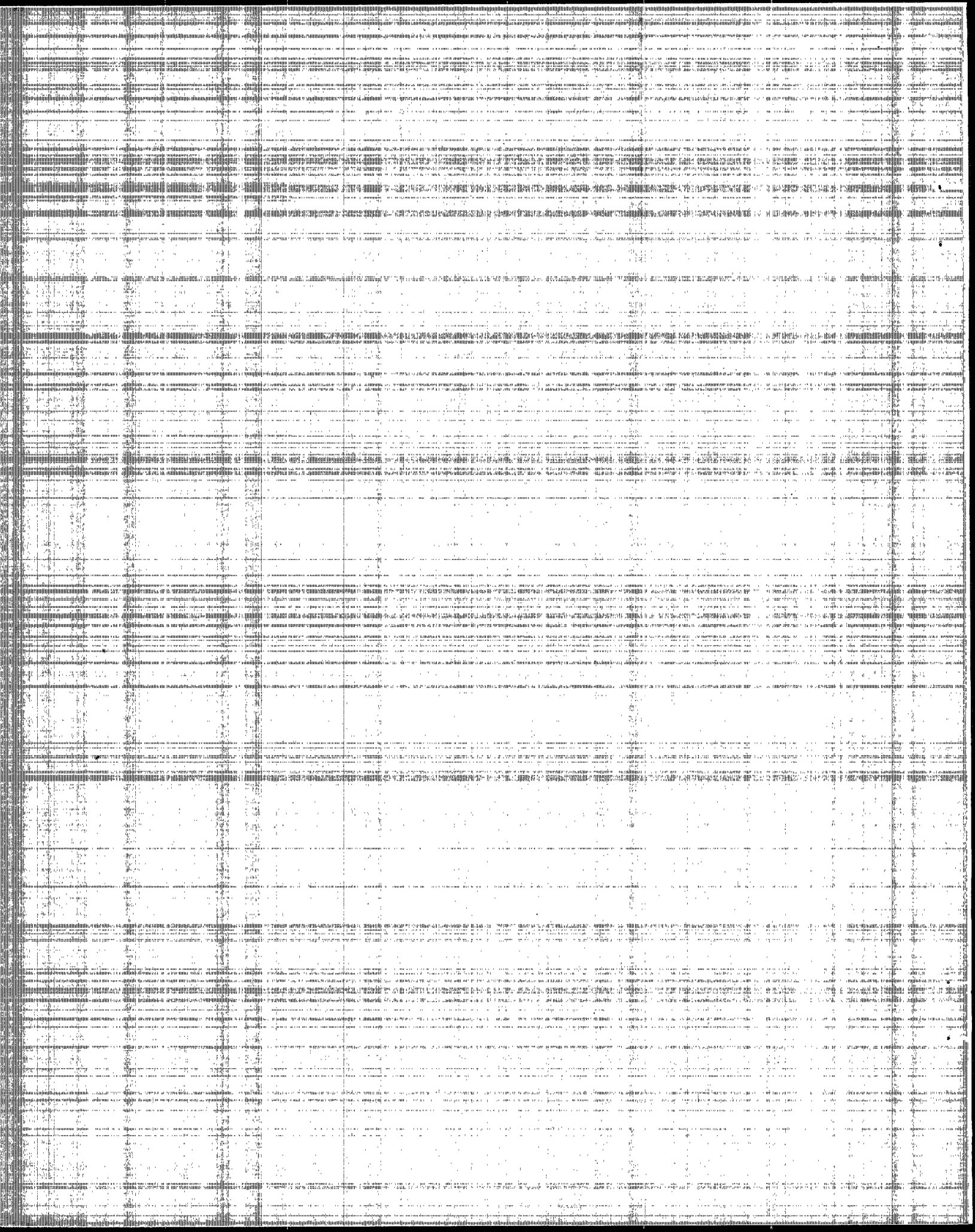
Joint NRC/EPA Sewage Sludge Radiological Survey: Survey Design And Test Site Results



Sewage Subcommittee of the
Interagency Steering Committee on
Radiation Standards (ISCORS)



Acknowledgments

This report, which presents the results of radioisotope analyses of sewage sludge and ash samples from nine test sites as a trial test of the procedures planned for use in a survey of some 300 facilities across the country, was coordinated by the Sewage Subcommittee of the Interagency Steering Committee on Radiation Standards (ISCORS). The document was based primarily upon the detailed laboratory results on the samples reported to the Subcommittee by the U.S. Environmental Protection Agency (EPA) National Air & Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama, and the U.S. Nuclear Regulatory Commission (NRC) contract laboratory, the Oak Ridge Institute for Science & Education (ORISE) in Oak Ridge, Tennessee.

Subcommittee members who participated in the planning and conduct of the nine test site survey effort and/or preparation of this report included (listed alphabetically):

Lee Abramson, NRC/Office of Nuclear Regulatory Research
Kevin Aiello, Middlesex County Utilities Authority
Jim Bachmaier, Department of Energy
Bob Bastian, EPA/Office of Wastewater Management
Dale Condra, ORISE
Mark Doehnert, EPA/Office of Radiation and Indoor Air
Dale Hoffmeyer, EPA/Office of Radiation and Indoor Air
Tony Huffert, NRC/Office of Nuclear Material Safety and Safeguards
Tom Lenhart, Northeast Ohio Regional Sewer District
Jill Lipoti, State of New Jersey
Roy Lovett, Department of Defense
Tin Mo, NRC/Office of Nuclear Regulatory Research
Robert Neel, NRC/Office of Nuclear Material Safety and Safeguards
Bob Nelson, NRC/Office of Nuclear Material Safety and Safeguards
Tom O'Brien, NRC/Office of State Programs
George Powers, NRC/Office of Nuclear Regulatory Research
Charleen Raddatz, NRC/Office of the Executive Director for Operations
Alan Rubin, EPA/Office of Science Technology
Dave Saunders, EPA/NAREL
Duane Schmidt, NRC/Office of Nuclear Material Safety and Safeguards
Loren Setlow, EPA/Office of Radiation and Indoor Air
Behram Shroff, EPA/Office of Radiation and Indoor Air
Phyllis Sobel, NRC/Office of Nuclear Material Safety and Safeguards
Scott Telofski, EPA/NAREL
Mary Thomas, NRC/Office of Nuclear Regulatory Research
Mary Wisdom, EPA/NAREL

Photo courtesy of Water Environment Federation, Alexandria, Virginia.

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DISCLAIMER

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

JOINT NRC/EPA SEWAGE SLUDGE RADIOLOGICAL SURVEY: SURVEY DESIGN AND TEST SITE RESULTS

A. SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA), through a subcommittee of the Interagency Steering Committee on Radiation Standards (ISCORS), are sponsoring a joint survey to collect information concerning radioactive materials in sewage sludge and ash from sewage treatment plants (referred to in the industry as publicly owned treatment works (POTWs)). Sanitary sewer disposal of radioactive material and sludge reconcentration became an issue in the 1980s with the discovery of elevated levels of radioactive materials in sewage sludge/incinerator ash at several POTWs. Although neither the NRC nor the Agreement States have seen further problems associated with POTW reconcentration of radioactive materials since NRC's regulations were revised in 1991, NRC and EPA are working together to conduct a survey of radioactive materials in sewage sludge and ash from POTWs.

The objectives of this joint NRC/EPA sewage sludge/ash survey are to: (1) obtain data on the levels of radioactive materials in sludge and ash at POTWs from across the country; (2) estimate the extent to which radioactive contamination comes from either NRC/State licensees or naturally-occurring radioactivity; and (3) support potential rulemaking decisions by NRC or EPA, if necessitated by the survey results. However, because of the design limitations, the survey alone may not be sufficient for rulemaking.

The intent is that the names of the POTWs will not be associated with the analysis results in publicly available records and reports. The reason for the anonymous survey is to encourage the cooperation of POTWs. However, if elevated levels of radioactive materials are detected that are determined to be a potential health and safety concern, as determined by NRC, further investigation will be conducted to determine the appropriate course of action.

The voluntary survey consists of two components - a questionnaire and a program to sample and analyze sewage sludge and incinerator ash. Questionnaires will be sent to selected POTWs associated with NRC and Agreement State licensees that have the greatest potential to discharge radioactive materials in accordance with existing regulations and to POTWs in all

areas of the country, including areas of relatively high background radioactivity. Using the information from the questionnaires, NRC and EPA will identify approximately 300 POTWs to be sampled. It is expected that it will take several months for both agencies to analyze the results from the questionnaire and a year to complete the analysis of samples to be received from the POTWs.

This report summarizes the results at nine POTW sites where the questionnaire methods and sampling and analytical procedures were tested. The survey was refined based on the experiences at the test cases and public comments on the survey. The results of the full survey will be published as a joint NRC/EPA report for use by POTW operators, Federal agencies, States, and local officials.

The sewage sludge/ash survey is being coordinated by a subcommittee of ISCORS, which was formed in 1995 to coordinate resolution of interagency issues related to radiation protection. The ISCORS Sewage Subcommittee is assisting NRC and EPA in the development of the survey, including analysis procedures and the selection of facilities to sample.

The NRC contractors 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 assisted ISCORS with the survey design. For example, the labs collaborated to ensure that the analytical laboratory procedures and quality assurance programs that both labs plan to use will produce consistent, accurate, and reliable laboratory measurements.

NRC requested Office of Management and Budget (OMB) approval for this survey. Notices were published in the Federal Register on January 6, 1997, and December 2, 1997, to solicit public comments on the survey effort. This information request was approved by OMB (clearance number 3150-0189), with an expiration date of June 30, 2001.

B. BACKGROUND

Federal Regulations

Specific amounts and concentrations of radioactive material are legally authorized to be disposed into the sanitary sewage collection system by Federal and State regulations. 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 POTWs, which should preclude contamination at POTWs. The current NRC regulations in 10 CFR 20.2003 permit disposal of specific quantities of soluble material into a sanitary sewer. NRC plans to use the survey information in assessing whether to apply further restrictions to the licensed radioactive material that is being discharged to sanitary sewage collection systems.

The EPA standard for the use and disposal of sewage sludge (biosolids) in 40 CFR Part 503 does not include limits for radioactive material. POTW operators have requested that EPA regulations address radioactive materials so POTWs would have a basis to restrict discharges of radioactive materials to the sewage collection system. EPA plans to use the survey results to evaluate the need to include limits on radioactive materials in biosolids standards.

Sources of Radioactive Materials

One possible source of radioactive material entering a POTW involves naturally-occurring sources such as groundwater, which can contain elevated levels of radioactive materials in some parts of the U.S., as well as drinking water treatment residuals disposed of into the sanitary sewage collection system. Another possible source is the authorized disposal by users of radioactive materials (such as NRC and Agreement State licensees) of man-made radioactive materials into the sanitary sewage collection system. The removal of contaminants by various methods at POTWs, and the reduction of the volume of solids that contains these contaminants (e.g. incineration of sludge), can cause reconcentration of radioactive materials in the treatment facility's sewage sludge or ash.

Background information on the nature of radioactivity in sewage sludge can be found in reports published by NRC in 1992 and 1994 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), respectively. Another useful background document is a report entitled "Radioactivity of Municipal Sludge" issued by EPA during the development of the first round rulemaking of the 40 CFR Part 503 sewage sludge technical rule.

Congressional Interest

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

A joint House/Senate hearing was held in 1994 to officially release and address questions raised in the GAO report. The hearing was stimulated by concerns associated with elevated levels of radioactive materials in incinerator ash at a major sewage treatment plant in the Cleveland, Ohio, area. The GAO stated that, over the past 20 years, NRC documented about a dozen situations where elevated levels of radioactive materials were identified in sewage sludge or sludge incinerator ash; but, there has been no national survey of radiation levels present in sewage sludge or sludge incinerator ash to determine if this is a widespread problem.

At the time of the hearing, EPA was planning to conduct a second National Sewage Sludge Survey (NSSS) to support its efforts to develop the second round of the 40 CFR Part 503 sewage sludge technical regulations. EPA's planned survey would have included the collection of data on concentrations of radioactive materials in a representative sampling of POTW sludges from across the country. (The first national survey conducted in the late 1980s did not include analysis of radioactive material.)

Testimony presented by both NRC and EPA during the 1994 hearing noted that there was no indication of a widespread problem in this area and the Cleveland incident appeared to be an isolated incident. Based on limited information on radiation levels in sewage sludge and ash across the country, it appeared that reconcentration of radioactive materials may have been

associated with authorized insoluble industrial releases from both NRC and Agreement State licensees, which was documented and used as a basis of the GAO report. These problems occurred prior to the revision to NRC's regulations in 1991.

Industry Interest

In 1996, the Association of Metropolitan Sewerage Agencies (AMSA) conducted a confidential voluntary survey of concentrations of radioactive materials in some of its members' POTW sewage sludges and ashes. The objective was to develop a better estimate of the concentration of radioactive materials in sewage sludges and sludge incinerator ashes. Samples from 55 wastewater plants in 17 States were supplied voluntarily and analyzed for radioactive materials. These plants were distributed across the country and ranged in size from small to among the largest POTWs. The most significant levels of radioactive material were the potassium and radium isotopes, which are naturally-occurring radioactive materials. The restricted nature of the AMSA survey limited its usefulness in assessing regional background levels of radioactive materials or the effects of licensees that dispose of radioactive material into sanitary sewers.

Current Plans

EPA is not currently planning to move forward with a second NSSS. Based on EPA's plans and the limitations of the AMSA survey, NRC and EPA decided to jointly fund a survey of POTW sewage sludges and ash to assess the potential need for NRC and/or EPA rulemaking. The survey information will also be referenced in a joint NRC/EPA guidance document for POTWs, which is currently under development by the ISCORS Sewage Subcommittee. 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.

C. SURVEY DESIGN

The objectives of this joint NRC/EPA sewage sludge/ash survey are to: (1) obtain data on the levels of radioactive materials in sludge and ash at POTWs from across the country; (2) estimate the extent to which radioactive contamination comes from either NRC/State licensees or naturally-occurring radioactivity; and (3) support potential rulemaking decisions by NRC or EPA, if necessitated by the survey results. However, because of the design limitations, the survey alone may not be sufficient for rulemaking. These limitations include: (1) it is a voluntary survey, (2) a small number of samples are collected at each POTW, (3) the samples are collected in a snapshot in time, and (4) the survey is biased to POTWs associated with facilities with the greatest potential to discharge radionuclides and to POTWs in areas of higher concentrations of naturally-occurring radioactive material (NORM). Therefore, the survey results will not be a statistically valid representation of radionuclide levels in sludges nationwide.

The survey consists of two components - a questionnaire and a program to sample and analyze sewage sludge and incinerator ash.

Development of the Questionnaire

NRC and EPA developed a questionnaire (Appendix A) to request information from POTWs, such as their sludge treatment processes and disposal practices. The questionnaire also requests the zip codes for their collection systems so NRC can identify the licensees associated with each POTW. NRC will request from each Agreement State a list of licensees for the zip codes associated with each POTW. In 1996, the questionnaire was sent to nine test sites to assess the questions and to obtain a better basis for estimating the actual cost (burden hours) to the POTWs.

POTWs That Were Selected to Receive the Questionnaire

The survey was designed to measure radioactive materials in sewage sludge and ash at POTWs across the United States (the 50 States, the District of Columbia, and Puerto Rico). To maximize its effectiveness, the survey will focus on the POTWs associated with licensees with the greatest potential to discharge radioactive material to the sanitary sewer and POTWs in areas known to have high levels of naturally-occurring isotopes such as radium, thorium, and uranium. With these objectives in mind, the list of POTWs to be sent the questionnaire was developed as follows:

1. Select POTWs associated with NRC and Agreement State licensees that have the greatest potential for discharge. NRC developed a list of licensees that have the greatest potential for discharge, and EPA established a list of POTWs associated with these licensees.

2. Select POTWs in areas known to have higher concentrations of NORM in ground and surface water, or that are associated with facilities that may potentially discharge NORM into the sewage collection system.

3. Include POTWs with incinerators because radioactive materials are expected to be at higher concentrations in ash than in sludge. There are about 180 POTWs with active incinerators. However, the number of POTWs with incinerators varies from State to State, and if all the incinerators are sampled, some States will include a disproportionately high number of samples. For these reasons, the survey plans to sample no more than a few POTWs with incinerators in each State.

4. Ensure that the POTWs on the list developed in Steps 1 and 2 are from all geographic areas of the United States (Coastal Plain, Appalachians, etc.) to reflect the regional differences in NORM. If the list developed in Steps 1 and 2 has only a few POTWs in any of the geographic areas, add POTWs from the 479 POTWs which responded to the questionnaire in the first EPA national survey, which was conducted in the late 1980's. The list of POTWs from the 1980's survey was chosen because it includes POTWs for various flow rates, percent industrial flow, and use and disposal practices and is a group of nationally representative POTWs.

5. Add POTWs requested by other ISCORS members and the States.

6. Include a small group of POTWs with low potential for elevated radioactive materials for comparison purposes.

NRC and EPA will jointly send the questionnaire to about 600 POTWs. The Association of Metropolitan Sewerage Agencies and the Water Environment Federation will provide a letter to be included with the questionnaire and will send a guidance document prepared by the National Biosolids Partnership (1999) and regulatory alert to the POTWs preceding the mailing of the questionnaires to help introduce the POTWs to the voluntary survey effort and provide assistance in conducting radiation surveys of their treatment facilities and industrial contributors.

The POTWs will be requested to voluntarily complete and return the completed questionnaires to NRC. NRC will then develop the list of licensees associated with each POTW from the zip codes in their collection system and assign each POTW to a geographic area. This information will be entered into an electronic database so that NRC and EPA can select the POTWs to be sampled. NRC will send letters to the POTWs that returned the questionnaire with lists of licensees in their service area. NRC will also develop a sample return tracking system to follow up on non-respondents.

Selection of POTWs for Sampling and Analysis

From the responses to the questionnaire, about 300 POTWs will be chosen for sampling and analysis. Based on the responses to the questionnaires, the POTWs will be assigned to the categories listed below. A number of POTWs will be sampled from each category. The actual number of samples to be taken from each category will be determined based on the responses to the questionnaire. It is the goal of this survey to obtain a representative number of POTWs from each category during the course of the survey. It is recognized that some factors, such as seasonality, may need to be studied further.

- Type of NRC/Agreement State licensees that could dispose into the sewage collection system

    1. Academic
    2. Medical
    3. Manufacturing and Distribution
    4. Research and Development
    5. Other licensees
    6. No licensees that discharge to the sewage collection system

- Geographic area

    1. Coastal Plain
    2. Appalachians
    3. North Central
    4. Central
    5. Rockies and Basin and Range
    6. Colorado Plateau
    7. California

8. Pacific Northwest, Alaska, Hawaii

Sample Collection and Analysis

The sampling will take place over a one-year period. In areas of high NORM, sampling may be adjusted during some seasons, because there may be seasonal effects to the concentrations of NORM at POTWs.

Each month, over a one-year period, NRC and EPA will jointly send the NRC contractor a list of the POTWs to be sent letters and sample collection materials. The NRC contractor will contact the POTW operators to review the sampling instructions and then mail the letters and sample collection packages to the POTWs. Since POTWs routinely take representative sludge and ash samples to monitor pollutants, the POTWs will use similar procedures to collect samples for this survey. The POTWs will return their samples to the NRC contractor who will assign a code to each POTW to ensure confidentiality.

It is assumed that each POTW will, on average, send two samples of processed sludges and/or ashes, so the total number of samples collected from all POTWs participating in the survey will be about 600. It is expected that each laboratory will analyze about 300 samples.

The physical sampling and analysis procedure that will be used in this survey is described in the Quality Assurance Project Plan for this project. All analyses will be performed using methods typically used for environmental monitoring samples. All the samples will receive gamma spectroscopy, gross alpha, and gross beta analyses. The gross alpha and beta analyses are considered screening analyses. To use resources most efficiently, additional isotope-specific analyses will only be performed on samples with the highest expected concentrations of the isotopes. Each month about ten percent of the samples (about 2 or 3 samples at each lab) will receive additional isotope-specific alpha or beta analysis; the action level for this additional analysis will be chosen based on the highest observed gross alpha and gross beta results from the survey samples analyzed that month.

Additional isotope-specific analysis will be conducted for the following radioactive materials:

beta emitters: strontium-89/90, carbon-14, hydrogen-3 (tritium)

alpha emitters: radium-226, thorium-227/228/230/232, uranium-234/235/238, plutonium-238/239

Radium, thorium and uranium are naturally-occurring radioactive materials. Uranium and plutonium are also found in the effluents from processes in nuclear facilities that are used to produce nuclear fuel for research or power reactors. Strontium is a medical isotope. Plutonium will be analyzed only for POTWs with fuel-cycle or weapons research and development facilities in the collection system. Carbon-14 is both naturally occurring and man-made and is discharged by radiopharmaceutical and research facilities. Tritium is discharged by academic, manufacturing, and weapons research and development facilities.

During the survey, the laboratories will send the analysis results to the ISCORS Sewage

Subcommittee in individual monthly letter reports that discuss the samples analyzed that month and report any lab or field problems. The reviews of these monthly letter reports could lead to changes in the analysis procedures or in the selection of POTWs to be sampled.

An NRC contractor will enter the sample analysis results into an electronic data base and analyze the results. The ISCORS Sewage Subcommittee has formed a working group to perform dose modeling studies to help evaluate the potential risks associated with the radioactive materials measured in the survey. At the conclusion of the sample analyses, the laboratories will report their results to the subcommittee in a final report. The ISCORS Sewage Subcommittee will prepare a final report on the survey results.

D. QUESTIONNAIRE RESULTS FOR THE TEST SITES

The questionnaire was sent to the nine test sites to obtain current site-specific information about the sludge treatment process and disposal practices of each facility. As a result of the experiences with the tests sites and public comments on the January 6, 1997 Federal Register notice, minor changes were made to the questionnaire.

Originally, it was estimated that it would take two hours to complete the questionnaire. For most of the test sites, the respondents took 20 minutes or less. Two respondents needed two hours because of the large number of zip codes in the collection system.

The revised questionnaire is attached in Appendix A.

E. SAMPLE ANALYSIS RESULTS FOR THE TEST SITES

Following the evaluation of the responses to the questionnaires, each test site was sent sample collection packages to obtain sewage samples for analysis at the laboratories. Samples from the nine test POTWs were analyzed by both laboratories to ensure comparability, consistency in sample handling, and validity of analytical methods.

To assist in the evaluation of sample collection procedures used in the survey, the laboratory staffs observed sample collection procedures at two of the test sites. Most test sites sent two sets of sludge or ash samples (one to each laboratory).

A joint NAREL and NRC contractor report presents the findings of the radioanalytical results of various sewage sludge/ash matrices that were analyzed from the test sites. The report compared the analytical results between the laboratories and made recommendations for changes to be implemented before beginning the full survey. All the samples received gamma spectroscopy and gross alpha and beta analyses. For the test cases, all the samples also received additional isotope-specific alpha or beta analysis, although these analyses will only be performed on about ten percent of the samples in the full survey. For the test sites, both labs analyzed all the samples for all the radioactive materials for inter-lab comparisons. The results of the analysis of the test samples are discussed in Appendix B.

The results from the test sites provide the beginning of the data base for the survey. By comparing each month's lab results (by radioactive isotope and for the gross alpha and gross

beta results) to the data collected to date, it should be possible to determine the higher concentrations of radioactive materials. As expected from other studies, the incinerator ash samples in the test sites contained higher concentrations of some radioactive materials than the non-ash samples.

The following changes in the laboratory analysis resulted from the experiences with the test sites and recommendations from the laboratories:

- In general, the laboratories found good agreement between their gamma analyses. Thus the final survey will not require that split samples be analyzed by both labs, as was done with the test survey.

- The gross alpha and gross beta analyses did not provide as good agreement, due to differences in calibration and/or analysis procedures at the labs. Although gross alpha and gross beta measurements are useful as gross screening tools, their accuracy should not be assumed to be better than about an order of magnitude. Therefore, the general magnitude of the results should be evaluated rather than detailed comparisons between individual measurements. For example, if every month, the top few samples were to be screened for further analysis using either gross alpha or gross beta results, the same samples would be selected using either laboratory's data.

- Although C-14 is naturally occurring, it is also man-made, and there are licensees (radiopharmaceutical and research facilities) that could potentially discharge C-14 to sewage collection systems. Because C-14 will not be detected readily by the sludge screening (gross beta) analyses, the screening analyses would not be useful for determining which samples to analyze for C-14. Instead, the association of a POTW with a facility that could discharge C-14 will be used to determine a limited number of samples to be analyzed for C-14.

- Both of the laboratories as well as the subcommittee recommended that tritium be excluded from the analysis because tritium does not reconcentrate due to its chemical behavior in sewage collection systems. However, since tritium was detected in several samples, the laboratories will analyze for tritium until the results indicate that this analysis can be discontinued.

- Return time to the labs should be minimized for detection of short-lived nuclides, as well as for sample preservation (avoidance of sample deterioration). The survey will continue to use overnight shipments of samples to the labs.

- The turnaround time at the POTWs was often not very good. This caused sample batching problems for the labs, which in turn caused increased turnaround times and more analysis expense. Therefore, the sampling instructions and phone calls to the POTWs will emphasize the need for quick sampling and return. A turnaround time of no more than one week is needed for efficient laboratory operation.

- All samples will be analyzed using gross alpha, gross beta and gamma spectroscopy analytical techniques; ten percent of the samples will receive additional isotopic-specific

alpha or beta analyses.

F. REFERENCES

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APPENDIX A

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 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, etc.).

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 or 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

Radionuclides In Sewage Sludge and Ash at POTW Test Sites and Comparison With Other Sources of Radioactivity

The purpose of this Appendix is to compare published data on typical concentrations of radionuclides in soil, fertilizer, and building materials to the concentrations of radionuclides found in the sludge and ash samples of a pilot study of nine Publicly Owned Treatment Works (POTWs). The pilot study was conducted by a federal interagency working group (Interagency Steering Committee on Radiation Standards (ISCORS)) to develop sampling and analysis procedures for a nationwide survey of radionuclide concentrations in municipal sewage sludge and incinerator ash, to be conducted in 1999.

Over the last several decades, the U.S. Environmental Protection Agency (EPA) has conducted surveys of sewage sludge, ash, compost, and the other products produced by POTWs, to determine whether concentrations of pollutants that may pose a danger to members of the public or POTW workers are present. Recently, the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of Energy (DOE), and the U.S. Department of Defense (DOD) have begun a collaborative effort with EPA to conduct a survey of POTWs nationwide to determine potential concentrations of naturally-occurring and commercially utilized sources of radioactive materials in the sludge or ash. The results of this survey will be available in about 2 years.

A pilot study of nine POTWs was conducted to assist the agencies in developing sampling and analysis procedures. It is important to note that the purpose of this pilot study was not to assess the relative safety or hazard of radioactive materials in sewage sludge and incinerator ash, but rather to assess the sampling and analysis procedures. As such, no conclusions were drawn as to the relevance of radioactive material concentrations detected in these samples. This document is intended to help put these raw data in perspective.

SOURCES OF RADIATION EXPOSURE

Radiation in the environment from natural sources is the major source of radiation exposure to man. Radiation exposure results from the naturally-occurring radionuclides in the environment (terrestrial radiation) and direct cosmic (extra-terrestrial) radiation. Naturally-occurring radionuclides are present in some plants and animals. In the human body, for example, radioactive potassium (K-40) is present in bones and soft tissues and is the principal naturally-occurring source of internal radiation exposure. Some sources of natural radiation have been enhanced (concentrated) by human technological activities and include wastes from mineral ores and the petroleum industry, sludge and scale from drinking water treatment, and articles made from naturally-occurring radioactive materials such as thorium in lantern mantles. Together, this radiation is often referred to as "natural" or "background" radiation. It is all around us and cannot be completely avoided. In addition to natural or background radiation, radiation from man-made sources, such as X-ray machines and nuclear reactors and fallout from nuclear weapons testing in the past, also results in a relatively small source of radiation exposure to man.

Naturally-occurring radioactive materials are found in soil and water as well as in materials used to build our homes, such as bricks and stones. Geological formations and soils may contain isotopes of uranium, thorium, radium, radon, and other radioactive elements. The public is generally aware of the radioactive gas, radon (radon-222), which is one of the decay products of the uranium isotope uranium-238 that is found naturally in soil. Radon is often found in the air we breathe and the water we drink. Radon-222 and its decay products contribute most of the radiation exposure received by members of the public.

RADIOACTIVE MATERIALS IN SEWAGE SLUDGE, ASH AND OTHER PRODUCTS

Sewage sludge and ash at POTWs may contain both naturally-occurring and man-made radioactive materials. Water that originates in or moves through geologic deposits containing naturally-occurring radionuclides could result in radioactivity being carried to the treatment facility with storm water runoff or infiltration entering the sewer system, and water treatment plant residuals discharged to the sewer system. Industrial, medical or research facilities may also discharge radioactive materials to the sanitary sewer system in accordance with prescribed State and Federal regulations. In addition, radioactive materials administered to patients for the diagnosis or treatment of illnesses are excreted into the sewer system. Other industrial or residential discharges (such as fertilizer residues) can contain naturally-occurring radioactive materials that are not subject to licensing or regulation.

Tables 1 and 2 provide the concentrations of radionuclides detected during the pilot survey of sludges and ash from nine POTWs, as well as typical ranges of radionuclide concentrations commonly found in U.S. soils and common items such as fertilizers and building materials. The curie (Ci), or fractions of a curie (e.g. picocurie), 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). A picocurie is one one-trillionth (1/1,000,000,000,000) of a curie. Radionuclide concentrations in these tables have been rounded to the nearest decimal point. Values in these tables do not show uncertainty calculations. Sludge and ash samples from POTWS associated with facilities known to discharge man-made radionuclides were included in the pilot survey. Inclusion in these tables does not imply that the range of radionuclide concentrations presented for the materials is protective of human health.

The ISCORS agencies make no representation as to human or environmental health and safety significance from exposure to radionuclides in the concentrations described in the tables. Further information may be obtained from Robert Bastian at EPA (email bastian.robert@epa.gov or phone 202-260-7378), Behram Shroff at EPA (email schroff.behram@epa.gov or phone 202-564-9707) or Mary Thomas at NRC (email mlt1@nrc.gov or phone 301-415-6230).

Table 1

Pilot 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)

Radio-nuclide	Soil [1]	Phosphate Fertilizer [2]	Building Materials [1]	Pilot Study Sludge	Pilot Study Ash
Am-241	NDA[3]	NDA	NDA	ND[4]	ND
Ba-140	NDA	NDA	NDA	ND	ND
Be-7 *	NDA	NDA	NDA	ND - 22	4.0 - 13
Bi-212	0.1 - 3.5	0.1 - 4.6	0.1 - 3.7	ND - 2.0	ND - 2.0
Bi-214	0.1 - 3.8	4.0 - 140	2.5 - 5.05	ND - 2.0	.02 - 16
C-14 *	NDA	NDA	NDA	ND	ND
Co-60	NDA	NDA	NDA	ND - 6.0	ND
Cr-51	NDA	NDA	NDA	ND - 4.0	ND
Cs-137	0.1 - 0.2[6]	NDA	NDA	ND - 1.0	0.03 - 0.08
H-3 *	NDA	NDA	NDA	ND - 135	ND
I-125	NDA	NDA	NDA	ND - 1.0	ND - 0.3
I-131	NDA	NDA	NDA	ND - 70	ND - 4.0
K-40 *	2.7-19	32 - 160[7]	0.8 - 30	2.0 - 8.0	14 - 16
Pa-234m *	0.1 - 3.8	4.0 - 140	0.2 - 5.0[5]	ND - 15	ND - 9.0
Pb-212 *	0.1 - 3.5	<0.1 - 4.6	0.1 - 3.7	0.2 - 2.0	1.0 - 2.0
Pb-214 *	0.1 - 3.8	4.0 - 140	0.2 - 5.0	ND - 2.0	2.0 - 17
Pu-238	NDA	NDA	NDA	ND - 0.03	ND - 0.01
Pu-239	NDA	NDA	NDA	ND - 0.08	ND - 0.01
Ra-223 *	<0.1 - 0.2	0.2 - 6.6	<0.1 - 0.2[5]	ND - 0.06	ND
Ra-224 *	0.1 - 3.5	<0.1 - 4.6	0.1 - 3.7[1]	ND - 1.0	0.5 - 4.0
Ra-226 *	0.1 - 3.8	0.1 - 24	0.1 - 3.5	1.0 - 29	3.0 - 25
Ra-228 *	0.1 - 3.5	<0.1- 4.6	0.1 - 3.7	ND - 2.0	2.0 - 9.0

Radio-nuclide	Soil [1]	Phosphate Fertilizer [2]	Building Materials [1]	Pilot Study Sludge	Pilot Study Ash
Sr-89	NDA	NDA	NDA	ND - 7.0	ND - 0.8
Sr-90	NDA	NDA	NDA	ND - 0.7	ND
Th-227 *	<0.1 - 0.2	0.2 - 6.6	<0.1 - 0.2	ND - 0.1	ND
Th-228 *	0.1 - 3.5	<0.1 - 4.6	0.1 - 3.7	ND - 1.0	ND - 2.0
Th-230 *	0.1 - 3.8	4.0 - 140	0.2 - 5.0	ND - 1.0	0.5 - 2.0
Th-232 *	0.1 - 3.5	<0.1 - 4.6	0.1 - 3.7	0.01 - 0.9	0.4 - 1.0
Th-234 *	0.1 - 3.8	4.0 - 140	0.2 - 5.0	ND - 12	2.0 - 5.0
Tl-201	NDA	NDA	NDA	ND - 24	ND
Tl-208 *	0.1 - 3.5	<0.1 - 4.6	0.1 - 3.7	ND - 0.5	ND - 0.6
U-234 *	0.1 - 3.8	4.0 - 140	0.2 - 5.0	0.2 - 44	5.0 - 8.0
U-235 * [8]	<0.1 - 0.2	0.2 - 6.6	<0.1 - 0.2	ND - 3.0	ND - 1.4
U-238 *	0.1 - 3.8	4.0 - 140	0.2 - 5.0[5]	0.2 - 12	2.0 - 5.0

NOTES:

1. R. Tykva and J. Sabol, "Low-Level Environmental Radioactivity - *Sources and Evaluation,*" Technomic Publishing Company, Inc., Lancaster, Pennsylvania (1995). This reference is the source of data for concentrations of radionuclides in soil and building materials except for the concentrations of U-238, U-235, and Cs-137 which came from references 5 and 6, respectively. The concentrations of the daughters or decay products of U-238, such as Th-234, Ra-226, etc., those of U-235, such as Th-227 and Ra-223, and those of Th-232 are set equal to those of their respective parent radionuclides by assuming that the daughters are in secular radioactive equilibrium with the parent radionuclides.

2. Source for data on fertilizers: National Council on Radiation Protection and Measurements, 1987, Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources; NCRP Report No. 95, pp. 24-32. This is the source of data for the concentrations of radionuclides in fertilizers except for the concentration of K-40 in soil which came from the reference in note 7.

3. NDA - No data available

4. ND - Not detected. The radionuclide was not detected in some of the samples during the pilot study. For detection limits for radionuclides, see the tables in "Report to the ISCORS Subcommittee on the Sewage Nuclide Concentration Test Samples," dated

November 23, 1998.

5. M. Eisenbud and T. Gesell, "Environmental Radioactivity," Fourth Edition (1997), Academic Press, New York, New York.

6. Cs-137 concentration range in soil obtained from Figure 4-4, p. 94 of NCRP Report No. 50, "Environmental Radiation Measurements," Recommendations of the National Council on Radiation Protection and Measurements (1976).

7. Source for data on K-40 in fertilizer: S. Cohen and Associates, 1997, Final Draft NORM Waste Characterization; EPA Contract No. 68D20155, WA No.5-09, pp. B-3-1 to B-3-24.

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

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

10. * - naturally-occurring radionuclide

Table 2 -
Pilot Survey Radionuclide Concentrations in Sewage Sludge and Ash
(All values are in pCi/g-dry weight)

NUCLIDE	SEWAGE SLUDGE SAMPLE RESULTS	ASH SAMPLE RESULTS
Am-241	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND	ND, ND, ND, ND, ND, ND, ND
Ba-140	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND	ND, ND, ND, ND, ND, ND, ND
Be-7	3.2, 3.08, 2.16, 2.8, 2.21, 2.26, 1.04, 0.72, 0.13, 0.11, 0.16, ND, 0.72, 0.47, ND, ND, 0.69 , 0.42, 0 .76, 0.76, 7.15, 8.73, 1.30, 1.13, 22.1, 21.9, 18.5, 14.2, ND, ND	4.09, 12.7, 4.25, 4.23, 5.12, 5.34, 5.21
Bi-212	ND, ND, ND, 0.81, ND, ND, ND, ND, ND, 0.18, ND, 0.55, ND, ND, ND, ND, ND, 0.37, ND, 0.47, ND, 0.50, ND, 1.49, ND, 0.76, ND, 0.63, ND, 0.56	ND, 0.81, ND, ND, 1.24, ND, 1.54
Bi-214	0.68, 0.49, 0.47, 0.47, 1.12, 0.61, 0.26, 0.38, 0.21, 0.13, 0.25, 0.24, 0.26, ND, 1.38, 0.40, 1.69, 2.24, 0.45, 0.48, 0.92, 0.57, 1.37, 0.40, 0.40, 0.25, 0.41, 0.22, 0.35, 0.19	3.15, 2.08, 3.12, 9.94, 15.5, 13.7, 15.8
C-14	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND	ND, ND, ND, ND, ND, ND, ND
Co-60	ND, 0.12, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, 6.47, 5.07, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND	ND, ND, ND, ND, ND, ND, ND
Cr-51	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, 3.54, ND, ND, ND, ND, ND, 1.38, ND, ND	ND, ND, ND, ND, ND, ND, ND
Cs-137	0,.30, 0.35, 0.07, ND, ND, 0.05, 0.06, ND, 0.03, 0.01, 0.03, 0.02, 0.02, ND, 1.08, 1.09, 0.02, 0.02, ND, ND, 0.06, 0.06, 0.20, 0.18, 0.05, 0.05, 0.08, 0.03, 0.02, 0.02	0.03, 0.08, 0.04, 0.05, 0.08, 0.04, 0.05
H-3	ND, ND, ND, ND, ND, ND, 30.4, ND, 3.75, ND , ND, ND, 1.69, ND, ND, ND, ND, ND, ND, ND, 135.0, ND, ND, ND, ND, ND, 1.65, ND, ND, ND	ND, ND, ND, ND, ND, ND, ND
I-125	ND, ND, 0.91, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND	ND, ND, ND, 0.26, ND, ND, ND
I-131	60.5, 69.8, 0.49, 0.47, 0.49, 0.49, 13.8, 14.2, ND, ND, ND, ND, 7.47, 13.7, 0.26, 0.71, 0.95, 0.96, 37.4, 38.5, 0.28, 0.51, ND, ND, 9.25, 5.14, 5.55, 2.59, ND, ND	0.16, 4.25, 0.16, 4.18, ND, ND, ND
K-40	4.99, 6.23, 2.97, 3.32, 2.80, 3.29, 3.45, 4.74, 7.70, 4.99, 7.74, 7.08, 3.33, 2.77, 2.22, 2.00, 7.36, 7.87, 2.15, 2.54, 5.04, 5.52, 5.74, 5.51, 4.54, 4.76, 5.12, 4.41, 6.88, 7.29	15.2, 15.4, 15, 14.2, 14.4, 14.4, 15.6
Pa-234m	ND, 9.47, ND, ND, ND, ND, 9.55, ND, 2.37, 1.90, 13.2, 11.4, 11.1, 9.33, 14.9, 11.4, ND, ND, ND, ND, ND, 1.36, ND, 2.64, ND, 3.19, 1.17, 2.49, 10.1, 10.5	8.52, 4.02, 6.21, 2.44, ND, ND, 3.37
Pb-212	0.18, 0.27, 0.57, 0.74, 0.59, 0.56, 0.25, 0.31, 0.25, 0.18, 0.56, 0.63, 0.25, 0.24, 0.22, 0.28, 0.51, 0.60, 0.23, 0.35, 0.49, 0.55, 1.55, 1.53, 0.68, 0.75, 0.80, 0.65, 0.52, 0.55	1.39, 0.91, 1.42, 1.50, 1.94, 1.61, 1.85
Pb-214	0.42, 0.47, 0.59, 0.50, 0.94, 0.45, 0.32, 0.34, 0.25, 0.14, 0.30, 0.24, 0.22, ND, 0.32, 0.29, 1.76, 2.35, 0.39, 0.43, 1.00, 0.63, 1.42, 0.44, 0.38, 0.19, 0.46, 0.24, 0.34, 0.22	3.40, 2.23, 3.42, 11.1, 16.6, 14.6, 17.3

Pu-238	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, 0.02, 0.02, ND, ND, ND, ND, ND, ND, ND, ND, 0.03, ND, ND, ND, ND, ND	0.01, ND, ND, ND, ND, ND, ND
Pu-239	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, 0.02, 0.08, 0.04, ND, ND, ND, ND, ND, 0.04, 0.07, 0.01, ND, ND, ND, ND, 0.01, ND	ND, ND, ND, ND, ND, 0.01, ND
Ra-223	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND ND, ND ND, ND, ND, ND, ND, 0.06, ND, ND, ND, ND, ND, ND, ND, ND	ND, ND, ND, ND, ND, ND, ND
Ra-224	ND, ND, ND, ND, ND, ND, ND, ND, ND, 0.19, ND, 0.70, ND, ND, ND, ND, ND, 0.43, ND, ND, ND, 0.49, ND, 1.46, ND, 0.62, ND, ND, ND, 0.59	ND, 0.49, ND, ND, 3.72, ND, 3.31
Ra-226	4.65, 6.19, 1.46, 3.02, 2.36, 1.71, 5.11, 7.82, 1.46, 1.13, 8.92, 1.80, 10.1, 10.6, 29.2, 6.38, 3.61, 4.53, 2.13, 4.08, 2.00, 2.55, 3.09, 3.42, 2.36, 3.25, 2.67, 2.65, 7.83, 1.97	8.34, 2.92, 9.36, 16.7, 25.0, 17.7, 25.1
Ra-228	0.66, ND, 1.05, 1.23, 0.61, 0.86, 0.74, 0.70, 0.37, 0.20, 0.67, 0.70, 0.91, 0.55, 0.46, 0.60, 1.52, 1.60, 1.20, 1.48, 1.24, 1.22, 1.95, 1.77, 1.19, 1.14, 1.40, 1.11, 0.64, 0.66	1.84, 1.58, 1.85, 7.81, 8.60, 8.20, 8.88
Sr-89	ND, ND, ND, ND, 7.12, ND, ND, ND, ND, ND, ND, ND, ND, ND, 1.17, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, 0.56, ND, ND, ND	0.75, ND, ND, ND, ND, ND, ND
Sr-90	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, 0.57, 0.74, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND	ND, ND, ND, ND, ND, ND, ND
Th-227 alpha	ND, ND, ND, 0.05, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, 0.07, ND, ND, ND, 0.06, ND, 0.07, ND, ND	ND, ND, ND, ND, ND, ND, ND
Th-227 gamma	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND	ND, ND, ND, ND, ND, ND, ND
Th-228	0.80, 0.52, 0.14, 0.62, 0.49, 0.50, 0.29, ND, 0.48, 0.24, 0.45, ND, 0.30, 0.47, 0.24, ND, 0.78, 0.54, 0.47, ND, 0.67, 0.63, 1.39, 0.91, 0.73, 0.71, 0.92, 0.83, 0.49, ND	1.30, ND, 1.13, 2.42, 2.04, 1.65, 1.44
Th-230 alpha	ND, 0.41, 0.16, 0.62, 0.57, 0.58, 0.35, 0.32, 0.42, 0.23, 0.25, 0.33, 0.22, 0.24, 0.16, 0.40, 0.29, 0.29, 0.11, 0.19, 0.53, 0.49, 0.78, 1.07, 0.84, 0.54, 0.99, 0.60, 0.30, 0.43	2.36, 0.99, 2.17, 0.74, 0.72, 0.55, 0.87
Th-230 gamma	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND	ND, ND, ND, ND, ND, ND, ND
Th-232	0.20, 0.26, 0.11, 0.40, 0.30, 0.36, 0.19, 0.35, 0.35, 0.18, 0.23, 0.42, 0.18, 0.27, 0.10, 0.15, 0.24, 0.43, 0.01, 0.01, 0.34, 0.39, 0.92, 0.91, 0.45, 0.55, 0.56, 0.49, 0.28, 0.27	1.19, 0.66, 1.02, 0.48, 0.71, 0.50, 0.35
Th-234	5.00, 5.43, 1.39, ND, 1.48, ND, 5.28, 2.79, 1.88, 0.83, 12.5, 11.9, 7.78, 3.19, 11.8, 7.54, 0.53, ND, 0.42, ND, 0.86, 0.86, 1.58, 1.00, 1.29, 2.18, 1.25, ND, 1.09, 10.6	5.03, 3.70, 5.08, 2.37, 2.42, 4.17, 2.09
Tl-201	ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, ND, 14.0, ND, ND, ND, 4.19, ND, 23.6, ND, ND, ND, ND, ND, 21.5, ND, 5.51, ND, ND	ND, ND, ND, ND, ND, ND, ND
Tl-208	ND, 0.1, ND, 0.26, ND, 0.19, ND, 0.09, ND, 0.06, ND, 0.20, ND, 0.06, ND, 0.05, ND, 0.17, ND, 0.11, ND, 0.17, ND, 0.51, ND, 0.24, ND, 0.22, ND, 0.18	ND, 0.29, ND, ND, 0.65, ND, 0.61
U-234	14.4, 6.95, 0.21, 0.81, 0.98, 0.98, 13.2, 11.8, 4.93, 2.62, 12.2, 12.3, 15.4, 12.7, 44.5, 43.8, 1.46, 1.24, 4.44, 1.61, 1.36, 1.31, 1.61, 2.00, 1.84, 1.76, 1.56, 1.51, 10.9, 10.8	5.16, 5.43, 5.78, 7.34, 7.34, 7.62, 6.01
U-235 alpha	0.55, 0.75, 0.01, 0.03, 0.19, 0.05, 0.35, 0.66, 0.16, 0.12, 0.50, 0.43, 0.58, 0.68, 1.81, 3.06, 0.03, 0.08, 0.15, 0.08, 0.09, 0.09, 0.13, 0.13, 0.17, 0.07, 0.21, 0.09, 0.49, 0.57	0.20, 0.42, 0.18, 0.18, ND, 0.14, 0.24
U-235 gamma	0.20, ND, ND, ND, ND, ND, 0.41, 0.48, 0.04, 0.07, 0.56, 0.52, 0.50, 0.64, 1.87, 2.04, ND, ND, ND, ND, 0.07, 0.15, 0.05, ND, 0.10, ND, 0.14, ND, 0.50, 0.46	0.32, 0.22, 0.34, 0.12, ND, ND, 1.39

U-238	10.3, 5.83, 0.18, 0.75, 0.90, 0.85, 6.72, 6.23, 2.74, 1.46, 9.77, 9.62, 12.5, 10.0, 11.5, 12.0, 0.74, 0.71, 0.95, 0.73, 1.23, 1.15, 1.06, 1.21, 1.33, 1.36, 1.41, 1.13, 8.63, 8.33	4.25, 3.81, 4.75, 3.26, 3.86, 3.33, 2.28
Gross Alpha[1]	21.0, 18.6, 5.0, 5.73, 5.19, 8.78, 13.4, 19.0, 5.17, 7.55, 18.5, 30.8, 23.7, 19.5, 50.8, 48.9, 12.6, 11.7, 16.4, 22.6, 8.70, 13.6, 14.9, 23.9, 10.2, 12.7, 10.5, 10.7, 19.8, 28.5	24.4, 46.5, 41.0, 82.3, 97.9, 92.6, 72.9
Gross Beta[1]	30.8, 22.1, 10.9, 8.58, 12.1, 9.36, 20.4, 15.5, 13.8, 10.8, 29.8, 26.2, 35.3, 21.3, 60.1, 34.8, 19.0, 15.3, 16.8, 10.5, 17.1, 15.9, 22.5, 16.5, 19.0, 12.5, 18.4, 16.8, 34.4, 24.6	51.5, 28.6, 51.4, 77.6, 65.4, 95.4, 47.2

NOTES:

1. Gross alpha and Gross beta – These measurements are generally used as indicators of the presence of alpha and beta emitting radionuclides in a sample. Gross alpha and gross beta activity analyses are used to screen samples to determine the need for nuclide-specific analyses. They were included in the pilot study, but have no corresponding background levels, and thus are not included in Table 1.

ND - Not detected. The nuclide was not detected in some of the samples during the pilot study. See the tables in the EPA National Air and Radiation Environmental Laboratory "Report to the ISCORS Subcommittee on the Sewage Nuclide Concentration Test Samples," November 13, 1998, for detection limits for nuclides.