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COLONIE INTERIM STORAGE SITE ENVIRONMENTAL SURVEILLANCE REPORT FOR CALENDAR YEAR 1993

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CONTENTS

	Page
FIGURES	iv
TABLES	iv
INTRODUCTION	1
HISTORY OF THE COLONIE INTERIM STORAGE SITE	5
THE ENVIRONMENTAL SURVEILLANCE PROGRAM AT CISS	6
BIBLIOGRAPHY	20
APPENDIX A RADIATION AT A GLANCE	A-1

FIGURES

Figure	Title	Page
1	Location of CISS	2
2	Air, Surface Water, Sediment, and Groundwater Environmental Surveillance Locations at or in the Vicinity of CISS	9
3	Background Air and Surface Water Environmental Surveillance Locations in the Vicinity of CISS	10
4	Comparison of Dose from the Site with Background and DOE Guidelines	15
A-1	Typical Annual Radiation Doses From Natural and Man-Made Sources	A-2

TABLES

Table	Title	Page
1	CISS Environmental Surveillance Program Summary	8
2	Comparison of Calculated Maximum Doses from CISS During 1993 with Applicable Standards and Natural Background Radiation	19
A-1	Comparison and Description of Various Dose Levels	A-6

INTRODUCTION

This report summarizes the results of environmental surveillance activities conducted at the Colonie Interim Storage Site (CISS) during calendar year 1993. It includes an overview of site operations, the basis for radiological and nonradiological monitoring, dose to the offsite population, and summaries of environmental programs at CISS. Environmental surveillance activities were conducted in accordance with the site environmental monitoring plan, which describes the rationale and design criteria for the surveillance program, the frequency of sampling and analysis, specific sampling and analysis procedures, and quality assurance requirements. Appendix A contains a discussion of the nature of radiation, the way it is measured, and common sources of it.

The primary environmental guidelines and limits applicable to CISS are given in U.S. Department of Energy (DOE) orders and mandated by six federal acts: the Clean Air Act; the Clean Water Act; the Resource Conservation and Recovery Act (RCRA); the Toxic Substances Control Act; the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and the National Environmental Policy Act (NEPA).

DOE began environmental monitoring of CISS in 1984 when DOE was authorized by Congress through the Energy and Water Development Appropriations Act to conduct a decontamination research and development program at the site. The site was subsequently assigned to DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established in 1974 to identify and decontaminate or otherwise control sites where residual radioactive materials remain from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy.

CISS is located at 1130 Central Avenue in Colonie, New York, approximately 4 miles northwest of downtown Albany (Figure 1). The site occupies approximately 11.2 acres. The CISS property includes a large masonry manufacturing facility, an office building, temporary trailers, a warehouse, two storage buildings, approximately 4 acres of paved surface, and approximately 4 acres of grassland. Three buildings were onsite when National Lead

Figure 1
Location of CISS

Industries was in operation. They included the large manufacturing facility and two small concrete block storage buildings along the southwestern boundary. The remaining temporary facilities were added by DOE.

National Lead Industries operated the plant as a foundry from 1937 to 1984 and for manufacturing various uranium and thorium components from 1958 to 1984. From 1966 to 1972, National Lead Industries held contracts to manufacture fuel from enriched uranium for experimental nuclear reactors. Operations were also conducted at the plant to reduce depleted uranium tetrafluoride to depleted uranium metal, which was then fabricated into shielding components, ballast weights, and projectiles. Electroplating operations were also conducted at the plant. As a result of these operations, the original buildings, grounds, and vicinity properties became radioactively contaminated. Since 1984, CISS has been used for interim storage of waste materials contaminated with low-level radioactivity. The waste material resulting from removal actions at the vicinity properties is stored inside the main building.

Environmental remediation of CISS is being conducted in accordance with CERCLA and applicable DOE requirements authorized by the Atomic Energy Act. CERCLA and its implementing regulations are the primary sources of federal regulatory authority for remedial actions to be conducted at CISS. The site was assessed under the hazard ranking system by the U.S. Environmental Protection Agency (EPA) in 1991 and did not meet the criteria for listing on the National Priorities List. However, CISS is listed on the New York State Department of Environmental Conservation (NYSDEC) Registry of Inactive Hazardous Waste Sites. Remediation of CISS and adjacent vicinity properties will be performed in accordance with CERCLA.

A second primary environmental statute, NEPA, requires federal agencies to analyze the potential environmental impacts of proposed major activities, including those of environmental restoration projects such as the one being conducted at CISS. DOE policy requires the integration of NEPA requirements with the procedural and documentation requirements of CERCLA, thereby minimizing duplication of effort and the commitment of resources needed to implement both statutes separately.

RCRA is the principal federal statute governing the management of hazardous waste. Because RCRA-regulated wastes have been stored at CISS, a RCRA interim status permit application was on file with the NYSDEC. However, NYSDEC terminated RCRA interim status for all facilities on November 8, 1992. A site closure plan was written, and NYSDEC approved the plan January 5, 1993. DOE is obligated to meet the requirements in the final RCRA closure plan in accordance with applicable site closure regulations. These requirements include the removal of RCRA-regulated wastes listed on the interim status permit application, the treatment of waste as necessary to meet applicable land disposal restriction requirements, and the cleanup of storage and treatment areas directly associated with the listed RCRA waste. RCRA closure activities conducted in 1993 included the offsite disposal of 15 drums of mixed (RCRA-regulated and radioactively contaminated) waste at a DOE-approved, permitted disposal facility and cleanup of the associated storage areas. Completion of final RCRA closure activities at CISS is expected in fall 1994.

During 1993, nonstructural building components and unusable equipment in the facility were removed, shredded to reduce the volume, and packaged in preparation for building decontamination and demolition. Other site activities included routine grounds and equipment maintenance, environmental surveillance, onsite sampling in support of future environmental restoration requirements, and a special study on groundwater.

Copies of this report are distributed to government officials, members of Congress, environmental and civic groups, the news media, and interested individuals. Results of the CISS environmental surveillance program have been published each year since the program began in 1984. The environmental surveillance report for 1993 and all previous reports may be inspected in the Administrative Record file in the William K. Stanford Town Library, 629 Albany Shaker Road, Loudonville, New York 12211-1126. The telephone number is (518) 458-9274. The data used to compile this environmental surveillance report are available upon request.

DOE maintains a 24-hour, toll-free telephone number (1-800-253-9759). An answering machine records comments or questions. The machine is checked regularly, and all calls are returned promptly.

HISTORY OF THE COLONIE INTERIM STORAGE SITE

Foundry operations conducted at CISS from the 1920s through 1960 included casting brass in sand molds and manufacturing babbitt metal (an alloy of lead, tin, copper, and antimony). Spent sand from the molds was disposed of onsite. Site operations also included the use of tetrachloroethene, which is a chemical contaminant at the site. Jet mainframes were manufactured from aluminum during the 1940s.

Radioactive materials were first handled at CISS in 1958. At that time, the property was owned and operated by National Lead Industries, which produced uranium products under a license issued by the U.S. Atomic Energy Commission (AEC). The most commonly used material was depleted uranium; however, small amounts of thorium and enriched uranium were also used. After the AEC license was terminated in 1968 and until CISS ceased to function as an operating facility in 1984, National Lead Industries continued using depleted uranium metal to fabricate shielding components, counterweights, and projectiles. Other processes conducted at the plant included an electroplating operation for plating of uranium with nickel and cadmium. Contaminated liquid and solid wastes were disposed of both onsite and at commercial disposal facilities. Some radioactively contaminated materials might have been used as fill during site modification. Cuttings from shaping and machining the depleted uranium were incinerated, and airborne releases from these incinerations resulted in surface contamination of the site and vicinity properties.

In 1984, Congress authorized DOE, a successor agency to AEC, to clean up radioactive contamination that had been discovered on various properties in Colonie. DOE assigned the site to FUSRAP and began work almost immediately. Radiological surveys identified 56 vicinity properties with contamination. Between 1985 and 1988, approximately 1,200 cubic yards of materials (soils, roofing, etc.) contaminated with low levels of radioactivity was removed from 53 vicinity properties and stored inside the main building at the site for future disposition. Drums containing radioactive waste and radioactive mixed waste (RMW) as defined by RCRA are also stored onsite. Contamination remaining on the final three properties, which are adjacent to CISS, will be remediated with the site.

THE ENVIRONMENTAL SURVEILLANCE PROGRAM AT CISS

The goals of the environmental surveillance program at CISS are to identify and quantify the effect of site activities on the environment and public health. DOE wants to be certain that site conditions do not adversely affect public health or the environment and that activities at the site comply with all environmental laws and regulations. Through the environmental surveillance program, DOE routinely collects the environmental data needed for evaluating the site.

Surveillance Program Description

The surveillance program includes methods for determining exposure to radiation from both external and internal sources. Gamma radiation measurements taken along the boundary of the site are used to assess external exposure. Additionally, the program monitors routes (or pathways) by which contaminants could migrate from the site to the offsite environment where they could potentially become sources of exposure to the public. Potential pathways include migration of dissolved contaminants in rainfall runoff or dispersion of radon gas or radioactive soil in the air. For example, if radioactive soil is present in the air, it could be deposited on a garden. A person could be exposed to this radioactivity by eating unwashed vegetables from the garden or by inhaling any radioactive soil that became airborne as the garden was cultivated.

Monitoring devices and sampling stations are located to be most effective in detecting potential contamination sources and ensuring that no contaminants are migrating from the site. In locating the sampling stations, the surveillance program considers factors such as wind directions, site terrain, and the paths through which water flows on and off the site. Other considerations include regulatory requirements, sampling frequency, and the kinds of sampling devices and laboratory analyses that are best for detecting or measuring a certain contaminant.

Even after an environmental surveillance program is set up, it is continuously reevaluated and modified for effectiveness. Sampling and monitoring stations are relocated, new ones are added, and old ones are eliminated as information needs change.

Environmental Surveillance

The radioactive contaminants at CISS are uranium and thorium. The environmental surveillance program at CISS monitors for external gamma radiation in the air. Surface water, sediment, and groundwater are monitored for total uranium and thorium-232. In addition, certain chemicals are also present that could be associated with uranium and brass processing operations conducted at the site years ago; therefore, the program monitors for metals and volatile organic compounds in groundwater. The CISS environmental surveillance program is summarized in Table 1. Figures 2 and 3 show the environmental surveillance locations at CISS.

To monitor radon and external gamma radiation in air, DOE has established "background" monitoring stations for radiation exposure rates at two locations several miles from the site. The data collected from these background stations are compared to the data collected from monitoring stations placed along the fenceline at the edge of the property. The radiological detection devices are in place 24 hours a day, year round. External gamma radiation exposure rates are measured to confirm that direct radiation from CISS is not significantly increasing radiation levels above natural background and to ensure compliance with environmental regulations. The fenceline locations represent the closest that a member of the public could come to the contamination on the site. The amount of external gamma radiation measured at the fenceline, therefore, represents the maximum levels that could potentially be encountered by a member of the public. To receive the maximum, a person would have to stand at the fenceline 24 hours a day for an entire year.

The data collected from the surveillance program are used for the assessment of doses to the public and not to onsite workers. Workers onsite participate in other monitoring programs to assess their personal exposure to radioactive materials. In addition, a ventilation system with high efficiency filtration was installed at CISS to prevent ambient emissions from

Table 1
CISS Environmental Surveillance Program Summary

Sample Type	Number of Sampling Locations	Analyses Performed	Frequency of Sampling for Chemical Analyses	Frequency of Sampling or Detector Exchanges for Radiological Analyses
External gamma radiation	13*	External gamma radiation exposure rates	Not applicable	Semiannually
Groundwater	16**	Metals, volatile organic compounds, total uranium, thorium-232	10 Wells-quarterly 6 Wells-annually	10 Wells - quarterly 6 Wells - annually
	3	Groundwater quality parameters - calcium, potassium, sulfate, chloride, sodium, bicarbonate, carbonate, nitrate, magnesium, total dissolved solids	Annually	Not applicable
Surface water	5***	Total uranium, thorium-232	Not applicable	Semiannually
Sediment	4***	Total uranium, thorium-232	Not applicable	Semiannually

Quality Controls

*All locations have environmental duplicates.

**One location has an environmental duplicate, and one location has a matrix spike and matrix spike duplicate.

***One location has an environmental duplicate.

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Figure 2
Air, Surface Water, Sediment, and Groundwater Environmental Surveillance
Locations at or in the Vicinity of CISS

Figure 3
Background Air and Surface Water Environmental Surveillance
Locations in the Vicinity of CISS

the building during work activities. Airborne radionuclide particulates from the ventilation system are continuously monitored whenever the system is in operation.

DOE uses a system of wells to monitor the groundwater beneath the site. One well is located in an area known to be unaffected by the site. This background well measures the amount of radioactive and chemical constituents that occur in the local environment. By comparing the samples from the background well with the samples from the other wells, DOE can determine whether contaminants at the site are affecting groundwater.

This same "comparison measurements" principle is used in monitoring the effect of the site on surface water and sediment. A background sampling location monitors surface water and sediment unaffected by CISS; other locations monitor the surface water and sediment in places that might be influenced by the site. Results from the background samples are compared with the site samples. All samples are analyzed by laboratories that are required to meet strict quality control requirements.

Regulatory Limits for Chemical Releases

The Safe Drinking Water Act (SDWA), which was enacted by Congress in 1974 to regulate drinking water systems, requires EPA to set national standards for levels of contaminants in drinking water, and provide for protection of aquifers. Under the Superfund Amendments and Reauthorization Act, drinking water standards and goals set under the SDWA became groundwater standards for CERCLA cleanups. In addition, New York groundwater and surface water quality standards, which are applicable requirements under CERCLA, became standards for CISS. These regulations are designed to protect ambient water quality by establishing radiological and chemical constituent standards for water pollutant discharges and cleanups. Limits for chemical contaminants are based on factors such as chemical toxicity of hazardous substances, state health (water source) values, and EPA drinking water regulations. The limits stress that releases should be minimized to a degree consistent with available technology.

Surveillance Results for Chemical Parameters at CISS

During 1993, drinking water standards or guidelines (as provided by EPA and the state) were exceeded in some groundwater samples analyzed for antimony, arsenic, barium, cadmium, chromium, copper, lead, nickel, and zinc. The only concentrations of arsenic above EPA and state standards were found in upgradient background wells in the lower groundwater system. Samples from the lower groundwater system contain large percentages of very fine native sediment known to contain metals such as arsenic. When samples from the lower groundwater system were filtered, no metals were detected above guidelines. Barium, cadmium, copper, and zinc exceeded EPA guidelines in only one well. This well is located inside the building. The presence of antimony, cadmium, copper, lead, and zinc may be a result of foundry operations. Barium, chromium, and nickel are commonly associated with electroplating processes.

Concentrations of tetrachloroethene (a volatile organic compound) and its degradation products, trichloroethene, and 1,2-dichloroethene also exceeded guidelines in four onsite wells on the southern side (downgradient) of the site. A special study was conducted to identify potential volatile organic contaminant offsite migration through groundwater. The field investigation included drilling and sampling five temporary wells downgradient of CISS, installing two permanent monitoring wells at locations determined to be in the potential line of migration, and collecting and analyzing surface water samples from upgradient and downgradient locations to determine the presence of volatile organic compound contaminants. The investigation did not identify concentrations of tetrachloroethene or its degradation products at any of the locations offsite.

The remaining 1993 groundwater sampling results met the standards. No metal or volatile organic was detected in the offsite downgradient wells. Groundwater in the CISS vicinity is not used as a source of drinking water.

Regulatory Limits for Radiological Releases

The primary federal statute governing air emissions is the Clean Air Act. The potential exists for point-source and fugitive emission sources of radionuclides at CISS. Point-source emissions could be emitted from the filtered ventilation system in the building at the site. Fugitive emissions could come from the main building during cleanup efforts in preparation for demolition. However, fugitive emissions should be minimal because of the building ventilation system. Results of filter monitoring demonstrate that the ventilation system is in compliance with the Clean Air Act.

In 1993, compliance with the National Emissions Standards for Hazardous Pollutants (NESHAPs) Subpart H for radionuclides other than radon was evaluated using the EPA Clean Air Act Assessment Package-1988 (CAP-88) PC computer model. Calculations performed indicated that the site is in compliance with Subpart H.

DOE has established total quantity limits, derived concentration guides, and dose limits for radiological releases from DOE facilities. Some regulations for radioactive contaminants set a limit on the amount or concentration of radioactivity that may be released; others set a limit on the dose a person could receive from releases. Conservative limits are set for the dose a person could receive from all sources. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," sets conservative limits to which the site must adhere.

DOE Order 5400.5 specifies that the radiation dose to any member of the public resulting from routine DOE activities should not exceed 100 mrem/yr above background. (See Appendix A for an explanation of units.) This limit excludes medical procedures, residual fallout from past nuclear accidents and weapons tests, and consumer products. The radiation standards in DOE Order 5400.5 include EPA recommendations for limiting the doses from atmospheric releases and from drinking water. These recommendations state that the dose to an individual must not exceed 10 mrem/yr from releases of radioactivity to the air. The 10 mrem/yr does not include radon because radon is subject to specific DOE limits. The recommendations also state that the concentration of manmade beta-gamma radiation in drinking water must not exceed a dose of 4 mrem/yr. There is no separate limit for liquid

releases alone, but these releases are included in the 100 mrem/yr for all pathways. Figure 4 illustrates the contribution from CISS to the dose to the public compared with the dose from background radiation and the DOE guideline of 100 mrem/yr.

Environmental surveillance results for 1993 show that CISS was in compliance with all applicable DOE radionuclide release standards and guidelines.

Surveillance Results for Radiological Parameters

Since environmental surveillance at the site began in 1984, analytical results have consistently shown that CISS is making no significant contribution of radioactivity to the environment. The results of radiological surveillance for 1993 again showed this to be true. The additional radiation dose to the offsite population attributable to CISS is very close to zero. This is consistent with results from previous years.

External gamma exposure monitoring results for 1993 showed average exposure rates of 6.5 milliroentgen per year (mR/yr) at the site fenceline. (One mR is approximately equivalent to 1 mrem.) This measurement does not include the normal background gamma exposure rate of 66.5 mR/yr. Measurements at onsite sampling stations ranged from 0 to 19 mR/yr. The highest rate measured at the fenceline (station 4) was 19 mR/yr above background. The reported exposure rates are those that an individual could receive if that person remained at the detector location 100 percent of the time for an entire year.

The property nearest this station is a single-family dwelling about 227 ft south of the southwestern boundary of the site, occupied 100 percent of the time. The calculated external gamma exposure rates at the house from contamination at CISS would be much lower than those measured at the surveillance location because of the distance between the house and the source of radiation. The maximum dose that individuals in the house could receive was calculated using conservative assumptions (which would tend to overestimate the possible dose). Hypothetically, the highest dose a person could have received from gamma radiation from CISS in 1993 would be equal to 0.12 mrem, a small fraction of the DOE guideline of 100 mrem/yr above background.

Figure 4
Comparison of Dose from the Site with Background and DOE Guideline

Results of groundwater monitoring for thorium and uranium showed that concentrations of uranium in some wells exceeded background during 1993. However, except for one onsite well located on a loading dock adjacent to a suspected source of buried uranium, all concentrations were well below DOE guidelines and within established federal and state standards for these radionuclides. Onsite and offsite downgradient wells show no current changes in uranium concentration, and data indicate that the uranium contamination is localized. Except in the well on the loading dock, radionuclide concentrations measured in groundwater associated with CISS are consistent with past data and approximate the range of natural background concentrations.

Radiological sampling of surface water and sediment yielded results that were nearly the same as background and below guidelines and standards. These results are consistent with monitoring results from previous years.

The ALARA (As-Low-As-Reasonably-Achievable) Program

The goal of any ALARA program is to keep radiation exposure to members of the general public and onsite workers as low as reasonably achievable. To implement this program at FUSRAP sites, every reasonable effort is made to maintain exposures to radiation from the sites as far as possible below the established dose limits for both worker and public exposure.

Traditionally, ALARA guides have been established to limit the amounts and concentrations of radioactive materials that could be released to the environment from nuclear facilities. Current regulations governing releases of radioactive materials emphasize minimizing the dose received from a release rather than the quantity of the release; consequently, the ALARA guidelines at all FUSRAP sites have been established to limit the total dose resulting from exposure (both internal and external) to radioactivity.

ALARA is implemented at FUSRAP sites by continuously evaluating all site activities to determine any potential increase in the risk of exposure to radiation. Dose estimates are used to identify trends to determine best management practices that should be implemented to

further reduce the dose to the general public and site workers. This program has been successful in limiting dose to levels that are nearly the same as background.

Dose

As radioactive materials decay, they release energy in the form of rays and particles. When people are exposed to radioactive materials, body tissues can absorb some of the released energy, resulting in an absorbed dose. (For example, when people feel warmth from sunlight, they are actually absorbing radiant energy emitted by the sun.) However, in terms of human health, it is the effect of the absorbed dose, rather than the actual amount of radiation emitted, that is important.

The potential health effects that can result from an absorbed dose depend on the amount and type of energy absorbed and on the part of the body exposed. The effective dose (ED) is used to express dose in terms of the potential health impact. Use of the ED allows doses from different types of radiation and doses to different parts of the body to be expressed on the same basis. ED is expressed in mrem.

The amount of radioactivity measured in environmental samples does not represent the actual radiological impact of the site on the environment and offsite public. To determine the potential health effects, releases from CISS are evaluated, and the maximum potential dose is calculated. Therefore, this report focuses on releases and maximum potential dose to explain the impact of the site on the surrounding communities.

Calculating Dose

With modern technology, very small amounts of radionuclides in environmental samples can be detected. Although all air and liquid emissions from CISS are monitored, the radionuclides at the site have such low concentrations when dispersed into the environment that they are difficult to distinguish from natural background radiation. Consequently, it is difficult to directly measure the public's exposure to some of the radioactive materials that may be released from the site. Therefore, mathematical models must be used to estimate the

concentrations of radionuclides present in the environment as a result of the measured releases to air and water. Beginning with the measured releases and factoring in many other conditions (e.g., wind direction, rainfall, population distribution, and, in some cases, actual measurements from environmental samples), estimated concentrations are calculated. These estimated concentrations are used to calculate estimated doses from site releases.

When maximum doses are calculated from releases to the air and water from CISS, the concept of a hypothetical individual who receives the maximum reasonable exposure from all pathways is used. Even though no such individual is known to exist, the concept of the maximally exposed individual is used to estimate the contribution from CISS to the dose of the offsite population; this ensures that the estimated dose is the highest any individual could have received as a result of site operations. For the purpose of this calculation, this hypothetical maximally exposed individual is assumed to live within 227 ft of the site, 100 percent of the time for an entire year.

Table 2 presents estimates of dose to the hypothetical maximally exposed member of the public from CISS operations in 1993. Actual doses to any member of the public are expected to be lower than these conservative estimates. It is important to remember that the estimated dose reported by CISS is only a part of the annual dose received by an individual; everyone is exposed to natural and man-made sources of radiation and receives a dose from that radiation regardless of exposure to radiation from CISS (see Figure 4).

Quality Assurance and Quality Control

When releases are monitored and radiation in the environment is measured, there must be confidence that the data are reliable. To ensure that the monitoring and measurement results are accurate, FUSRAP has a quality assurance and quality control program based on state and federal guidelines. Subcontractor laboratories that provide services for CISS must have established quality assurance and quality control programs and must participate in interlaboratory comparisons, evaluations, and audits of their facilities.

Table 2
Comparison of Calculated Maximum Doses from CISS During 1993
with Applicable Standards and Natural Background Radiation

Exposure Pathway	Dose for Hypothetical Maximally Exposed Individual from CISS (mrem/yr)	Applicable Standard^a (mrem/yr)	Percent of Standard	Percent of Natural Background^b
Direct gamma radiation ^c	0.12	NA	NA ^d	0.04
Drinking water	-- ^e	4 ^f	NA	-- ^e
Airborne pathways		10 ^g	0.45	0.02
HEPA system	0.0034			
Surface Soils	0.042			
All pathways	0.17	100 ^h	0.17	0.06

^aAbove natural background.

^bThe site-specific estimate of the average dose received from natural background radiation is 306.5 mrem/yr.

^cAbove natural background.

^dThere is no separate standard for direct gamma radiation alone, but it is included in the 100 mrem standard for all sources.

^eExposure from this pathway is negligible.

^fDOE Order 5400.5 provides a standard of 4 mrem/yr from a DOE site for manmade beta-gamma radiation. The standard excludes radium, uranium, radon, and other naturally occurring radionuclides. Groundwater in the vicinity of CISS is not a source of drinking water.

^gThe standard for airborne effluents, excluding radon, applies to the sum of the doses from all airborne pathways: inhalation, exposure to radionuclides deposited on the ground surface, submersion in a plume, and consumption of foods contaminated as a result of the deposition of radionuclides.

^hExposure pathways are added to compare calculated maximum doses from CISS releases with the DOE "all pathways" standard.

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APPENDIX A RADIATION AT A GLANCE

RADIATION AT A GLANCE

Of all activities at FUSRAP sites, those associated with radiation receive the most attention. What exactly is radiation and where does it come from? To answer these questions, it is best to start with a few basics.

All matter is made up of extremely small particles called atoms. Atoms contain even smaller particles called protons, neutrons, and electrons. When an atom has a stable mix of protons and neutrons, it is nonradioactive. However, when atoms have too many of either protons or neutrons, these unstable atoms can break apart, or decay, in an attempt to become stable. As atoms decay, energy is released; this released energy is called radiation.

Sources of Radiation

Radiation originates from natural events that happen all the time, but it can also be made by man. Most of the radiation people are exposed to occurs naturally. It has always been present, and every person who has ever lived has been exposed to radiation. Although modern technology may seem to have greatly increased the exposure rate, this is not necessarily the case. Exposure to man-made radiation varies greatly based on a given individual's lifestyle choices and medical treatments.

Sources of natural, or background, radiation include internal radiation from food (we all have approximately 500,000 atoms disintegrating in our bodies every minute), cosmic radiation from the sun and from outside the solar system, and terrestrial radiation from rocks, soils, and minerals (Figure A-1). People have no control over the amount of natural radiation around them, and the amount of natural radiation stays about the same over time. The natural radiation present in the environment today is not much different than it was hundreds of years ago. In general, over 80 percent of the radiation the average person is exposed to is from natural sources. Man-made radiation accounts for less than 20 percent of the total, most of it from medical procedures.

Source: NCRP 1987.

4.151 4070.1

Figure A-1
Typical Annual Radiation Doses from Natural and Man-Made Sources

Man-made sources of radiation include consumer products, medical procedures, and the nuclear industry. Some consumer products such as smoke detectors and even porcelain dentures contain radioactive elements. Probably the best-known source of man-made radiation is nuclear medicine. For example, to conduct a brain, liver, lung, or bone scan, doctors inject patients with radioactive compounds and then use radiation detectors to make a diagnosis by examining the resulting image of the organ.

Man-made radioactive materials also include cesium-137 and strontium-90, present in the environment as a result of previous nuclear weapons testing. As with background radiation, exposure to other sources of radiation varies greatly depending on individual choices, such as smoking tobacco products (polonium-210) and eating certain foods (bananas contain potassium-40).

Levels of Radiation

The average dose caused by background radiation varies widely. In the United States, the average is about 300 mrem/yr; some people in other parts of the world receive a dose more than four times this amount. For example, in some areas of Brazil, doses to inhabitants can be more than 2,000 mrem/yr from background radiation. These wide variations are the result of several factors, most notably the types and amounts of radionuclides in the soil.

This diversity in background radiation is responsible for the large differences in doses. Because people live in areas with high levels of background radiation without proven harm, it is assumed by most in the scientific community that small variations in environmental radiation levels have an inconsequential, if any, effect on humans.

Measuring Radiation

To determine the possible effects of radiation on the health of the environment and people, these effects must be measured. More precisely, the potential for radiation to cause damage must be ascertained. Measurements of these potential effects are derived from the

activity of each isotope and are expressed in terms of the absorbed dose to an individual and the effective dose or potential to cause biological damage.

Activity

When we measure the amount of radiation in the environment, what is actually being measured is the rate of radioactive decay, or radioactivity, of a given element. This radioactivity is expressed in a unit of measure known as a curie (Ci). A curie is a measure of radioactivity, not a set quantity of material. More specifically, one curie equals 37,000,000,000 (3.7×10^9) radioactive disintegrations per second. One gram of a radioactive substance may contain the same amount of radioactivity as several tons of another radioactive substance. For example, one gram of tritium (a radioactive form of hydrogen) emits about 10,000 Ci, while one gram of uranium emits about 0.000000333 (333×10^{-9}) Ci. Because the levels of radioactive contamination at most FUSRAP sites are very low, the picocurie is commonly used in reporting contaminant levels. One picocurie is equal to 1×10^{-12} curies. Contaminants in water are reported in picocuries per liter (pCi/L), and contaminants in soil are reported in picocuries per gram (pCi/g).

Absorbed Dose

The total amount of energy per mass unit absorbed as a result of exposure to radiation is expressed in a unit of measure known as a rad. However, in terms of human health, it is the effect of the absorbed energy that is important, not the actual amount of energy emitted.

Effective Dose

The measure of potential biological damage caused by exposure to and subsequent absorption of radiation is expressed in a unit of measure known as a rem. One rem of any type of radiation has the same total damaging effect, regardless of the source of the radiation. Because a rem represents a fairly large dose, dose is usually expressed as a millirem (mrem), or 1/1,000 of a rem. The larger the dose, the higher the potential for damage. The dose

from FUSRAP site activities is a small fraction of the dose that residents in the area surrounding the site receive from natural background radiation. Table A-1 explains the potential health effects of a range of radiation doses.

Table A-1
Comparison and Description of Various Dose Levels

Dose	Description
1 mrem	Approximate daily dose from natural background radiation, including that due to radon.
2.5 mrem	Cosmic dose to a person on a one-way airplane flight from New York to Los Angeles.
4 mrem/yr	Annual exposure limit from manmade radiation in drinking water.
10 mrem	Typical dose from one chest X-ray using modern equipment.
10 mrem	Annual exposure limit, set by EPA, for exposures from airborne emissions (excluding radon) from operations of nuclear fuel cycle facilities, including power plants, uranium mines, and mills.
25 mrem	Annual exposure limit from low-level waste-related exposures.
65 mrem	Average yearly dose to people in the United States from man-made sources.
60-80 mrem	Average yearly dose from cosmic radiation to people in the Rocky Mountain states.
83 mrem	Estimate of the largest dose any offsite person could have received from the March 28, 1979, Three Mile Island nuclear accident.
100 mrem	Annual limit of dose from all DOE facilities to a member of the public who is not a radiation worker.
110 mrem	Average occupational dose received by United States commercial radiation workers in 1980.
170 mrem	Average yearly dose to an airline flight crew member from cosmic radiation.
300 mrem	Average yearly dose to people in the United States from all sources of natural background radiation.
900 mrem	Average dose from a lower-intestine diagnostic X-ray series.
1,000-5,000 mrem	EPA's Protective Action Guidelines state that public officials should take emergency action when the dose to a member of the public from a nuclear accident will likely reach this range.

5,000 mrem	Annual limit for occupational exposure of radiation workers set by the U.S. Nuclear Regulatory Commission and DOE.
8,000 mrem	Average yearly dose to the lungs from smoking 1½ packs of cigarettes per day.
10,000 mrem	The BEIR V report estimated that an acute dose at this level would result in a lifetime excess risk of death from cancer, caused by the radiation, of 0.8 percent.
25,000 mrem	EPA's guideline for voluntary maximum dose to emergency workers for non-lifesaving work during an emergency.
75,000 mrem	EPA's guideline for maximum dose to emergency workers volunteering for lifesaving work.
50,000- 600,000 mrem	Doses in this range received over a short period of time will produce radiation sickness in varying degrees. At the lower end of this range, people are expected to recover completely, given proper medical attention. At the top of this range, most people will die within 60 days.

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