NUREG-1388

Environmental Monitoring of Low-Level Radioactive Waste Disposal Facility

Manuscript Completed: November 1989
Date Published: December 1989

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ABSTRACT

This branch technical position (BTP) paper on the environmental monitoring program for a low-level radioactive waste disposal facility provides general guidance on what is required by Section 61.53 of Title 10 of the *Code of Federal Regulations* (10 CFR) of applicants submitting a license application for such a facility. In general, the environmental monitoring program consists of three phases: preoperational, operational, and postoperational. Each phase of the monitoring program should be designed to fulfill the specific objectives defined in the BTP paper. During the preoperational phase, the objectives of the program are to provide site characterization information, to demonstrate site suitability and acceptability, to obtain background or baseline information, and to provide a record for public information. During the operational phase, the emphasis on measurement shifts. Monitoring data are obtained to provide early warning of releases and to document compliance with regulations, the dose limits of 10 CFR Part 61, or applicable standards of the U S. Environmental Protection Agency. Data are also used to update important pathway parameters to improve predictions of site performance and to provide a record of performance for public information. The postoperational environmental monitoring program emphasizes measurements to demonstrate compliance with the site-closure requirements and continued compliance with the performance objective in regard to the release of radionuclides to the environment. The data are used to support evaluation of long-term effects on the general public and for public information. Guidance is also provided in the BTP paper on the choice of which constituents to measure, setting action levels, relating measurements to appropriate actions in a corrective action plan, and quality assurance.

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ACKNOWLEDGMENTS

The authors wish to thank the Chairman, the staff, and the consultants of the Advisory Committee on Nuclear Waste, U.S. Nuclear Regulatory Commission, for their constructive suggestions in the completion of this paper.

1 INTRODUCTION

1.1 Background

The Atomic Energy Act of 1954 and the Energy Reorganization Act of 1974 assign to the U.S. Nuclear Regulatory Commission (NRC) the responsibility for licensing and regulating commercial nuclear facilities. The licensing requirements for near-surface disposal of low-level radioactive waste (LLW) are specified in Part 61 of Title 10 of the *Code of Federal Regulations* (10 CFR Part 61).

With passage of the Low-Level Radioactive Waste Policy Amendments Act of 1985, Congress improved procedures for the implementation of interstate compacts, subject to Congressional approval, for the purpose of establishing and operating regional LLW sites. Initial steps have been taken by States and members of interstate compacts that will lead to the development of new sites for LLW disposal. To provide timely assistance in this process, the NRC is issuing this branch technical position (BTP) paper on environmental monitoring programs for near-surface LLW disposal facilities. As part of a license application, a description of the environmental monitoring program required in 10 CFR 61.53 must be submitted.

On November 5, 1987, the NRC announced in the *Federal Register* (52 *FR* 42486) the availability of a draft BTP paper entitled "Environmental Monitoring of Low-Level Radioactive Waste Disposal Facilities" and requested public comments. Thirteen private organizations and Government agencies, as well as several individuals, commented on the draft BTP paper. Subsequently, NRC's Advisory Committee on Nuclear Waste also provided comments. This final BTP paper has been revised with the comments of these groups taken into consideration.

1.2 Purpose and Scope

The purpose of this paper is to provide general guidance to applicants and regulatory authorities (NRC Agreement States) on the design of a monitoring program for LLW disposal facilities. The basic NRC requirement for monitoring of near-surface LLW disposal sites is located in 10 CFR 61.53. The regulation calls for environmental monitoring during the preoperational, operational, and postoperational stages of the facility. The primary objective of environmental monitoring is to assist in ensuring that the performance objectives in 10 CFR Part 61 are met. The staff's interpretation of this basic objective, as well as of other related objectives, is discussed herein. This paper is not intended to be a handbook of detailed or mandatory procedures, and it must be stressed that a detailed environmental monitoring program for an LLW disposal facility must be tailored to the site-specific operating and environmental conditions. Because each site has unique topography, meteorology, demography, and geohydrology, only general guidance can be given. In the design of an environmental monitoring program, there is no substitute for good professional judgment, combined with a thorough knowledge of the local environment.* Although only general guidance can be given, this paper provides insight into the opinions and expectations of the NRC staff for the acceptance review of the applicant's environmental monitoring program. However, the guidance presented herein is not mandatory, and flexibility in applying this guidance on a case-by-case basis is suggested.

In this paper, the staff defines the objectives of the three phases of an environmental monitoring program; these objectives constitute an acceptable basis for such a program. The staff also provides general guidance to the applicant for the design of the monitoring program as well as references that provide greater detail on the planning, design, and implementation of an environmental monitoring program relevant to the operation of an LLW disposal facility.

Early in the development of an LLW disposal facility, the applicant is encouraged to meet with NRC staff members to discuss in specific detail the design of an appropriate environmental monitoring program suitable for a particular site. This interaction is especially important during the preoperational phase, which covers a rather broad scope of monitoring requirements, as defined in 10 CFR 61.53(a). This interaction may also help to reduce the number of major deficiencies identified during the subsequent NRC or State review that delay the licensing action.

For the purpose of this paper, an environmental monitoring program consists of the collection of samples and the measurement of concentrations of radioactivity, radionuclides, direct radiation, chemicals, and other physical properties of specific media in the environs of an LLW disposal site during all phases of facility operation. The monitoring program described herein is broader than that for other existing nuclear facilities where consideration is directed only to the measurement of radiological components in the environment. The regulations in 10 CFR 61.53 require a broad range of monitoring, covering the three phases of operation for a new LLW disposal site. Nonradiological and physical parameters are included in the monitoring because they serve as indicators for waste migration and for site characterization; however, the applicant's compliance with environmental standards is subject to the regulations of the State or the U.S. Environmental Protection Agency (EPA).

Monitoring of worker exposure during site operations in accordance with 10 CFR Part 20, such as dosimetry for personnel and radiation surveys of containers, equipment, materials, and support facilities, does not come

*International Commission on Radiological Protection (ICRP). "Principles of Monitoring for the Radiation Protection of the Population." *Annals of the ICRP International Commission on Radiological Protection*. Publication 43, Vol. 15, No. 1, 1985.

under the scope of environmental monitoring as defined in this paper. Effluent monitoring of associated facility operations or supplemental operations, such as effluent releases from stacks resulting from waste handling or incineration, and the discharge of liquid effluent from treatment of leachate, is also not covered in this paper. Generally, monitoring of worker exposure and effluents will be required in the applicant's safety analysis report to demonstrate compliance with the requirements of 10 CFR 61.12(k). Also, the monitoring of accidental releases is not included herein because emergency situations involving sudden major radioactive releases as a result of such events as criticality or a fire may require a special surveillance effort beyond the routine monitoring program.

2 ENVIRONMENTAL MONITORING PROGRAM OBJECTIVES

2.1 Regulatory Requirements

The requirements pertaining to an environmental monitoring program are described in 10 CFR 61.53, "Environmental Monitoring":

> (a) At the time a license application is submitted, the applicant shall have conducted a preoperational monitoring program to provide basic environmental data on the disposal site characteristics. The applicant shall obtain information about the ecology, meteorology, climate, hydrology, geology, geochemistry, and seismology of the disposal site. For those characteristics that are subject to seasonal variation, data must cover at least a twelve month period.
>
> (b) The licensee must have plans for taking corrective measures if migration of radionuclides would indicate that the performance objectives of Subpart C may not be met.
>
> (c) During the land disposal facility site construction and operation, the licensee shall maintain a monitoring program. Measurements and observations must be made and recorded to provide data to evaluate the potential health and environmental impacts during both the construction and the operation of the facility and to enable the evaluation of long-term effects and the need for mitigative measures. The monitoring system must be capable of providing early warning of releases of radionuclides from the disposal site before they leave the site boundary.
>
> (d) After the disposal site is closed, the licensee responsible for post-operational surveillance of the disposal site shall maintain a monitoring system based on the operating history and the closure and stabilization of the disposal site. The monitoring system must be capable of providing early warning of releases of radionuclides from the disposal site before they leave the site boundary.

2.2 Environmental Monitoring Program Phases

Environmental monitoring has three major phases: preoperational, operational, and postoperational. Preoperational monitoring occurs during the period before license application and could continue during the application review period. Operational monitoring occurs from the beginning of facility construction through the period when waste is no longer accepted and the facility is closed. Postoperational monitoring occurs from closure through the long-term care period. Although monitoring during each phase is related to the performance objectives in 10 CFR Part 61, the emphasis, scope, and intensity of monitoring will vary from phase to phase. The monitoring program should be planned so that the data collected during each phase will be compatible with and supplemental to data collected during previous and subsequent phases.

2.3 Objectives of the Environmental Monitoring Program

The principal objectives of the three phases of an environmental monitoring program for an LLW disposal facility are as follows:

(1) **Preoperational Monitoring Objectives**

- (a) Provide site characterization information.
- (b) Demonstrate site suitability and acceptability.
- (c) Obtain background or baseline data.
- (d) Provide records for public information.

(2) **Operational Monitoring Objectives**

- (a) Demonstrate compliance with applicable environmental radiation standards.
- (b) Obtain data on critical pathway parameters to allow more accurate evaluation of radiation doses to the general public.
- (c) Provide records for public information.

(3) **Postoperational Monitoring Objectives**

- (a) Demonstrate compliance with site-closure requirements.

(b) Provide data to support long-term impact evaluation, such as long-term impacts on ground water.

(c) Provide records for site closure and for public information.

3 GENERAL GUIDANCE ON PREOPERATIONAL ENVIRONMENTAL MONITORING

This section provides general guidance on the design of a preoperational environmental monitoring program, including definition of the specific areas that should be covered. Details on methods and frequency of sampling and location of sampling will vary among specific sites because of the variation of environmental factors such as geology, hydrology, climate, land use, water use, and local population. The following documents discuss the design and implementation of a preoperational program in greater detail:

(1) U.S. Nuclear Regulatory Commission, NUREG-0902, "Site Suitability, Selection and Characterization," Branch Technical Position, Low-Level Waste Licensing Branch, April 1982

(2) U.S. Department of Energy, DOE/LLW-67T, "Site Characterization Handbook—National Low-Level Waste Management Program," March 1988

(3) U.S. Department of Energy, DOE/LLW-13 ?g (draft), "Environmental Monitoring for Low-Level Waste-Disposal Sites," Low-Level Radioactive Waste Management Handbook Series, March 1989

(4) U.S. Nuclear Regulatory Commission, NUREG/CR-5054, "Recommendations to the NRC for Review Criteria for Alternative Methods of Low-Level Radioactive Waste Disposal: Environmental Monitoring and Surveillance Programs," Battelle Pacific Northwest Laboratory, July 1988

The primary purpose of the preoperational program is to characterize the site environment. Part of the overall program consists principally of collecting new or existing monitoring data to evaluate the geological, hydrogeological, climatological, ecological, radiological, and nonradioactive pollutant environments of the site and the surrounding area. These data are needed to assist in demonstrating the site's acceptability and suitability for LLW disposal compared with other alternative sites in the applicant's site-selection process.

In the preoperational phase, environmental media are sampled and analyzed to provide background or baseline data to characterize the site environment. Some of the environmental sampling data can be used as indicators for long-term impact assessment. For some characteristics that may be subject to seasonal changes, the program must be continued for at least 1 year and should be extended through NRC's license review period of 12 to 15 months. Characteristics such as wind speed, wind direction, and atmospheric stability; subsurface and surface water levels; and radionuclide and nonradiological contaminant concentrations in air and water may be subject to seasonal changes. As previously noted, the applicant is encouraged to discuss the preoperational program with the NRC staff before initiation of the program in order to reduce the number of major deficiencies. During the initial review of the license application, the NRC staff will continue to work closely with the applicant to identify any additional preoperational monitoring needed so that the applicant can still take action during the review process. The following section describes the environmental factors or parameters that should be covered in a preoperational monitoring program.

3.1 Environmental Factors and Parameters

3.1.1 Meteorology and Climate

Meteorological data are collected during the preoperational stage to provide baseline information on meteorologic conditions, to determine the site's water budget, to evaluate the impact from airborne releases of effluents, to obtain information on the frequency probability of severe meteorological events, and to provide baseline data on air quality. The significant, specific meteorological parameters are onsite wind speed, wind direction, and atmospheric stability frequencies; atmospheric pressure; precipitation; temperature; evaporation; solar radiation; severe weather; and the concentration of contaminants in the air.

Most of these data and other meteorological information such as humidity, snow depth, and inversion height can be obtained from a nearby weather station that has climatological patterns similar to those of the site. If there is no weather station nearby, the key parameters measured on site are wind speed, wind direction, and atmospheric stability, as well as the precipitation rate and evaporation rate. Initial onsite measurements of these parameters for a period of at least 12 consecutive months, or preferably 24 consecutive months, are necessary. This program should be continued during the operational phase.

Background radiologic and nonradiologic air quality data should be measured for a period of at least 12 consecutive

months, preferably for 24 consecutive months, to account for seasonal variation. Depending on the availability of power, air sampling stations should be located at some strategic points, such as upwind and downwind of the facility, the area of maximum impact, the nearest residential area, and the fenceline. These stations can also be used during the operational phase.

3.1.2 Hydrology

3.1.2.1 Ground Water Hydrology

Ground water data are needed to provide information on site suitability. The information is used to demonstrate that the site is relatively simple hydrologically, that the site can provide a water table of sufficient depth so that ground water intrusion into the waste is unlikely, or if disposal below the water table is proposed, that molecular diffusion will be the predominant means of radionuclide movement and the ground water pathway impact can be modeled to meet performance objectives.

At disposal sites in humid climates, the primary mechanism for radionuclide migration will most likely be ground water flow. Humid sites generally have more direct ground water recharge than do arid sites, usually resulting in larger seasonal fluctuations of water level and water quality, with the likelihood that flow rates will be higher and more transient. Arid sites may have very deep, relatively stagnant flow systems with little seasonal change in water level or quality. Ground water flow may not be the principal release pathway at arid sites because of the long travel time necessary for contaminants to reach the water table (or a confined aquifer) and for the contaminated ground water to reach the facility boundary. Although both the saturated and unsaturated zones are important in both cases, the monitoring emphasis will depend largely on the behavior of the flow system. For example, at arid sites the unsaturated zone should be emphasized. At humid sites, both the saturated and unsaturated zones should be considered.

Preoperational ground water monitoring includes studying the recharge and discharge zones, determining the rate and direction of ground water movement, and determining the potentiometric and water table elevations for all potentially affected aquifer systems in the vicinity of the LLW disposal facility. The applicant should install monitoring wells so that variability of flow rate and direction can be assessed. The movement of infiltrate in the unsaturated zone and the potential for deep percolation should be evaluated and used in the design of the monitoring network. Water levels and capillary potentials should be determined often enough so that seasonal fluctuations can be taken into consideration.

Water samples from the saturated zone, and from the unsaturated zone when possible, should be collected and analyzed for radiological and selected nonradiological constituents so that the water chemistry can be assessed. Sampling frequency must be established on a site-by-site basis, taking into account expected changes in water quality and hydrologic conditions during the year. The applicant should define vertical and horizontal hydraulic gradients and use the information to design a ground water monitoring system for the operational and postoperational phases. Furthermore, hydraulic gradient data will provide an understanding of the hydrogeologic system at the site necessary for hydrologic modeling and for use in pathway analysis and performance assessment. The applicant should sample, when possible, nearby residential, municipal, agricultural, and industrial wells. The preoperational sampling should be continued for 12 consecutive months and should be carried on throughout the license review. The preoperational program should be designed so that it can be integrated into the programs for the operational and postoperational periods.

3.1.2.2 Surface Water Hydrology

Surface water data are needed during the preoperational phase to verify that the site will be generally well drained and free of areas of flooding or frequent ponding, to determine the amount of runoff that could erode or inundate the site, to demonstrate that the surface water pathway analysis meets performance objectives, and to provide baseline data on water quality (NUREG-0902). This compilation will include data on water users and historic floods, as well as data on droughts, rainfall, and snowfall.

Field measurements will include runoff, infiltration rates, erosion rates, surface water discharge rates, and water quality in regard to radiological and nonradiological components. In addition, sediment samples from nearby surface water courses should be taken and analyzed for both radiological and nonradiological components.

3.1.3 Geology and Seismology

Information on geology is needed to demonstrate that the natural processes affecting the site occur at consistent and definable rates and that the site will be geomorphically and tectonically stable for a period of 500 years (NUREG-0902). The information includes geomorphology, stratigraphy, lithology, tectonics, structure, seismology, and geologic hazards. Regional information can be obtained from organizations such as the U.S. Geological Survey. Site-specific information is likely to require firsthand field investigation by the applicant.

Preoperational measurements such as surface and trench geologic mapping and sampling, borehole logging, and analysis may be necessary. Accumulated seismic data

must be assembled and evaluated in areas of potential active faulting or other earthquake danger. Short-term monitoring may be useful in confirming local conformance to regional seismic characteristics.

3.1.4 Geochemistry and Hydrochemistry

Geochemistry and hydrochemistry information is needed to provide background chemistry data, to permit monitoring of key indicators of water quality and leachate migration, and to identify parameters that may affect transport of the waste leachate to the environment. Preoperational geochemical monitoring may include measurement of ground water composition and Eh-pH, radionuclides in both water and soil, soil ion exchange capacity, and distribution coefficients of selected radionuclides between soil and water. Additional tests could include field and laboratory measurements of leachate migration rates. Sampling frequency and duration for time-variant parameters and factors are similar to those for hydrologic measurements.

3.1.5 Ecology

Information on ecology is needed to define the baseline terrestrial and aquatic characteristics of the site in order to support environmental impact assessments and mitigation planning. Important concerns include abundance of species, their characteristics, importance of the species, and seasonal and migratory patterns. Ecological information includes terrestrial fauna species, terrestrial flora species, aquatic species, livestock, food chain, migratory species, game animals, habitat, and threatened and endangered species. The presence of burrowing rodents and deep-rooted vegetation at the site should also be determined because rodents and vegetation are potential vectors. Most of this information can be obtained from organizations such as the U.S. Fish and Wildlife Service and the State's Fish and Game Service.

A preoperational program includes surveying the site vicinity for major vegetation types and commercially or recreationally important vertebrate and invertebrate species. Sampling should be conducted for a minimum of 12 consecutive months to determine the seasonal variation of species. Site reconnaissance surveys (including aerial photography) can be used to confirm information obtained from existing sources, to determine species and habitat conditions, and to select sites and techniques for more intensive investigation, as necessary.

3.1.6 Demography

Demographic data on geographic distributions and sizes of both existing and projected human populations, within designated distances of up to a 50-mile radius of the site, are needed. This information will be used to analyze the potential impact on health from operation of the facility. The information includes population centers, population density, distribution of local residents, transient population, and projected population. Most of the information can be obtained from the U.S. Bureau of Census or State or local government records.

Preoperational data collection near the site includes measuring or estimating the distribution of local residents around the site to evaluate the area of maximum impact from facility operation. These data should include information on nearby schools and hospitals.

3.1.7 Background Radiation Characteristics

Background radiological data are needed to establish baseline data on radiological characterization of the site. These data will be used as baseline information to evaluate the impact of operation of the facility, decommissioning, and site closure, and may be used as references to set action levels.

Preoperational monitoring includes measurements of direct gamma radiation and of the concentrations of radioactive material in the air, soil, sediment, surface water, ground water, and biota. At least 1 year of preoperational data should be submitted in the applicant's license application. Most of these measurements may have to be continued during the operational phase.

3.1.8 Land Use

Land use data in the vicinity of the site are needed to evaluate the potential impacts of facility operation. Information includes residential, industrial, agricultural, and recreational land use; special areas; zoning restrictions; local land use plans; farmland use classification; and utility land uses. This information generally can be obtained from State and local government agencies, the U.S. Department of Interior, and the U.S. Department of Agriculture. The land use information should include location of cultural resources in the vicinity of the site. Buildings, structures, or objects of historical, archeological, architectural, scenic, cultural, or landmark significance in the vicinity of the site should be identified before construction of a disposal facility.

Preoperational monitoring may include field reconnaissance and limited surface testing of archeological finds, if necessary. The applicant should consult the State Historic Preservation Officer in all data collection activities to ensure compliance with standards and procedures.

4 GENERAL GUIDANCE ON OPERATIONAL ENVIRONMENTAL MONITORING

The principal purposes of the operational environmental program are to monitor site performance and to demonstrate compliance with applicable standards. Some of the preoperational monitoring may have to be carried over through the construction phase of an LLW disposal facility. During construction, because no radioactive materials have yet been disposed of at the site, the environmental monitoring covers mainly the nonradiological impacts of facility construction on the environment, such as dust generation, soil erosion, traffic, and noise. Because the monitoring of these effects is subject to the regulation and compliance requirements of the State or the EPA, the following discussion will emphasize radiological aspects resulting from operation. Nonradiological constituents are discussed only to the extent that they affect transport of radionuclides and are good indicators for early warning of waste migration into ground water.

It is expected that the operational environmental monitoring program will be conducted during the entire time that waste is being buried, a period estimated to be 30 years. Appropriate records and data must be submitted to the NRC during periodic license renewal action to demonstrate compliance with regulatory standards for continued operation and to be used as public information. The data and records will provide information for the design of the postoperational program.

4.1 Considerations in the Design of an Operational Environmental Monitoring Program

4.1.1 Pathway Analysis

The knowledge of pathways of possible migration of waste from the burial site to members of the public is important to the design of an operational environmental monitoring program. Pathway analysis predicts the quantities of radioactive materials that may reach persons under a measured or assumed set of conditions and estimates the potential dose to humans resulting from this exposure. By performing a pathways analysis, which consists of (1) pathways identification, (2) pathways modeling, and (3) dose calculation, the critical pathways for exposure of humans can be identified. An important objective of the operational program is the monitoring of critical pathways by selecting appropriate environmental sampling media in appropriate sampling locations. The critical pathways on which monitoring efforts should be concentrated are dependent on waste stream characteristics, facility operation and design, and site environmental factors. The detail or level of monitoring for a particular pathway also depends on the performance assessment to demonstrate compliance with applicable standards. The NRC is currently developing a performance assessment methodology covering the potential radiological impacts of operation of an LLW disposal facility. To provide technical guidance to applicants and Agreement States in this area, models will be identified or developed to estimate source terms and to assist in pathway analysis.

4.1.2 Critical Nuclides and Critical Groups

The critical nuclides are those radionuclides most subject to release, and the critical groups are those population groups potentially subject to the greatest exposure. To identify critical radionuclides, the characteristics of the wastes that are to be buried at the facility must be known. The following documents or references provide some information on the characterization of the wastes in existing LLW disposal facilities. The information can be used as a basis for estimating source inventories.

(1) U.S. Nuclear Regulatory Commission, NUREG/CR-4370, "Update of Part 61 Impacts Analysis Methodology," Envirosphere Co., January 1986

(2) U.S. Nuclear Regulatory Commission, NUREG-0945, "Final Environmental Impact Statement on 10 CFR Part 61: Licensing Requirements for Land Disposal of Radioactive Waste," November 1982

(3) U.S. Department of Energy, DOE/RW-006, Revision 1, "Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics," updated annually

During the preoperational phase, demographic data should be obtained and incorporated into the pathway analysis to identify any population group whose location or dietary, domestic, or occupational habits make it a critical group.

4.2 Measurement of Parameters in the Environment

4.2.1 Physical Parameters

Data collection to characterize fundamental parameters of the site such as geology, ecology, and seismology may not need to be repeated during the operational phase. However, time-variant parameters that are important in dose assessment should be remeasured and evaluated periodically. Data on the onsite wind speed, wind direction, and atmospheric stability should be collected to determine movement of air releases during routine or accident situations. Precipitation, temperature, and evaporation data should be measured on site to determine water

budget. Ground water direction and velocity should be reevaluated during periodic license renewal action, usually every 5 years, because changes may occur as a result of variation in precipitation rates, water use, pumping, and other factors. These changes may indirectly affect the ground water monitoring program.

4.2.2 Radiological Contaminants

The sampling and measuring of radiological contaminants in the environment constitute the major activity of an operational environmental monitoring program. The sample locations, sampling frequency, and radionuclide measurement are site specific and are determined on a case-by-case basis. In general, samples should be collected to determine background levels and areas of maximum impact in which people can be exposed and in which measurements can be useful to interpret the results of the overall monitoring program. The sampling program depends on the critical pathway determination, which is site specific, and on the compliance requirements. Radionuclides to be measured in the sampling media depend on the waste characterization, pathway consideration, and compliance requirements. Action levels should be set on sampling media to provide early warning of problems, if any (see Section 4.2.3).

4.2.2.1 Environmental Sampling Media

4.2.2.1.1 Air

Air monitoring is one of the major components in an operational monitoring program. Radioactive material can become airborne from spills, waste handling, or incinerator operation. Gases containing tritium (H-3) or carbon-14 (C-14), for example, can be generated by chemical reaction or biological activity in the waste, or by evaporation of volatile compounds. Evaporation may be the critical pathway at an arid site because sparse vegetative ground cover and lower soil moisture enhance airborne and evaporation processes.

Air monitoring should include fenceline and offsite sampling. The locations of the sampling stations should be based on meteorological data (wind directions) and critical-group locations. The measurement of airborne radioactivity such as total alpha, total beta, and a gamma spectrum or of specific radionuclides is dependent on the site-specific compliance requirement. The measurement of total alpha, total beta, and a gamma spectrum can be used as a screening technique to determine the need for specific radionuclide analysis.

4.2.2.1.2 Direct Radiation

Direct gamma radiation should be measured. Thermoluminescence dosimeters (TLDs), which are easily installed at a fixed location, are commonly used for offsite environmental monitoring. Offsite TLDs should reflect background variation because it is not expected that direct gamma radiation from an LLW disposal facility would change offsite background radiation significantly.

4.2.2.1.3 Ground Water

During the operational phase, the waste inventory will increase gradually as the disposal units are progressively filled, thus progressively increasing the potential ground water source term. Therefore, it is important that the ground water monitoring program be designed to provide an early warning to allow for timely mitigating action. Ground water sampling stations should be located up and down gradients of operating trenches or at sumps at disposal units to detect potential leachate from the trenches. The vadose (unsaturated) zone in which contaminants could migrate should be monitored to detect any migration of waste from the disposal unit before it reaches the saturated zone. Nonradiological parameters such as pH, specific conductance, nitrate, fluoride, and total organic carbon can be used as indicators to provide an early warning of potential problems. The measurement of total alpha, total beta, and a gamma spectrum can be used as radiological screening for action levels. Specific radionuclide analyses may be needed if action levels are exceeded. The applicant should establish action levels for ground water and other key sampling parameters and reporting requirements (see Section 4.2.3).

4.2.2.1.4 Surface Water

During the operational phase, surface water sampling should be conducted in areas of runoff from active operation. If there is a direct discharge into the surface stream, the outfall and the water course, upstream and downstream, should be monitored. Sample analyses should be similar to the ground water sample analyses during the operational phase.

4.2.2.1.5 Soil and Sediment

Soil and sediment samples should be taken at strategic locations, including all directions around the facility, with emphasis on the direction of prevailing winds as based on the annual wind rose patterns, the area of maximum impact (as defined earlier), the runoff areas, the outfalls, and the actual waste- handling operating areas. Analyses may include total alpha, total beta, and a gamma spectrum or radionuclide analysis if action levels are exceeded. Soil and sediment monitoring generally serves as an indicator of long-term impacts from operation.

4.2.2.1.6 Vegetation, Farm Crops, and Other Indicators

Vegetation and farm crops representing the dominant species of the area should be sampled periodically at offsite locations typifying both background and impacted areas. Analyses are similar to soil and sediment analyses

and serve as indicators for the ingestion pathway impact analysis. Other indicators such as small mammals, game birds, burrowing rodents or their fecal pellets, fish, and milk (if obtainable) should be sampled and analyzed.

4.2.3 Action Levels

The applicant should set action levels on the key environmental media to provide early warning of problems, if any, and to ensure that mitigating measures are taken in a timely manner and in compliance with 10 CFR 61.53(b). In the design of operational and postoperational monitoring programs, the following types of action levels should be considered:

(1) *Triggering Level:* This level is defined as the level of concentration of radionuclides, radioactivity, or chemical indicators above which an investigation is required. The investigation includes checking of laboratory procedures, checking for contamination, resampling, radionuclide analysis, increased frequency of sampling, and expansion of the monitoring program. The triggering level should be related to multiples of background concentrations or a fraction of applicable dose limits.

(2) *Reporting Level:* This level is defined as the level of concentration of radionuclides, radioactivity, or chemicals that exceeds or is about to exceed regulatory standards. If regulatory standards are exceeded, the applicant must report to the NRC or State authorities the monitoring results, its investigation and findings, and mitigating measures taken to correct the problem.

5 GENERAL GUIDANCE ON POSTOPERATIONAL ENVIRONMENTAL MONITORING

After closure of an LLW disposal site, it is expected that the facility buildings and land will have been properly decommissioned and that residual contamination will have been decontaminated to acceptable levels. Disposal units are capped to limit infiltration, to protect intruders, and to prevent biointrusion. The site is then placed under institutional control. The postoperational monitoring ensures that the site continues to meet closure requirements. At this time, most of the environmental sampling can be terminated except for ground water monitoring, which must be carried on to provide data to support long-term impact evaluation.

5.1 Physical Surveillance

Physical surveillance should be conducted periodically after site closure. The surveillance program should provide for physical inspection of the site and the performance of any required repairs to maintain the site integrity. This inspection includes monitoring the perimeter fence, backfilling subsidence of the trenches, and repairing damage caused by erosion.

5.2 Environmental Sampling Media

5.2.1 Ground Water

After site closure, the primary path for radionuclide release to the environment is through ground water. The ground water monitoring program for the operational phase should be continued during the initial period after site closure but can be gradually reduced if no potential problem is identified. The analysis of chemical indicators and radioactive materials should be continued.

If subsurface water is known to reach ground surface and eventually enter any streams, rivers, or lakes, these water bodies should be monitored.

5.2.2 Other Sampling Media

Vegetation, particularly deep-rooted plants, should be sampled periodically to determine any uptake of radionuclides. Burrowing animals or their fecal pellets should also be sampled and analyzed. Such plants and animals serve to indicate whether the biological barrier continues to be effective.

6 QUALITY ASSURANCE/QUALITY CONTROL

The applicant's environmental monitoring program should include a quality assurance/quality control (QA/QC) program. These programs are needed for the following reasons: (1) to identify deficiencies in the sampling and measurement processes to those responsible for these operations so that corrective action can be taken and (2) to obtain some measure of confidence in the results of the monitoring programs in order to assure the regulatory agencies and the public that the results are valid.

In general, the design of a quality assurance program should take the following factors into account.*

(1) Quality of equipment and instruments.

*International Commission on Radiological Protection (ICRP), "Principles of Monitoring for the Radiation Protection of the Population," *Annals of the ICRP International Commission on Radiological Protection*, Publication 43, Vol. 15, No. 1, 1985.

(2) Training and experience of personnel.

(3) Verification of procedures by the routine analysis of control samples and the use of standard methods for analysis.

(4) Frequency of calibration and maintenance of equipment and instruments. Variability in the measuring system will be an important aspect of this program.

(5) The traceability of the results of the monitoring programs to a national standard.

(6) The degree of documentation needed to demonstrate that the required quality was achieved and is maintained.

Quality control applies to all steps of a measurement program. These steps include sampling procedures, precautions in the transport of samples, initial physical or chemical preparation, radiochemical separation, measurement of activity, data interpretation, reporting, and record keeping.*

The applicant should refer to the following NRC documents for the design of a QA/QC program. Quality assurance should apply to all phases of the environmental monitoring program.

(1) U.S. Nuclear Regulatory Commission, Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations)—Effluent Streams and the Environment"

(2) U.S. Nuclear Regulatory Commission, NUREG-1293, "Quality Assurance Guidance for Low-Level Radioactive Waste Disposal Facility," January 1989

*International Commission on Radiological Protection (ICRP), "Principles of Monitoring for the Radiation Protection of the Population," *Annals of the ICRP International Commission on Radiological Protection*, Publication 43, Vol. 15, No. 1, 1985.