Course Title: **Radiological Control Technician**
Module Title: **Environmental Monitoring**
Module Number: **2.09**

Objectives:

2.09.01 State the goals of an environmental monitoring program.

2.09.02 State the exposure limits to the general public as they apply to environmental monitoring.

2.09.03 Define the term "critical nuclide."

2.09.04 Define the term "critical pathway."

☞ 2.09.05 State locations frequently surveyed for radiological contamination at outdoor waste sites associated with your site and the reasons for each.

2.09.06 Define the term "suspect waste site," and how they can be identified.

☞ 2.09.07 Describe the methods used for environmental monitoring at your site.

References:

1. Gollnick, Daniel, Basic Radiation Protection Technology, 2nd Edition, Pacific Radiation Corp., Altadena, CA, 1988.
2. NCRP Report #50, "Environmental Radiation Measurements," (1976).
3. DOE Order 5400.5.
4. 40 CFR 61.
5. 40 CFR 141 (Safe Drinking Water Act).
6. 40 CFR 191.
7. Environmental Radioactivity, Iral C. Nelson, Pacific Northwest Labs.

Instructional Aids:

1. Overheads
2. Overhead projector/screen
3. Chalkboard/whiteboard
4. Lessons learned

I. MODULE INTRODUCTION

A. Self Introduction

1. Name
2. Phone number
3. Background
4. Emergency procedure review

B. Motivation

Environmental monitoring plays a large role in the field of radiological control. Environmental monitoring is used to estimate human population doses, determine the impact a site has on the environment, monitor for unplanned releases as well as quantifying planned releases, and gives us data useful in determining pathway data.

C. Lesson Overview

1. Environmental monitoring goals
2. Principles of program design
3. Radiological control responsibilities
4. Analysis of environmental samples
5. Site environmental monitoring methods
6. Transport mechanisms

D. Introduce learning objectives — O.H.: objectives

II. MODULE OUTLINE

A. GOALS OF ENVIRONMENTAL MONITORING PROGRAMS — Objective 2.09.01

1. Estimate Human Population Doses

a. ALARA dictates that we must be aware of changes in radiation exposure to the general population which results from nuclear operations

b. Issuing TLDs to population is not practical. In addition the TLDs are not sensitive enough to detect changes in environmental radiation levels

c. The only practical way to determine population exposure is by measurement of environmental radiation levels:

1) External radiation level

2) Radioactivity present in air

3) Radioactivity present in food

4) Radioactivity present in water

d. Population exposure can then be determined by using these values combined with a knowledge of the drinking water sources and the types of food consumed in the region

2. Determine Site Impact (DOE Order 5484.1 and DOE/EH-0173T)

a. Environmental levels are determined prior to beginning site operations. A pre-operational survey (or characterization) is required for a minimum of 1 year, and preferably 2 years, prior to the startup of any new site or waste site

b. Environmental levels are then measured during site operation and changes are tracked to determine site impact

c. The exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent greater than 100 mrem (1 mSv). The 100 mrem effective dose equivalent in a year is the sum of the effective dose equivalent from exposures to radiation sources external to the body during the year plus the

Objective 2.09.02
The DOE primary standard of 100 mrem to members of the public in a year is lower than the previous primary limit of 500

committed effective dose equivalent from radionuclides taken into the body during the year.

mrem. The lower value was selected in recognition of the ICRP recommendation to limit the long-term average effective dose equivalent to 100 mrem per year, or less.

Experience suggests that the lower dose is readily achievable for normal operations of DOE facilities.

d. A higher dose limit, not to exceed the 500 mrem effective dose equivalent recommended by the ICRP as an occasional annual limit, may be authorized for a limited period if it is justified by unusual operating conditions.

e. For airborne emissions from all DOE sources of radionuclides, the exposure of members of the public to radioactive materials released to the atmosphere as a consequence of routine DOE activities shall not cause members of the public to receive, in a year, an effective dose equivalent greater than 10 mrem.

f. For exposure from sources from the management and storage of spent nuclear fuel, high-level, and transuranic wastes at disposal facilities, the exposure of members of the public to direct radiation or radioactive material released shall not cause members of the public to receive, in a year, a dose equivalent greater than 25 mrem to the whole body or a committed dose equivalent greater than 75 mrem to any organ.

g. For the drinking water pathway, it is the policy of DOE to provide a level of protection for persons consuming water from a public drinking water supply operated by the DOE that is equivalent to that provided to the public by the public community drinking water standards of 40 CFR 141. These systems shall not cause persons consuming the water to receive an effective dose equivalent greater than 4 mrem in a year.

3. Detect and Quantify an Unplanned Release

    a. Although adequate Radiation Safety programs are maintained at all licensed sites, there is always the possibility of an "unknown release."

    b. Environmental monitoring can serve as a secondary backup system to the primary defense of a good Radiation Safety program.

        1) Windscale reactor fire in 1957 detected by I-131 detected downwind of the site.

        2) Chernobyl detected by the Western powers through environmental monitoring programs in Europe.

4. Meet Legal or Regulatory Requirements

    a. DOE regulations dictate environmental monitoring requirements for that site.

    b. Larger facilities and plants are required to maintain continuous, extensive monitoring programs according to DOE requirements, Federal and State regulations, and regulatory guides.

    c. Monitor all inactive, existing, and new low-level waste (LLW) disposal sites to assess both radiological and nonradiological hazards (DOE Order 5820.2A).

    d. Monitor and maintain all surplus facilities prior to decontaminating or decommissioning (DOE Order 5820.2).

5. Create and Maintain a Good Public Image

    a. Operating an environmental monitoring program more extensively than required by law shows the site to be a "good neighbor."

b. Extensive environmental monitoring also provides added protection against lawsuits.

6. Obtaining Pathway Data — Objective 2.09.03

a. A critical nuclide is one of a group of nuclides which cause the largest dose contribution to the actual population at risk near the site. Typical operational reactor "critical nuclides" include: — Objective 2.09.04

1) Actinium-227

2) Barium/Lanthanum-140

3) Cesium-137

4) Cobalt-60

5) Hydrogen-3 (Tritium)

6) Iodine-131

7) Manganese-54

8) Plutonium-238

9) Plutonium-239

10) Radium-226

11) Strontium-89

12) Strontium-90

13) Thorium-230

14) Thorium-232

b. A "pathway" is any route that radioactivity can follow in passing from a licensee to a person in the general population where it becomes internally deposited or contributes external dose.

c. A critical pathway is the route taken, from the point of release to body entry, of a critical radionuclide which causes human exposure.

d. Environmental monitoring enables pathway data to be collected and analyzed. This can help verify or reject theoretical "transport mechanism" data used in determining population exposure.

7. Test Adequacy of Radiological Control Measures

   a. Small amounts of non-routine radionuclides beginning to show up in the environmental samples could indicate problems at the site

   b. Radiological Controls and operations at the site can then be reviewed prior to any releases above the prescribed limits

8. Study of Air and Water Mixing Patterns

   a. To aid in the study of transport mechanisms, small amounts of radioisotopes are sometimes released under controlled conditions to determine air and water pathways.

   b. This data is used in determining population dose estimates

9. "Non-Industry" Applications

   a. Atmospheric and oceanic circulation studies

   b. Monitoring of redistribution of radioactivity due to man's use of radioactive materials, and man's extensive modification of the earth's surface. Redistribution of naturally-occurring radionuclides in the environment can cause significant changes in the background radiation levels in an area. Changes are made by:

      1) bringing in topsoil from other areas

      2) the use of fertilizers

3) plowing the ground

4) the addition of water to the ground

    a) can serve to attenuate radiation

    b) May also introduce new radionuclides

5) the presence of structures

    a) attenuate radiation

    b) may also introduce new radionuclides

6) industrial activities

    a) can emit naturally occurring radionuclides to the air or water

7) There are many other changes that individuals make

B. PRINCIPLES OF PROGRAM DESIGN

In order to meet regulatory requirements, environmental monitoring programs must be operated at DOE facilities. One of the main reasons to operate an environmental monitoring program is to determine what increases in radioactivity in the environment is due to the operation of the site.

1. Pre-operational Program Design

Prior to operating a site, an environmental monitoring program will be run in order to:

This information helps to identify critical nuclides and critical pathways for the new site.

a. Locate Radiation Anomalies

b. Document Ambient Levels

c. Identify Critical Pathways/Nuclides

d. Document Meteorology Patterns

2. Post-operational Program Design

   Another phase of environmental monitoring is entered once the site begins operations. Measurements are now made to aid in dose assessment, for the determination of compliance with allowed releases, and for the identification of any changes in radioactivity in the environment due to the operation of the site. In order to accomplish these goals, we need:

   a. A monitoring program with enough sensitivity to detect environmental changes in radioactivity.

   b. A monitoring program with enough selectivity to be able to separate nuclides of interest from background interference.

      The post-operational program is commonly on a smaller scale than the pre-operational program. Due to the extensive monitoring done prior to start of operations, attention to the post-operational program can be focused primarily on the critical nuclides, and the instrumentation on the critical pathways.

C. RADIOLOGICAL CONTROL RESPONSIBILITIES

1. Radiological Surveys are conducted to monitor radioactive contamination

   a. General Monitoring Requirements:

      1) Ambient air in the immediate vicinity of active and inactive sites

      2) Surface water (rivers, estuaries, lakes and oceans) and sediments are monitored for constituents indicating the status of operational practices and control.

      3) Soil and vegetation are monitored to detect possible contamination from fallout and uptake.

      4) Ground water wells are surveyed to ensure their physical integrity.

5) Background dose rates are monitored near facilities that may have elevated dose rates.

6) Radiation surveys are performed to detect contamination spread.

2. Survey frequencies for particular sites are to be determined by the technical judgement of Environmental Protection and/or Radiological Control and may depend on the site history, radiological status, use and general conditions.

3. Appropriate documentation must be completed for each environmental survey.

4. Radiological Surveys: — Objective 2.09.05

   (Insert site specific information here.)

   a. Soil

   b. Water

   c. Air

5. Suspect Waste Site Investigations — Objective 2.09.06

   a. A suspect waste site is any site that is thought for any reason to contain dangerous waste, hazardous waste and/or radioactive waste. This does not include sites already identified.

6. Suspect waste site identification

   a. Any employee having any reason to believe that a site contains dangerous waste, hazardous waste, and/or radioactive waste should report this information to management.

   b. The following conditions should be looked for:

      1) Soil discoloration is present

      2) An unusual soil depression or disturbance exists

3) Pipes emerging from the ground (indicates a possible crib, tank or other structure)

4) Plant stress

5) The unusual absence of plant life

6) Vaults, chambers, concrete or steel structures, drums, pipes, or munitions protruding from the surface of a disturbed area

7) Holes, sinkholes, or collapsed structures (indicates the presence of man-made structures or voids beneath the surface)

8) The presence of hazardous and/or radioactive material in soil samples

9) Documentation or personnel interviews which indicate the past existence of a waste disposal site

D. ANALYSIS OF ENVIRONMENTAL SAMPLES

1. Environmental sample types include:

   a. Air samples

   b. Soil samples

   c. Vegetation samples

   d. Animal samples

   e. Surface water samples

   f. Groundwater samples

   g. Background radiation

   h. Radiation surveys.

2. Methods of Monitoring

a. Environmental levels of external gamma radiation are measured using film or thermoluminescent dosimeters.

   1) The lower detection level for film badges is approximately 10 mrem/month

   2) The lower detection level for TLDs is approximately 1 mrem/month. Corrections must be made, however, for fading of dosimeters, and energy dependence

b. Activity deposited on the ground (or "fallout") is isotopically analyzed and quantified to determine release point of origin and amount released. Generally, gas-flow proportional counters are used for gross alpha and beta determinations. Gamma spectrum are obtained using Germanium semiconductor systems. Alpha spectroscopy can also be used to isotopically analyze and quantify environmental samples

   1) Fallout simply means radioactive particles that settle out onto the ground. The term does not necessarily imply a nuclear detonation has occurred.

   2) "Flypaper" technique is used, which consists of an adhesive covered piece of waterproof paper, which is positioned in the environment to catch and hold particulate matter which settles out. This technique traps approximately 70% of the particles that fall on it.

   3) Rain water is also collected and analyzed for radioactivity that may have been washed from the air.

   4) Grass and other broadleaf vegetation is also a good collection media for "fallout." (Note how this may be part of a critical pathway, e.g., cows graze on contaminated pastures, and the general population drinks the now contaminated milk).

c. Atmospheric sampling is accomplished by drawing air through a filter at a known rate and then counting the filter for particulate activity.

1) Air sampling for particulates

a) Inertial separation is one method for radioactive particulate air sampling. It is especially effective in determining the size distribution of particles. This information is necessary for internal dose assessment following inhalation of particulate radionuclides. A Cascade Impactor is an example of a sampler utilizing the inertial separation method.

b) Filtration is another method for radioactive particulate air sampling. This consists simply of a pump which pulls air through a filter matrix. The filter is then removed and counted to determine airborne radioactive particulate concentrations.

(1) Dust loading is a factor in collection efficiency. As the filter becomes plugged up with dust, air flow generally decreases, but the collection efficiency usually increases.

(2) The rate at which air (particles) is drawn through the filter also is a factor in collection efficiency.

(a) At low rates of air flow, efficiency is relatively high due to diffusion of particles in the filter media. In other words, the air particles "drift" through the filter media, and become trapped in the dead air spaces in the filter.

(b) At high rates of air flow, efficiency is also relatively high due to the phenomena of impaction. This is an increased collection of particles due to the higher speed of the particles causing them to "crash" into the filter media, and bury themselves in the fibers of the filter. It is necessary to realize, however, that for gross beta and especially gross alpha counting, this method will introduce more self-shielding in the counting process.

2) Air sampling for gases

a) Continuous flow sampling for radioactive gases is a common method of air concentration determination. Air is pumped or exhausted through a chamber housing a detector. The detector, coupled with an air flow-rate meter, can give real-time determination of airborne radioactivity concentration. An example of a system utilizing this method is a Stack Monitor.

b) Grab sampling is another method of measuring air activity concentration. This method uses an evacuated chamber which is opened in the environment to be sampled, then re-sealed. The inside surfaces of the chamber are coated with a scintillation phosphor, such that when different types of radiation interact with the phosphor, small flashes of light are produced. When the chamber is placed in a light-tight housing with a photomultiplier tube, these flashes of light are measured and are indicative of the activity concentration in the grab cell. Another type of grab sampler is an evacuated tube or chamber with a thin-walled G-M tube mounted along it's central axis. For analysis, then, the G-M is connected to a scaler, and a gross count is made.

c) Adsorption is the assimilation of gas, vapor or dissolved matter by the surface of a solid or liquid (the adsorbent). Gaseous air activity concentration is measured by drawing the air to be measured through the adsorbent, and then counting the adsorbent. Common adsorbents are activated charcoal, silver zeolite (AgZ), and silica gel.

d) Condensation is used in monitoring for airborne tritium activity. Water vapor in the air which may contain tritium components are condensed by using a super-cooled strip of metal in the ambient air. Water vapor will condense and freeze on this strip. The ice is then melted, and a liquid scintillation counter is then used to count for tritium.

d. Aquatic samples may include sediments, bottom organisms, vegetation, fin fish, or shell fish. Water needs to be analyzed only if it is used for consumption or irrigation. In most cases, samples of shell fish and fin fish are saved to document the principal route of human exposure. If waste is being discharged into a flowing stream of potable water, a continuous sampler should be used.

e. Food sampling is not necessary if proper regulations are followed that restrict the discharge of liquid and solid radioactive effluents (other than that which is desirable for good relationships with the public). The type of sampling will be determined by the isotope released.

1) Radionuclides such as Co-60 and Zn-65 concentrate in shellfish. Sampling should be done if these radioactive fission products are discharged into an estuary populated with shellfish.

2) If I-131 is released, cow pastures should be sampled as well as the milk produced. I-131 will appear in milk within 24 hours.

E. SITE ENVIRONMENTAL MONITORING METHODS — Objective 2.09.07

(Insert site specific information here.)

F. TRANSPORT MECHANISMS

1. Atmospheric Transport

   a. Airborne radioactive contaminants are carried downwind and dispersed by normal atmospheric mixing processes.

   b. Internal irradiation occurs if the radionuclides are inhaled and incorporated in the body.

   c. External irradiation occurs by beta and gamma irradiation from the plume.

   d. Material is removed from the plume by impaction of the plume with the ground surface or by washout due to rain.

   e. Deposition of the material from the plume leads to further exposure pathways through:

      1) Direct external exposure from contaminated surfaces

      2) Inhalation of re-suspended material

      3) Ingestion of contaminated foodstuffs

   f. Factors considered in determining the deposition of radioactive material back to earth include:

      1) Wind speed

      2) Temperature

      3) Stack height

      4) Particle size

      5) Weather conditions

g. A reverse in the normal upward movement of hot air can slow down the dilution of radioactive release. The condition where hot air develops over cooler air is called a temperature inversion. A temperature inversion can occur when:

1) A warm front covers a cooler earth

2) A cool front is injected under warm air (sea breeze)

3) The normal cycle of a summer day when the earth cools off faster than the air above

2. Surface Water Transport

a. Liquid effluents may be discharged into various types of surface water bodies:

1) Rivers

2) Estuaries

3) Lakes

4) Oceans

b. In rivers, the rate of transport is slower than in the atmosphere

c. Radionuclides may be absorbed by bottom sediments, and may accumulate in the aquatic biota

d. Although these two processes involve only a small fraction of the inventory, they may be significant with respect to radiation exposure

e. Radioactive materials released in rivers eventually feed into the ocean

1) In the ocean surface layer (75 m in depth and located above the thermocline) the mixing time is 3-5 years.

2) Below the thermocline in the deep ocean, the mixing is much slower.

f. Some aquatic mixing factors include

1) Depth of water

2) Type of bottom

3) Shoreline configuration

4) Tidal factors

5) Wind

6) Temperature

7) Salinity

8) Solubility of radioactive material

9) Depth at which pollutant is introduced

3. Movement in the Ground

a. Radionuclide movement in the ground is generally the slowest.

b. Movement of most radionuclides depends upon convective transport in water.

c. In humid regions the rate of ground water movement near the surface is on the order of 1 ft/day. In arid areas, the rate is much slower.

d. There is an abundance of solid material for absorption of radionuclides and interaction with this geologic media can reduce the rate of radionuclide movement to a small fraction of underground water movement.

III. SUMMARY

A. Review major topics

1. Environmental monitoring goals
2. Principles of program design
3. Radiological control responsibilities
4. Analysis of environmental samples
5. Site environmental monitoring methods
6. Transport mechanisms

B. Review learning objectives

IV. EVALUATION

Evaluation should consist of a written examination comprised of multiple choice, fill-in the blank, matching and/or short answer questions. 80% should be the minimum passing criteria for examinations.

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