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RCT: Module 2.06, Air Sampling Program and Methods

Course 8772

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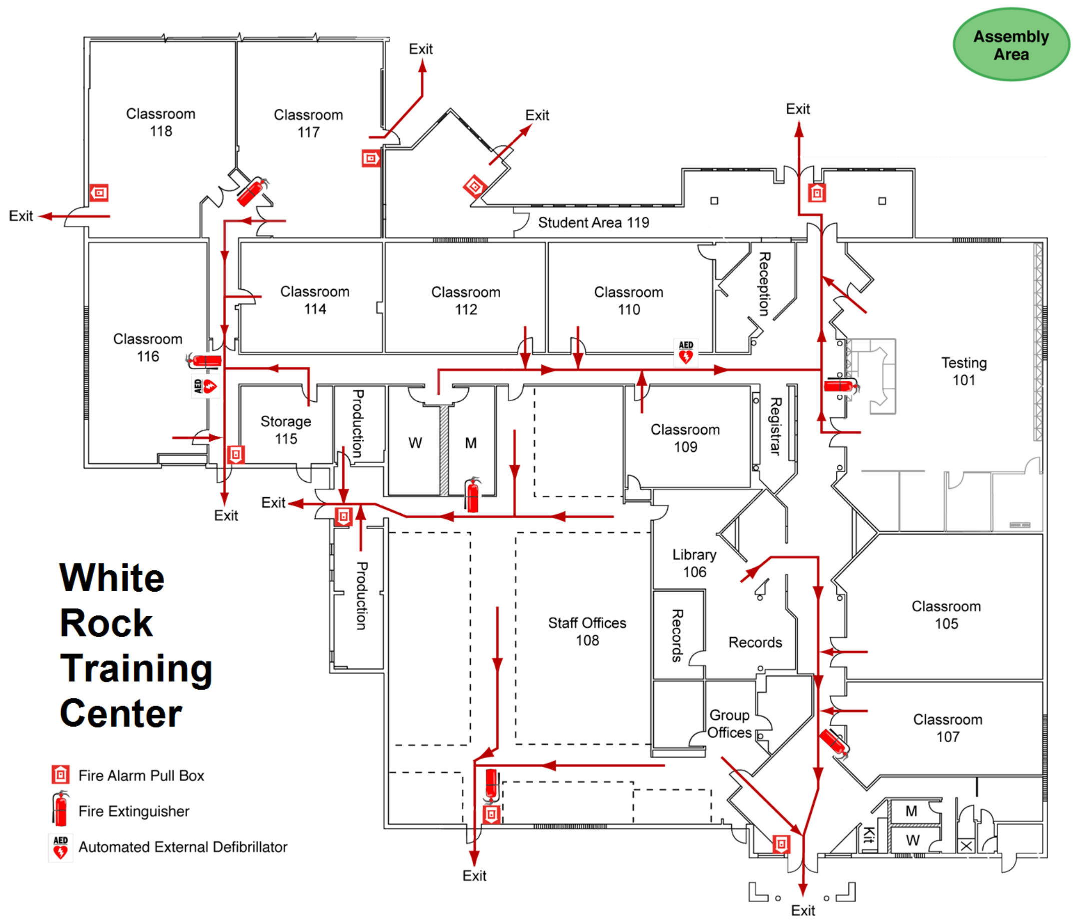

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Introduction

Course Overview

The inhalation of radioactive particles is the largest cause of an internal radiation dose. Airborne radioactivity measurements are necessary to ensure that the control measures are and continue to be effective. Regulations govern the allowable effective dose equivalent to an individual. The effective dose equivalent is determined by combining the external and internal dose equivalent values. Typically, airborne radioactivity levels are maintained well below allowable levels to keep the total effective dose equivalent small.

This course will prepare the student with the skills necessary for RCT qualification by passing quizzes, tests, and the RCT Comprehensive Phase 1, Unit 2 Examination (TEST 27566) and will provide in-the-field skills.

Course Objectives

2.06.01 State the primary objectives of an air monitoring program.

2.06.02 Describe the three physical states of airborne radioactive contaminants em.

2.06.03 List and describe the primary considerations to ensure a representative air sample is obtained.

2.06.04 Define the term “isokinetic sampling” as associated with airborne radioactivity sampling.

2.06.05 Identify the six general methods for obtaining samples or measurements of airborne radioactivity concentrations and describe the principle of operation for each method.

a. Filtration
b. Volumetric
c. Impaction/impingement
d. Adsorption
e. Condensation/dehumidification
f. In-line/flow-through detection

2.06.06 Describe the general considerations for selection of an air monitoring method.

2.06.07 State the purpose of the five primary types of airborne radioactivity samplers/monitors.

a. Personal air samplers (breathing zone)
b. High volume/flow rate air samplers
c. Low volume/flow rate air samplers
d. Portable continuous air monitors
e. Installed continuous air monitoring systems

2.06.08 List the factors that affect the accuracy of airborne radioactivity measurements and describe how these factors affect sample accuracy.

2.06.09 Describe the site air monitoring program that includes monitoring frequencies, calculational methods, applicable derived air concentration limits, and methods for determining radon interference.

Target Audience

This course is designed for Los Alamos National Laboratory (LANL) new-hire radiological control technician (RCT) employees with no operational experience.

Acronyms

ALI	annual limit on intake
CAM	continuous air monitor
CED	committed effective dose
DAC	derived air concentration
HI	hazard index
HPFC	health physics field coordinator
HTO	tritiated water
ICRP	International Commission on Radiological Protection
LANL	Los Alamos National Laboratory
PAS	personal air sampler
RCT	radiological control technician
RMI	routine monitoring instruction
RP	radiation protection

Introductory Knowledge

To understand the "allowable effective dose equivalent values," you must have a basic understanding of the annual limit on intake (ALI) and derived air concentration (DAC).

- Annual Limit on Intake (ALI)—The quantity of a single radionuclide that, if inhaled or ingested in 1 year, would irradiate a person, represented by a reference man (ICRP Publication 23), to the limiting value for control of occupational exposure—a committed effective dose (CED) of 5 rem.

- Derived Air Concentration (DAC)—The concentration of a radionuclide in air that, if breathed over a period of a work year (2000 h), would result in the ALI for that radionuclide being reached and a CED of 5 rem. The DAC is obtained by dividing the ALI by the volume of air (2400 m^3) breathed by an average worker during a working year.

Example 2.06-1:

In its report #30, the International Commission on Radiological Protection (ICRP) set a DAC for tritium gas (T_2) of 540 mCi/m^3 and a DAC for tritiated water (HTO) of 20 µCi/m^3. Notice that the DAC for tritium gas is 27,000 times higher than the DAC for HTO.

	DAC
HTO	20 µCi/m^3
T_2	540,000 µCi/m^3

Exercise: Calculate the dose a worker would receive if he/she were exposed to 300 mCi/m^3 of tritium gas for 30 minutes.

Exercise: Calculate the dose a worker would receive if he/she were exposed to 300 mCi/m^3 of HTO for 30 minutes.

Notes. . . .

Air Monitoring Program

2.06.01 State the primary objectives of an air monitoring program.

The primary objectives of an air monitoring program are to

- measure the concentration of the radioactive contaminant(s) in the air by collection and analysis;
- identify the type and physical characteristics of the radioactive contaminant;
- help evaluate the hazard potential to the worker;
- evaluate the performance of airborne radioactivity control measures; and
- assess air concentration data to determine if bioassay sampling should be initiated to verify whether an exposure has occurred and, if so, to determine the magnitude of the exposure.

The primary goal of the air monitoring program is to determine if the level of protection provided to the worker is sufficient to minimize the internal dose equivalent. Allowable concentration values are used as an index of the degree of control needed and achieved. Documented measurements of the airborne radioactivity concentrations are required to demonstrate that satisfactory control is achieved and maintained.

Air sampling is required where an individual is likely to receive an exposure of 40 or more DAC-hours in a year. Other situations requiring sampling occur when

- establishing the need for posting of airborne radioactivity areas and determining the need for respiratory protection of workers,
- assessing unknown hazards during maintenance on systems contaminated with radioactive material or when there is a loss of process controls,
- assisting in determining the type and frequency of bioassay measurements needed for a worker,
- providing an estimate of worker exposures for situations where bioassay measurements may not be available or their validity is questionable,

- developing baseline airborne radioactivity levels and verifying containment integrity during the startup of a new facility or new operation within an existing facility,
- wearing required respiratory protection devices for protection against airborne radionuclides, and
- performing real-time air monitoring as necessary to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate the inhalation of airborne radioactive material.

Physical States of Airborne Radioactive Contaminants

2.06.02 State the basic goal of a contamination control program and list actions that contribute to its success.

Airborne radioactive contaminants are generally divided into three categories, based on their physical state:

- particulates,
- gases, and
- vapors.

The physical properties of airborne radioactive particles can affect inhalation deposition, their dynamical properties in air, and particle solubility in the lungs.

Particulates

Particulate contaminants are solid and liquid particles, ranging upward from molecular sizes (approximately 10 to 3 cm), suspended in the air. Solids are fumes, dusts, and smokes and are distinguished mainly by their mode of generation. Liquids are mists or fogs, depending on the dispersion of the liquid particulates.

The term "aerosols" is used collectively to refer to relatively stable suspensions of either solid or liquid particles in a gaseous medium. The retention of inhaled radioactive particles after deposition in the pulmonary region of the lung is strongly influenced by the dissolution characteristics of the particles. Dissolution in the lungs allows clearance into the blood and the rest of the systemic circulation. Therefore, the various chemical forms of radioactive particles are classified with respect to their potential solubility in the lungs:

- Class Y for the very insoluble particle that takes years to clear from the lungs,
- Class W for the somewhat more soluble particles that take weeks to dissolve and clear into the systemic circulation, and
- Class D for the relatively soluble particles that dissolve in a matter of days in the lung.

Gases

Gases are substances that, under normal conditions of temperature and pressure, are distinguished from a solid or liquid by a low density and viscosity. Gases have no defined shape and can expand or contract with changes in temperature and pressure. The retention of gases in the body from inhalation is poor, so radioactive gases are usually treated as an external source of exposure. Radioactive gases typically found are fission product gases, such as xenon and krypton, and naturally occurring radon. Although these gases contribute primarily to external exposure, the particulate daughters to which they decay can contribute to internal exposure.

Vapors

Vapors are considered the gaseous phase of a substance that is normally a solid or liquid under normal conditions of temperature and pressure. The contaminant may be dispersed in vapor form at abnormal conditions of temperature and pressure. As the temperature and pressure conditions return to "normal," the contaminant will return to its normal solid or liquid form or become a particulate. Sampling methods for vapors should isolate or measure the contaminant, regardless of whether the vapor or particulate form is present.

Representative Air Samples

2.06.03 List and describe the primary considerations to ensure a representative air sample is obtained.

To ensure that the air sample is representative of the actual conditions, the airborne radioactivity concentration entering the

- sample line must be representative of the airborne radioactivity concentration in the air near the sampling device and
- sampling inlet must be representative of the airborne radioactivity concentration at the point of concern or the air that is breathed (i.e., the breathing zone).

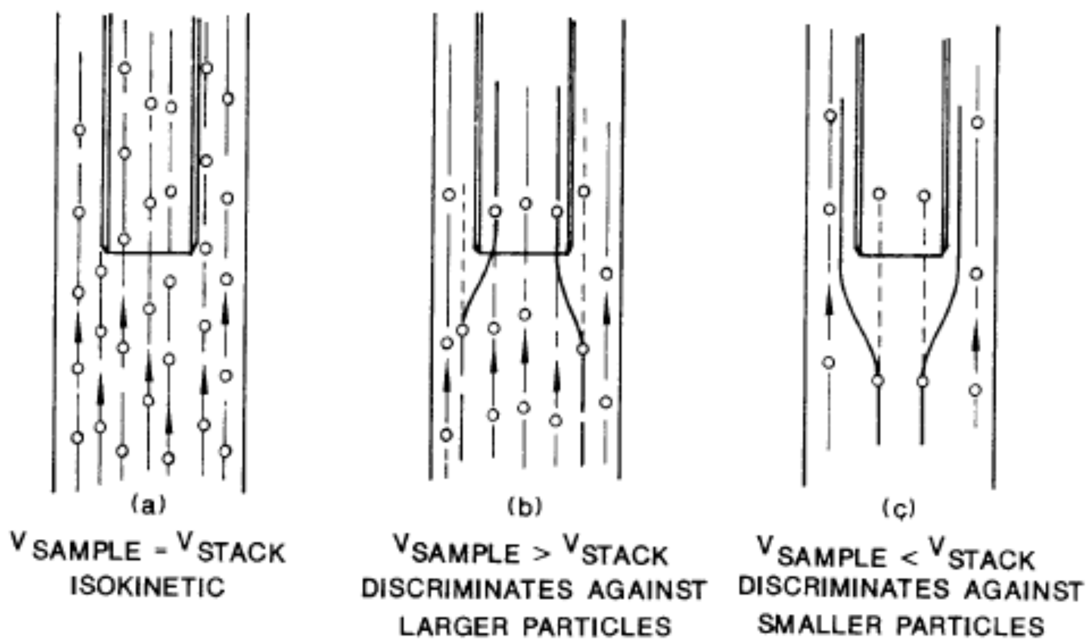
Notes. . . .

Isokinetic Sampling

2.06.04 Define the term "isokinetic sampling" as associated with airborne radioactivity sampling.

Isokinetic sampling occurs under the condition that the sample line velocity is equal to the system velocity at the sample point. Air flow into sampling lines must be balanced with respect to the flow of air around the probe or sample inlet. Each air flow must be the same velocity.

To ensure that the sample is representative, the flow rate in the sample line or inlet must be the same as the flow rate in the system, such as the duct or stack. If the velocities are not the same, then discrimination can occur for smaller or larger particles. When the sample line velocity is equal to the system velocity at the sample point, it is called isokinetic sampling.



Basic Sampling Methods

The three basic sampling methods are as follows:

- A volumetric sample is one in which part of the atmosphere is isolated in a suitable container, providing the original concentration of the contaminant at a particular place and time.
- An integrated sample is one in which the contaminant is concentrated on some collecting medium, providing an average concentration over the collection time.
- A continuous sample is one in which the sample air flow is directed past or through a detection device providing a measurement of the activity per unit volume of air.

Breathing zone air monitoring should be performed continuously in areas where workers are likely to exceed a 40-DAC-h exposure in 1 year. This air monitoring is used to identify possible worker internal exposures and the need for follow-up bioassay measurements.

Source-specific air sampling is performed near an actual, or likely, release point in a work area. This air sampling is typically used for verifying containment or confinement integrity, documenting airborne radioactivity levels, and providing guidance on personnel protective measures.

Grab air sampling is used for temporary or nonroutine situations and as a backup for other types of air sampling in the event of equipment failure.

Air Sampling Methods

2.06.05 State the purpose of using protective clothing in contamination areas.

The six general methods for obtaining samples or measurements of airborne radioactivity concentrations are

- filtration,
- volumetric,
- impaction/impingement,
- adsorption,
- condensation/dehumidification, and
- inline/flow-through detection.

Filtration

Filter samplers use filtration of the air to concentrate the airborne radioactive particulate (aerosol) contaminants. The filter sampling technique uses an air mover, such as a vacuum pump, to draw air through a removable filter medium at a known flow rate for a known length of time. If the flow rate and sample time are known, the total volume collected can be calculated.

After the filter medium is analyzed to determine the amount of radioactive material collected on the filter when the sample is taken, the airborne concentration can also be calculated. The filtration medium selected for a sample depends on several factors:

- the collection efficiency required,
- the flow resistance of the medium,
- the mechanical strength of the filter,
- the pore size,
- the area of the filter,
- the background radioactive material of the filter,

- the cost,
- the self-absorption within the filter, and
- the chemical solubility.

The most common types of filters are

- cellulose-asbestos filters;
- glass fiber filters; and
- membrane filters, which are manufactured with various pore sizes and can be dissolved in organic solvents and analyzed in a counter (e.g., a liquid scintillation counter).

Filter samples are evaluated by direct radiation counting or by radiochemical assay. Filters may be mounted into different types of holders, including those with open faces for direct sampling and those with inline enclosure for sampling through a sampling hose, with sample air flow drawn through a flow meter with a suitable air pump.

Volumetric

Volumetric samplers use a sample container into which the sample is drawn and isolated for analysis.

Several methods are used to draw the sample into the container.

- The container may be evacuated by a vacuum pump and isolated away from the sample location. The container is opened at the sample location to draw the air into the container. The sample is sealed in the container and removed for analysis.
- An air mover may be used at the sample location to draw a representative atmospheric sample into the container.

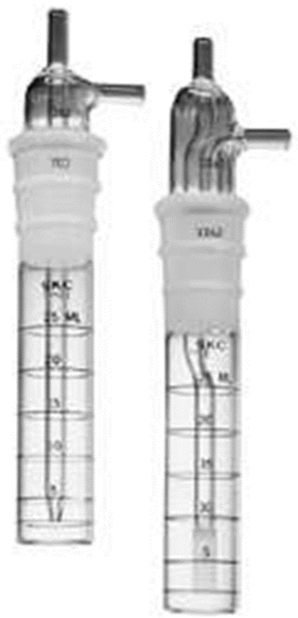
Impaction/Impingement

Impingers or impactors concentrate particulate contaminants on a prepared surface by abruptly changing the direction of the sample air flow at some point in the sampler. Particles are collected on a selected surface as the airstream is sharply deflected. Because of their inertia, the particles are unable to follow abrupt changes in airstream direction. The surface on which the particles are collected must be able to trap the particles and retain them after impact.

Several methods are commonly used to trap the particles, such as

- coating the collection surface with a thin layer of grease or adhesive; and
- immersing the collection surface in a fluid, such as water or alcohol. The liquid is then analyzed after the sample is collected.

Impingers and impactors may use several stages or impingement distances to discriminate for or against different particle sizes. Impactors are frequently used to isolate particles larger than the undesired smaller particles, such as transuranics over radon daughters or radon daughters over fission products.



Adsorption

Adsorber sampling devices concentrate the contaminants by causing them to adhere to the surface of the adsorption medium. This technique uses an air mover to draw and collect the sample through the adsorption media. Adsorbers are commonly used to collect organic vapors and nonreactive gases and vapors.

- Activated charcoal is used primarily for radioiodine sampling, but it also traps noble gases, such as xenon, krypton, and argon.
- Silica gel is primarily used for tritium oxide vapor sampling.
- Silver zeolite is used for radioiodine sampling when trapped noble gases would interfere with the radioiodine analysis.

Condensation/Dehumidification

Condensation or dehumidifier sampling devices use a "cold trap" to condense water vapors in the sampled atmosphere and provide a liquid sample for further analysis. Liquid nitrogen or a refrigeration unit is often used to cool the condensation surface and cause condensation of the water vapor as it passes over the cold surface.

Calculations must include the relative humidity and temperature of the air at the time the sample is taken to determine the concentration of water vapor per unit volume of air. This technique is normally applied only for sampling tritium oxide vapor (HTO or T_2O).

Inline/Flow-Through Detection

Inline or flow-through samplers use an air mover to direct the sample air flow through or past the detection device. These samplers are used for radionuclides that are difficult to collect or detect by other means. Inline detectors are used to measure gaseous activity after filtration and adsorption have been accomplished. Flow-through detectors are used for radionuclides, such as tritium, that emit low-energy radiation that could not otherwise pass through the detector window.

Multipurpose Samplers and Monitors

Various sampling methods may be combined into one sampler or monitor. Some samplers use the filtration method for particulates, the adsorption method for vapors, and the volumetric grab-sample method for gases (in that order).

Some advantages of combining these methods are that

- one vacuum pump supplies the air flow for all the samples and
- all samples are drawn at the same time to minimize the amount of time spent by the technician drawing samples.

Some monitors have detectors installed to monitor each sample and provide an immediate readout, as well as other capabilities, such as alarms, data records, process controls, and trending.

Notes. . . .

Considerations for Selecting an Air Monitoring Method

2.06.06 Describe the general considerations for selection of an air monitoring method.

The environmental conditions in the area where the sample is to be obtained include humidity, high temperature, explosiveness, and dust. The physical characteristics of the area in which the sample is to be obtained include electricity availability and close spaces, which can influence selection.

The energy and type of radiation of the radionuclide being monitored are

- the expected concentration level,
- the physical state of the airborne contaminant,
- the type of survey required, and
- procedural requirements.

Notes. . . .

Primary Types of Air Samplers/Monitors

2.06.07 State the purpose of the five primary types of airborne radioactivity samplers/monitors
a. Personal air samplers (breathing zone)
b. High volume/flow rate air samplers
c. Low volume/flow rate air samplers
d. Portable continuous air monitors
e. Installed continuous air monitoring systems

The five primary types of airborne radioactivity samplers/monitors are

- personal air samplers (breathing zone),
- high-volume/flow rate air samplers,
- low-volume/flow rate air samplers,
- portable continuous air monitors (CAMs), and
- installed continuous air monitoring systems.

Personal Air Samplers (PASs)

PASs provide an estimate of the airborne radioactivity concentration in the air that the worker is breathing during the sampling period. These devices contain a small battery-powered pump that is calibrated to a flow rate of approximately 2 liters per minute, which is the breathing rate of a worker performing light activity.

The sampling line terminates in a filter cassette, which contains the filtration medium for the radioactive particulate contaminants. The sample filter cassette is attached close to the nose and mouth of the individual.

High-Volume/Flow Rate Air Samplers

High-volume/flow rate samplers provide an estimate of the airborne radioactivity concentration at a particular location in a short period of time. These samplers do not have installed detectors, and the sample must be removed from the sampler and analyzed on separate analysis equipment.

Samplers may be used to

- provide a routine estimate of the general area airborne radioactivity,
- verify boundaries of areas posted for airborne radioactivity, and
- monitor the airborne radioactivity related to a specific work activity.

High-volume samplers typically use flow rates of at least 10 cfm.

Low-Volume/Flow Rate Air Samplers

Low-volume/flow rate samplers provide an estimate of airborne radioactivity concentrations averaged over a longer period of time at a particular location than do high-volume/flow rate samplers. Low-volume samplers generally have flow rates set at approximately 20 lpm, which is the breathing rate of a worker performing light activity.

Although these samplers must run longer for reasonable sensitivity, they are generally quiet and can be used for continuous duty. Low-volume/flow rate samplers may be used to provide average airborne radioactivity estimates over a period of time for

- commonly traversed areas that normally have a low probability of airborne radioactivity problems,
- areas not commonly traversed that have a higher probability of airborne radioactivity problems,
- backup samples in areas where airborne radioactivity problems are discovered by other means, and
- work maintenance activities normally characterized by low airborne radioactivity concentrations.

Portable Continuous Air Monitors (CAMs)

Portable CAMs provide an estimate of airborne radioactivity concentrations averaged over time at a particular location and provide immediate readout and alarm capabilities for preset concentrations.

These air monitors are portable low-flow-rate (20 lpm) sampling systems containing the necessary sampling devices and built-in detection systems to monitor the activity on the filters, cartridges, planchettes, and/or chambers in the system.

The system may provide a visual readout device for each type of sample medium, a recording system for data, and computer functions, such as data trending, preset audible and visual alarms/warning levels, and alerts for system malfunctions.

Typical CAMs provide information on alpha and/or beta/gamma particulates, radioiodine activity, and noble gas activity.

Portable CAMs can be used as

- low-volume general area samplers,
- monitors with alarm capabilities for areas where airborne radioactivity conditions may quickly degrade,
- trending devices in selected areas, and
- devices to locate system leaks (if used with the appropriate-length hose or tubing).

Installed CAM Systems

Installed CAM systems provide an estimate of airborne radioactivity concentrations averaged over time at a fixed, designated location and provide immediate local and remote readout and alarm capabilities for preset concentrations.

These air monitors are fixed low-flow-rate sampling systems and contain the necessary sampling devices and built-in detection systems to monitor the activity of selected areas or airstreams. The system may provide a local and remote visual readout device, a recording system for data, and computer functions, such as data trending, preset audible and visual alarms/warning levels, and alerts for system malfunctions.

Installed CAM applications include

- fixed installations capable of sampling several locations through valved sample lines,
- stack monitors, and
- duct monitors.

Accuracy of Airborne Radioactivity Measurements

2.06.08 List the factors that affect the accuracy of airborne radioactivity measurements and describe how these factors affect sample accuracy.

Factors affecting the accuracy of airborne radioactivity measurements include the following.

- The sample is not representative of the atmosphere being sampled.
- The sample is not representative of the air being breathed by the worker.
- The sampling media may be incorrect or improperly installed for the selected sampler, causing leaks or improper flow rates.
- The sampling device may be malfunctioning, incorrectly operated, or improperly calibrated, causing errors in flow rate measurements.
- A lack of accuracy and operation in the timing device may cause errors in the time value.
- The flow rate measuring device’s lack accuracy and operation may cause errors in the flow rate value.
- Mishandling of the sample media may cause cross-contamination or removal of sample material.
- Sample loading, humidity, and other factors may cause changes in the collection efficiency of the medium.
- Analysis equipment may be improperly used or selected.
- Inherent errors in the counting process could be caused by sample geometry, self-absorption, resolving time, backscatter, and statistical variations.
- Mathematical errors may occur during calculations due to the rounding of numbers and simple mistakes.
- Samples may be incorrectly marked, and data recording may be inaccurate.

Notes. . . .

LANL Air Monitoring Program

2.06.09 Describe the site air monitoring program that includes monitoring frequencies, calculational methods, applicable derived air concentration limits, and methods for determining radon interference.

Basic Air Sample Calculation

The analysis of the sample provides the activity of the sample at the time of the sample analysis. This value may be corrected for decay for the time period between when the sample was taken to when it was analyzed.

The volume of the sample must be determined from the sample data recorded, such as flow rates at the beginning and end of the sample, and the sample time period. The basic calculation listed would also include the conversions necessary for the desired units, such dpm/liter to µCi/cm^3.

$$CONCENTRATION = \frac{decay\ corrected\ activity}{sample\ flow\ rate \times sample\ time\ period}$$

The calculation would also include correction factors, as necessary, for

- interference of other radionuclides, such as radon and thoron daughters;
- collection efficiency;
- counter efficiency;
- self-absorption by the sample media;
- counter background; and
- temperature and pressure as applied to flow rate.

Many errors are inherent or induced in the sampling analysis process and affect the accuracy of the resulting data. The operator of the sampling and analysis equipment must be aware of these points of error to ensure that the resulting data are as accurate as possible. Quality assurance that is applied to all phases of the air monitoring program will minimize many errors.

Derived Air Concentration (DAC)

The DAC is defined as the concentration of a radionuclide in air that, if breathed over a period of a work year (2000 h), would result in a CED of 5 rem. Radionuclides must be known to determine the appropriate DAC value from the airborne concentration. For unknown radionuclides, use the most restrictive DAC (lowest value) for any isotopes that may be present.

Perform air monitoring to characterize workplace airborne radioactivity concentrations. For a known mixture of radionuclides, determine the combined DAC for all radionuclides.

Sampling of DACS Used at LANL

Radionuclide	Absorption type μCi/mL			Absorption type Bq/m³		
	F	M	S	F	M	S
H-3 (Water)	2 E−05	2 E−05	2 E−05	7 E + 05	7 E + 05	7 E + 05
H-3 (Elemental)	2 E−01	2 E−01	2 E−01	9 E + 09	9 E + 09	9 E + 09
Co-60	-	7 E−08	3 E−08	-	2 E + 03	1 E + 03
Sr-90	1 E−08	-	7 E−09	4 E + 02	-	2 E + 02
Y-90	-	3 E−07	3 E−07	-	1 E + 04	1 E + 04
Cs-137	8 E−08	-	-	3 E + 03	-	-
Th-232	-	3 E−12	4 E−11	-	1 E−01	1 E + 00
U-234	5 E−10	2 E−10	7 E−11	1 E + 01	9 E + 00	2 E + 00
U-235	5 E−10	3 E−10	8 E−11	1 E + 01	1 E + 01	3 E + 00
U-238	5 E−10	3 E−10	8 E−11	2 E + 01	1 E + 01	3 E + 00
U-239	1 E−05	9 E−06	9 E−06	5 E + 05	3 E + 05	3 E + 05
Pu-238	-	6 E−12	5 E−11	-	2 E−01	1 E + 00
Pu-239	-	5 E−12	6 E−11	-	2 E−01	2 E + 00
Pu-240	-	5 E−12	6 E−11	-	2 E−01	2 E + 00
Pu-241	-	2 E−10	2 E−09	-	1 E + 01	1 E + 02
Pu-242	-	5 E−12	6 E−11	-	2 E−01	2 E + 00
Am-241	-	5 E−12	-	-	1 E−01	-

Procedures

Procedure RP-1-DP-018, *Air Monitoring*, provides methods and techniques for performing air monitoring to identify and control airborne radioactivity.

Procedure RP-SOP-031, *Planning Routine Radiological Monitoring*, governs the planning and development of routine monitoring instructions (RMIs) and provides the justification and monitoring frequencies for surveys for LANL facilities.

RP procedure RP-SOP-014, *Responding to CAM Alarms*, states the necessary actions that RCTs must take when responding to a workplace CAM alarm.

Radiation Protection (RP) Staff Responsibilities

Staff Health Physicists and Radiological Engineers

- perform air monitoring determination calculations and verify the correct placement of air monitoring equipment.

Health Physics Field Coordinators (HPFCs)

- provide assistance and guidance to RCTs in supporting air-monitoring equipment.

Radiological Control Technicians (RCTs)

- perform filter changes on CAMs and other air monitoring installations and
- verify air-monitor flow rates and adjust where needed.

Determining the Need for Air Monitoring

Air sampling and monitoring commensurate with the hazards of the activities planned for the area must be performed to ensure that airborne radioactivity is characterized. Air sampling and monitoring equipment (e.g., portable and fixed air samplers, CAMs, or lapel samplers) must be selected according to the specific job being monitored.

Air-sampling equipment must be used where an individual is likely to receive an exposure of 40 or more DAC-hours in a year.

Note: A 40 DAC-h exposure would result in a CED to an individual of approximately 0.1 rem.

Real-time air monitoring must be performed as necessary to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate inhalation of airborne radioactive material. These real-time air monitors must have alarm capability and enough sensitivity to alert potentially exposed individuals that immediate action is required to minimize or terminate inhalation exposures.

From RP-1-DP-018, *Air Monitoring*

Table 4. Available Air Monitoring Equipment

Type	Available Instruments
Alpha Continuous Air Monitors	Alpha 7, Alpha 6, ASM 1000/AS1700, TA-55CAM and others
Beta Continuous Air Monitors	AMS-3, AMS-3A, AMS-4
Tritium Continuous Air Monitors	Femto-Tech U24/U24-D, Overhoff T301
Fixed-Head Air Sampler (FAS)	Multiple available
Giraffe or Other Portable Air Sampler	HI-Q MRV series
High Volume Air Sampler	Multiple available
Lapel Air Sampler	Multiple available

Guidance from NUREG-1400, *Air Sampling in the Workplace*, included in RP-1-DP-018, is used to determine the need for retrospective and real-time air monitoring.

The hazard index (HI) is the potential intake expressed as a percent of the amount of material that, if inhaled, could result in a CED of 5 rem (for stochastically limited nuclides) or 50 rem (for deterministically limited nuclides).

Hazard Index

$$HI = \frac{Q \times 1 \times 10^{-6} \times R \times C \times D \times 100}{DAC \times 2400},$$

where

Q = the amount of radioactive material (in curies),

R = the release fraction of the material,

DAC = the derived air concentration value in units of μCi/ml,

C = the confinement factor, and

D = the dispersibility and other modifying factors.

Table 9. Recommended Air Sampling

HI	Air Monitoring Needed
< 2	Very low level of hazard from airborne radioactivity. Air sampling is generally not necessary; however, monthly or quarterly grab samples may be appropriate in some situations to confirm that airborne levels are indeed low.
2 to 10	Fairly low level of hazard from airborne radioactivity. A HI of 2 corresponds to 40 DAC-h which is the level at which air sampling is required.
> 10	Potential for moderate hazard from airborne radioactivity. In addition to general air sampling, evaluate the need to determine intakes by either breathing zone air sampling or bioassay measurements. Note that facility-specific dosimetry enrollment criteria in DES and RP-SVS technical basis documents specifying bioassay enrollment must be followed.
> 100	Potential for relatively high level of hazard from airborne radioactivity. In addition to general or breathing-zone air sampling, early warning air monitoring is required For example, continuous air monitoring using CAMs.

From RP-1-DP-018, *Air Monitoring.*

Determining Placement of Air Monitors

After determining which areas require air monitoring, determine the placement of air monitors.

Consider the following when selecting the location and number of air monitors:

- the size of the area or facility,
- the type of operations conducted at the facility,
- the contamination levels and potential for contamination,
- the traffic and airflow patterns,
- the specific facility features (such as the location of ventilation intake and exhaust registers),
- the locations having high source-term potential, and
- any available historical air monitoring results.

Consider breathing zones when placing air monitors:

- Position air monitors to measure air concentrations to which people are exposed.
- Place the air sample inlet approximately 6 feet above the floor and either between any workers and the potential point of release or so that the air sample is representative of the air breathed by the workers.

- Initiate a program of personal breathing-zone air monitoring if proper placement of air monitors is not achieved.

Document the placement of air samplers and air monitors.

Air Monitoring Frequency

Procedure RP-SOP-031, *Planning Routine Radiological Monitoring* governs the planning and development of routine monitoring instructions (RMIs) and provides the justification for surveys and frequency for LANL facilities.

Per RP-SOP-031, air filters are *typically* changed weekly and counted after allowing for the decay of radon and thoron daughters.

RP-SOP-014, Responding to CAM Alarms

RCTs should be aware that a prompt and appropriate response to CAM alarms is necessary to minimize exposure of personnel to airborne radioactive material and internal intake of airborne radioactive material by personnel.

A CAM alarm must be treated as a true CAM alarm until proven otherwise. The immediate response to a CAM alarm should always be to leave the area. (This does not apply if a CAM alarms while it is undergoing testing by health physics personnel.)

When a CAM alarms, personnel must evacuate the area and contact an RCT.

The RCT must

- notify the HPFC and request assistance if needed;
- check personnel for contamination;
- control the area and ensure entry and exit controls are appropriate;
- perform nasal swipe surveys, if required;
- attempt to determine the possible cause of the CAM alarm; and
- develop a reentry plan, if needed.

A reentry plan may need to be developed, depending on the cause of the alarm.

A reentry plan may include

- using facility-specific procedures;

- using appropriate personal protective equipment and respiratory protection;
- acquiring team leader approval for >50 DAC;
- checking the CAM—stopping or resetting the alarm and determining if the CAM is malfunctioning;
- performing direct/LAS surveys, and attempting to determine the source of alarm; and
- replacing the CAM filter.

Radon Determination

When counting CAM filters:

- Count the CAM filter on a locally available sample counter, such as a Berthold, SAC-4, or Ludlum 2929/3030/3030E.
- Repeat the CAM filter sample count after at least 20 minutes.
- If the activity is caused by radon daughters, the second count will be less than 70% of the first count.

RCT: Module 2.06, AIR SAMPLING PROGRAM AND METHODS

Course 8772

July 2017

RCT_2.06_Air-Samp-Prgm-Meth_8772_SM,R3.0

UNCLASSIFIED

Overview of Lesson

The inhalation of radioactive particles is the largest cause of an internal radiation dose. Airborne radioactivity measurements are necessary to ensure that the control measures are and continue to be effective. Regulations govern the allowable effective dose equivalent to an individual. The effective dose equivalent is determined by combining the external and internal dose equivalent values. Typically, airborne radioactivity levels are maintained well below allowable levels to keep the total effective dose equivalent small.

Objectives

2.06.01 – State the primary objectives of an air monitoring program.

2.06.02 – Describe the three physical states of airborne radioactive contaminants.

2.06.03 – List and describe the primary considerations to ensure a representative air sample is obtained.

2.06.04 – Define the term "isokinetic sampling" as associated with airborne radioactivity sampling.

Objectives

2.06.05 – Identify the six general methods for obtaining samples or measurements of airborne radioactivity concentrations and describe the principle of operation for each method.

a. Filtration
b. Volumetric
c. Impaction/impingement
d. Adsorption
e. Condensation/dehumidification
f. In-line/flow-through detection

Objectives

2.06.06 – Describe the general considerations for selection of an air monitoring method.

2.06.07 – State the purpose of the five primary types of airborne radioactivity samplers/monitors:

a. Personal air samplers (breathing zone)
b. High volume/flow rate air samplers
c. Low volume/flow rate air samplers
d. Portable continuous air monitors
e. Installed continuous air monitoring systems

Objectives

2.06.08 – List the factors that affect the accuracy of airborne radioactivity measurements and describe how these factors affect sample accuracy.

2.06.09 – Describe the LANL air monitoring program that includes monitoring frequencies and calculational methods, applicable derived air concentration limits, and methods for determining radon interference.

Introductory Knowledge

To understand the “allowable effective dose equivalent values,” you must have a basic understanding of the Annual Limit on Intake (ALI), and Derived Air Concentration (DAC).

- Annual Limit on Intake (ALI) - The quantity of a single radionuclide which, if inhaled or ingested in 1 year, would irradiate a person, represented by a reference man (ICRP Publication 23), to the limiting value for control of occupational exposure – a committed effective dose (CED) of 5 rem.

Introductory Knowledge

- Derived Air Concentration (DAC) - The concentration of a radionuclide in air that, if breathed over a period of a work year (2000 h), would result in the ALI for that radionuclide being reached and a CED of 5 rem. The DAC is obtained by dividing the ALI by the volume of air (2400 m^3) breathed by an average worker during a working year.

Introductory Knowledge

Example 2.06-1

In its report #30, the International Commission on Radiological Protection (ICRP) set a DAC for tritium gas (T_2) of 540 mCi/m^3 and a DAC for tritiated water (HTO) of 20 µCi/m^3. Notice that the DAC for tritium gas is 27,000 times higher than the DAC for HTO.

	DAC
HTO	20 µCi/m^3
T_2	540,000 µCi/m^3

Introductory Knowledge

Example 2.06-1

HTO	20 µCi/m^3
T_2 (gas)	540,000 µCi/m^3

- Exercise: Calculate the dose a worker would receive if he/she were exposed to 300 mCi/m^3 of tritium gas for 30 minutes.
- Exercise: Calculate the dose a worker would receive if he/she were exposed to 300 mCi/m^3 of HTO for 30 minutes.

2.06.01 – Air Monitoring Program

The primary objectives of an air monitoring program are to

- measure the concentration of the radioactive contaminant(s) in the air by collection and analysis;
- identify the type and physical characteristics of the radioactive contaminant;
- help evaluate the hazard potential to the worker;
- evaluate the performance of airborne radioactivity control measures; and
- assess air concentration data to determine if bioassay sampling should be initiated to verify whether an exposure has occurred and, if so, to determine the magnitude of the exposure.

2.06.01 – Air Monitoring Program

The primary goal of the air monitoring program is to determine if the level of protection provided to the worker is sufficient to minimize the internal dose equivalent.

Allowable concentration values are used as an index of the degree of control needed and achieved.

Documented measurements of the airborne radioactivity concentrations are required to demonstrate that satisfactory control is achieved and maintained.

2.06.01 – Air Monitoring Program

Air sampling is required where an individual is likely to receive an exposure of 40 or more DAC-hours in a year. Other situations requiring sampling occur when

- establishing the need for posting of airborne radioactivity areas and determining the need for respiratory protection of workers;
- assessing unknown hazards during maintenance on systems contaminated with radioactive material or when there is a loss of process controls;
- assisting in determining the type and frequency of bioassay measurements needed for a worker;

2.06.01 – Air Monitoring Program

Other situations requiring sampling occur when *(continued)*:

- providing an estimate of worker exposures for situations where bioassay measurements may not be available or their validity is questionable.
- developing baseline airborne radioactivity levels and verifying containment integrity during the startup of a new facility or new operation within an existing facility.
- wearing required respiratory protection devices for protection against airborne radionuclides;
- performing real-time air monitoring as necessary to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate the inhalation of airborne radioactive material.

2.06.02 – Physical States of Airborne Radioactive Contaminants

Airborne radioactive contaminants are generally divided into three categories, based on their physical state:

- Particulates
- Gases
- Vapors

The physical properties of airborne radioactive particles can affect inhalation deposition, their dynamical properties in air, and particle solubility in the lungs.

2.06.02 – Physical States of Airborne Radioactive Contaminants

Particulates

- Particulate contaminants are solid and liquid particles, ranging upward from molecular sizes (approximately 10 to 3 cm), suspended in the air.
- Solids are fumes, dusts, and smokes and are distinguished mainly by their mode of generation.
- Liquids are mists or fogs, depending on the dispersion of the liquid particulates.

2.06.02 – Physical States of Airborne Radioactive Contaminants

Particulates *(continued)*

- The term "aerosols" is used to collectively refer to relatively stable suspensions of either solid or liquid particles in a gaseous medium.
- The retention of inhaled radioactive particles after deposition in the pulmonary region of the lung is strongly influenced by the dissolution characteristics of the particles.
- Dissolution in the lungs allows clearance into the blood and the rest of the systemic circulation.

2.06.02 – Physical States of Airborne Radioactive Contaminants

Particulates *(continued)*

- Therefore, the various chemical forms of radioactive particles are classified with respect to their potential solubility in the lungs.
  - Class Y for the very insoluble particle that takes years to clear from the lungs.
  - Class W for the somewhat more soluble particles that take weeks to dissolve and clear into the systemic circulation.
  - Class D for the relatively soluble particles that dissolve in a matter of days in the lung.

2.06.02 – Physical States of Airborne Radioactive Contaminants

Gases

- Gases are substances that, under normal conditions of temperature and pressure, are distinguished from a solid or liquid by a low density and viscosity. Gases have no defined shape and can expand or contract with changes in temperature and pressure.
- The retention of gases in the body from inhalation is poor, so radioactive gases are usually treated as an external source of exposure.
- Radioactive gases typically found are fission product gases, such as xenon and krypton, and naturally occurring radon.
- Although these gases contribute primarily to external exposure, the particulate daughters to which they decay can contribute to internal exposure.

2.06.02 – Physical States of Airborne Radioactive Contaminants

Vapors

- Vapors are considered the gaseous phase of a substance that is normally a solid or liquid under normal conditions of temperature and pressure.
- The contaminant may be dispersed in vapor form at abnormal conditions of temperature and pressure.
- As the temperature and pressure conditions return to "normal," the contaminant will return to its normal solid or liquid form, or become a particulate.
- Sampling methods for vapors should isolate or measure the contaminant, regardless of whether the vapor or particulate form is present.

2.06.03 – Representative Air Samples

To ensure that the air sample is representative of the actual conditions, the airborne radioactivity concentration entering the

- sample line must be representative of the airborne radioactivity concentration in the air near the sampling device.
- sampling inlet must be representative of the airborne radioactivity concentration at the point of concern, or the air that is breathed (i.e., the breathing zone).

2.06.04 – Isokinetic Sampling

Isokinetic sampling is sampling that occurs under the condition that the sample line velocity is equal to the system velocity at the sample point.

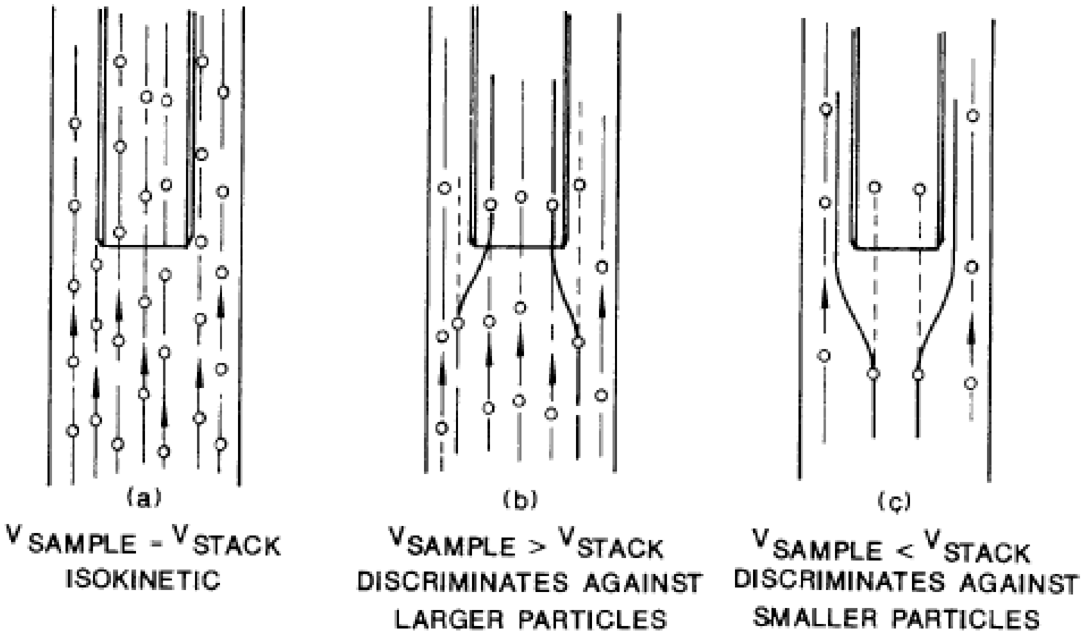
Air flow into sampling lines must be balanced with respect to the flow of air around the probe or sample inlet. Each air flow must be the same velocity.

To ensure that the sample is representative, the flow rate in the sample line or inlet must be the same as the flow rate in the system, such as the duct or stack.

If the velocities are not the same, then discrimination can occur for smaller or larger particles.

2.06.04 – Isokinetic Sampling

When the sample line velocity is equal to the system velocity at the sample point, it is called isokinetic sampling.



2.06.04 – Isokinetic Sampling

Basic Sampling Methods

The three basic sampling methods are as follows:

A volumetric sample is one in which part of the atmosphere is isolated in a suitable container, providing the original concentration of the contaminant at a particular place and time.

An integrated sample is one in which the contaminant is concentrated on some collecting medium, providing an average concentration over the collection time.

A continuous sample is one in which the sample air flow is directed past or through a detection device, providing a measurement of the activity per unit volume of air.

2.06.04 – Isokinetic Sampling

Basic Sampling Methods

- Breathing zone air monitoring should be performed continuously in areas where workers are likely to exceed a 40-DAC-h exposure in 1 year.
- This air monitoring is used to identify possible worker internal exposures and the need for follow-up bioassay measurements.
- Source-specific air sampling is performed near an actual, or likely, release point in a work area.

2.06.04 – Isokinetic Sampling

Basic sampling methods *(continued)*

- This air sampling is typically used for verifying containment or confinement integrity, documenting airborne radioactivity levels, and providing guidance on personnel protective measures.
- Grab air sampling is used for temporary or nonroutine situations and as a backup for other types of air sampling in the event of equipment failure.

2.06.05 – Air Sampling Methods

The six general methods for obtaining samples or measurements of airborne radioactivity concentrations are

- Filtration
- Volumetric
- Impaction/Impingement
- Adsorption
- Condensation/Dehumidification
- Inline/Flow-Through Detection

2.06.05 – Air Sampling Methods

Filtration

- Filter samplers use filtration of the air as the method of concentrating the airborne radioactive particulate (aerosol) contaminants.
- The filter sampling technique uses an air mover, such as a vacuum pump, to draw air through a removable filter medium at a known flow rate for a known length of time.
- If the flow rate and sample time are known, the total volume collected can be calculated.
- After the filter medium is analyzed to determine the amount of radioactive material collected on the filter when the sample is taken, the airborne concentration can also be calculated.

2.06.05 – Air Sampling Methods

Filtration *(continued)*

- The filtration medium selected for a sample depends on several factors:
  - The collection efficiency required
  - The flow resistance of the medium
  - The mechanical strength of the filter
  - The ore size
  - The area of the filter
  - The background radioactive material of the filter
  - Cost
  - Self-absorption within the filter
  - Chemical solubility

2.06.05 – Air Sampling Methods

Filtration *(continued)*

- The most common types of filters are:
  - Cellulose-asbestos filters
  - Glass fiber filters
  - Membrane filters, which are manufactured with various pore sizes and can be dissolved in organic solvents and analyzed in a counter (e.g., a liquid scintillation counter).
- Filter samples are evaluated by direct radiation counting or by radiochemical assay.

2.06.05 – Air Sampling Methods

Filtration *(continued)*

- Filters may be mounted into different types of holders, including those with open faces for direct sampling and those with inline enclosure for sampling through a sampling hose, with sample air flow drawn through a flow meter with a suitable air pump.

2.06.05 – Air Sampling Methods

Volumetric

- Volumetric samplers use a sample container into which the sample is drawn, by some method, and isolated for analysis.
- Several methods are used to draw the sample into the container.
  - The container may be evacuated by a vacuum pump and isolated away from the sample location. The container is opened at the sample location to draw the air into the container. The sample is sealed in the container and removed for analysis.
  - An air mover may be used at the sample location to draw a representative atmospheric sample into the container.

2.06.05 – Air Sampling Methods

Volumetric *(continued)*

2.06.05 – Air Sampling Methods

Impaction/Impingement

- Impingers or impactors concentrate particulate contaminants on a prepared surface by abruptly changing the direction of the sample air flow at some point in the sampler.
- Particles are collected on a selected surface as the airstream is sharply deflected.
- Because of their inertia, the particles are unable to follow abrupt changes in airstream direction.
- The surface on which the particles are collected must be able to trap the particles and retain them after impaction.

2.06.05 – Air Sampling Methods

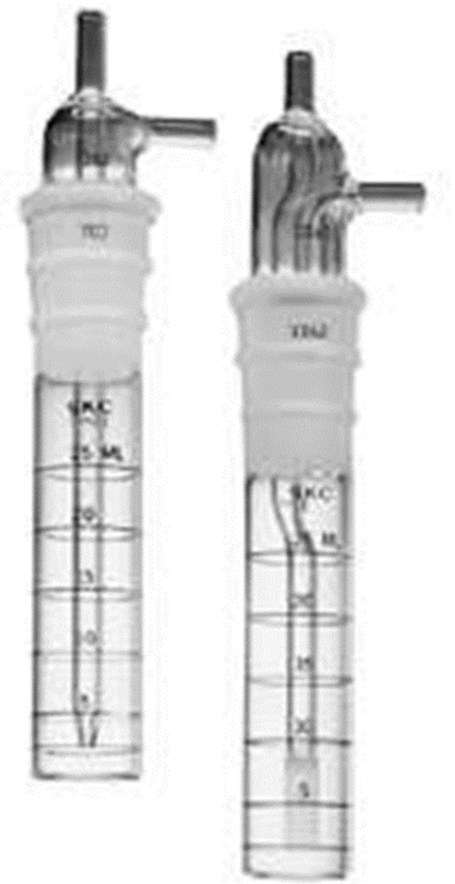
Impaction/Impingement

- Several methods are commonly used to trap the particles, such as
  - Coating the collection surface with a thin layer of grease or adhesive and
  - Immersing the collection surface in a fluid, such as water or alcohol. The liquid is then analyzed after the sample is collected.
- Impingers and impactors may use several stages or impingement distances to discriminate for or against different particle sizes.

2.06.05 – Air Sampling Methods

Impaction/Impingement

- Impactors are frequently used to isolate particles larger than the undesired smaller particles, such as transuranics over radon daughters or radon daughters over fission products.



2.06.05 – Air Sampling Methods

Adsorption

- Adsorber sampling devices concentrate the contaminants by causing them to adhere to the surface of the adsorption medium.
- This technique uses an air mover to draw and collect the sample through the adsorption media.

2.06.05 – Air Sampling Methods

Adsorption *(continued)*

- Adsorbers are commonly used to collect organic vapors and nonreactive gases and vapors.
  - Activated charcoal is used primarily for radioiodine sampling, but it also traps noble gases, such as xenon, krypton, and argon.
  - Silica gel is used primarily for tritium oxide vapor sampling.
  - Silver zeolite is used for radioiodine sampling when trapped noble gases would interfere with the radioiodine analysis.

2.06.05 – Air Sampling Methods

Condensation/Dehumidification

- Condensation or dehumidifier sampling devices use a "cold trap" to condense water vapors in the sampled atmosphere and provide a liquid sample for further analysis.
- Liquid nitrogen or a refrigeration unit is often used to cool the condensation surface and cause the water vapor to condense as it passes over the cold surface.
- Calculations must include the relative humidity and temperature of the air at the time the sample is taken to determine the concentration of water vapor per unit volume of air.
- This technique is normally applied only for sampling tritium oxide vapor (HTO or T_2O).

2.06.05 – Air Sampling Methods

Inline/Flow-Through Detection

- Inline or flow-through samplers use an air mover to direct the sample air flow through or past the detection device.
- These samplers are used for radionuclides that are difficult to collect or detect by other means.
- Inline detectors are used to measure gaseous activity after filtration and adsorption have been accomplished.
- Flow-through detectors are used for radionuclides, such as tritium (which emits low-energy radiation) that could not otherwise pass through the detector window.

2.06.05 – Air Sampling Methods

Multipurpose Samplers and Monitors

- Various sampling methods may be combined into one sampler or monitor.
- Some samplers use the filtration method for particulates, the adsorption method for vapors, and the volumetric grab-sample method for gases (in that order).
- Some advantages of combining these methods are that
  - One vacuum pump supplies the air flow for all the samples and
  - All samples are drawn at the same time to minimize the amount of time spent by the technician drawing samples.

2.06.05 – Air Sampling Methods

Multipurpose Samplers and Monitors *(continued)*

- Some monitors have detectors installed to monitor each sample and provide an immediate readout, as well as other capabilities, such as alarms, data records, process controls, and trending.

2.06.06 – Considerations for Selecting an Air Monitoring Method

The environmental conditions in the area where the sample is to be obtained include humidity, high temperature, explosiveness, and dust.

The physical characteristics to consider in the area in which the sample is to be obtained include electricity availability and close spaces, which can influence selection.

The energy and type of radiation of the radionuclide being monitored are

- The expected concentration level.
- The physical state of the airborne contaminant.
- The type of survey required.
- Procedural requirements.

2.06.07 – Primary Types of Air Samplers/Monitors

The five primary types of airborne radioactivity samplers/monitors are:

- Personal air samplers (breathing zone)
- High-volume/flow rate air samplers
- Low-volume/flow rate air samplers
- Portable continuous air monitors (CAMs)
- Installed continuous air monitoring systems

2.06.07 – Primary Types of Air Samplers/Monitors

Personal Air Samplers (PASs)

- PASs provide an estimate of the airborne radioactivity concentration in the air that the worker is breathing during the sampling period.
- These devices contain a small battery-powered pump that is calibrated to a flow rate approximately 2 liters per minute, which is the breathing rate of a worker performing light activity.
- The sampling line terminates in a filter cassette, which contains the filtration medium for the radioactive particulate contaminants.
- The sample filter cassette is attached close to the nose and mouth of the individual.

2.06.07 – Primary Types of Air Samplers/Monitors

Personal Air Samplers (PASs) *(continued)*

2.06.07 – Primary Types of Air Samplers/Monitors

High-Volume/Flow Rate Air Samplers

- High-volume/flow rate samplers provide an estimate of the airborne radioactivity concentration at a particular location in a short period of time.
- These samplers do not have installed detectors, and the sample must be removed from the sampler and analyzed on separate analysis equipment.

2.06.07 – Primary Types of Air Samplers/Monitors

High-Volume/Flow Rate Air Samplers *(continued)*

- Samplers may be used to
  - Provide a routine estimate of the general area airborne radioactivity
  - Verify boundaries of areas posted for airborne radioactivity
  - Monitor the airborne radioactivity related to a specific work activity
- High-volume samplers typically use flow rates of at least 10 cfm.

2.06.07 – Primary Types of Air Samplers/Monitors

High-Volume/Flow Rate Air Samplers *(continued)*

2.06.07 – Primary Types of Air Samplers/Monitors

Low-Volume/Flow Rate Air Samplers *(continued)*

- Low-volume/flow rate samplers provide an estimate of airborne radioactivity concentrations averaged over a longer period of time at a particular location.
- Low-volume samplers generally have flow rates set at approximately 20 lpm, which is the breathing rate of a worker performing light activity.
- Although these samplers must run longer for reasonable sensitivity, they are generally quiet and can be used for continuous duty.

2.06.07 – Primary Types of Air Samplers/Monitors

Low-Volume/Flow Rate Air Samplers *(continued)*

- Low volume/flow rate samplers may be used to provide average airborne radioactivity estimates over a period of time for:
  - Commonly traversed areas that normally have a low probability of airborne radioactivity problems
  - Areas not commonly traversed that have a higher probability of airborne radioactivity problems
  - Backup samples in areas where airborne radioactivity problems are discovered by other means
  - Work maintenance activities normally characterized by low airborne radioactivity concentrations.

2.06.07 – Primary Types of Air Samplers/Monitors

Low-Volume/Flow Rate Air Samplers *(continued)*

2.06.07 – Primary Types of Air Samplers/Monitors

Portable Continuous Air Monitors (CAMs)

- Portable CAMs provide an estimate of airborne radioactivity concentrations averaged over time at a particular location and provide immediate readout and alarm capabilities for preset concentrations.
- These air monitors are portable low-flow-rate (20 lpm) sampling systems containing the necessary sampling devices and built-in detection systems to monitor the activity on the filters, cartridges, planchettes, and/or chambers in the system.

2.06.07 – Primary Types Of Air Samplers/Monitors

Portable Continuous Air Monitors (CAMs) *(continued)*

- The system may provide a visual readout device for each type of sample medium, a recording system for data, and computer functions such as data trending, preset audible and visual alarms/warning levels and alerts for system malfunctions.
- Typical CAMs provide information on alpha and/or beta/gamma particulates, radioiodine activity and noble gas activity.

2.06.07 – Primary Types of Air Samplers/Monitors

Portable Continuous Air Monitors (CAMs) *(continued)*

- Portable CAMs can be used as
  - low-volume general area samplers
  - monitors with alarm capabilities for areas where airborne radioactivity conditions may quickly degrade
  - trending devices in selected areas
  - devices to locate system leaks, if used with the appropriate length hose or tubing.

2.06.07 – Primary Types of Air Samplers/Monitors

Portable Continuous Air Monitors (CAMs) *(continued)*

2.06.07 – Primary Types of Air Samplers/Monitors

Installed Continuous Air Monitoring (CAM) Systems

- Installed CAM systems provide an estimate of airborne radioactivity concentrations averaged over time at a fixed, designated location and provide immediate local and remote readout and alarm capabilities for preset concentrations.
- These air monitors are fixed low-flow-rate sampling systems and contain the necessary sampling devices and built-in detection systems to monitor the activity of selected areas or airstreams.
- The system may provide a local and remote visual readout device, a recording system for data, and computer functions such as data trending, preset audible and visual alarms/warning levels, and alerts for system malfunctions.

2.06.07 – Primary Types of Air Samplers/Monitors

Installed Continuous Air Monitoring (CAM) Systems

- Installed CAM applications include
  - Fixed installations capable of sampling several locations through valved sample lines
  - Stack monitors
  - Duct monitors

2.06.08 – Accuracy of Airborne Radioactivity Measurements

Factors affecting the accuracy of airborne radioactivity measurements include:

- The sample is not representative of the atmosphere being sampled
- The sample is not representative of the air being breathed by the worker
- The sampling media may be incorrect or improperly installed for the selected sampler, causing leaks or improper flow rates
- The sampling device may be malfunctioning, incorrectly operated, or improperly calibrated, causing errors in flow rate measurements.

2.06.08 –Accuracy of Airborne Radioactivity Measurements

Factors *(continued)*

- A lack of accuracy and operation in the timing device may cause errors in the time value
- The flow rate measuring device's lack of accuracy and operation may cause errors in the flow rate value
- Mishandling of the sample media may cause cross-contamination or removal of sample material
- Sample loading, humidity, and other factors may cause changes in the collection efficiency of the medium
- Analysis equipment may be improperly used or selected

2.06.08 – Accuracy of Airborne Radioactivity Measurements

Factors *(continued)*

- Inherent errors in the counting process could be caused by sample geometry, self-absorption, resolving time, backscatter, and statistical variations
- Mathematical errors may occur during calculations due to the rounding of numbers and simple mistakes
- Samples may be incorrectly marked, and data recording may be inaccurate

2.06.09 – LANL Air Monitoring Program

Basic Air Sample Calculation

- The analysis of the sample provides the activity of the sample at the time of the sample analysis.
- This value may be corrected for decay for the time period between when the sample was taken to when it was analyzed.
- The volume of the sample must be determined from the sample data recorded, such as flow rates at the beginning and end of the sample, and sample time period. The basic calculation listed would also include the conversions necessary for the desired units such dpm/liter to µCi/cc.

2.06.09 – LANL Air Monitoring Program

Basic Air Sample Calculation *(continued)*

$$CONCENTRATION = \frac{decay\ corrected\ activity}{sample\ flow\ rate \times sample\ time\ period}$$

2.06.09 – LANL Air Monitoring Program

Basic Air Sample Calculation *(continued)*

- The calculation would also include correction factors, as necessary, for:
  - Interference of other radionuclides, such as radon and thoron daughters
  - Collection efficiency
  - Counter efficiency
  - Self-absorption by the sample media
  - Counter background
  - Temperature and pressure as applied to flow rate

2.06.09 – LANL Air Monitoring Program

Basic Air Sample Calculation *(continued)*

- Many errors are inherent or induced in the sampling analysis process and affect the accuracy of the resulting data. The operator of the sampling and analysis equipment must be aware of these points of error to ensure that the resulting data are as accurate as possible. Quality assurance that is applied to all phases of the air monitoring program will minimize many errors.

2.06.09 – LANL Air Monitoring Program

Derived Air Concentration (DAC)

- The Derived Air Concentration (DAC) is defined as the concentration of a radionuclide in air that, if breathed over a period of a work year (2000 hrs), would result in a committed effective dose (CED) of 5 rem.
- Radionuclides must be known to determine the appropriate DAC value from the airborne concentration.
- For unknown radionuclides, use the most restrictive DAC (lowest value) for any isotopes that may be present.
- Perform air monitoring to characterize workplace airborne radioactivity concentrations.
- For a known mixture of radionuclides, determine the combined DAC for all radionuclides.

2.06.09 – LANL Air Monitoring Program

Derived Air Concentration (DAC) *(continued)* – Sampling of DACs used at LANL

Radionuclide	Absorption type μCi/mL			Absorption type Bq/m^3		
	F	M	S	F	M	S
H-3 (Water)	2 E−05	2 E−05	2 E−05	7 E + 05	7 E + 05	7 E + 05
H-3 (Elemental)	2 E−01	2 E−01	2 E−01	9 E + 09	9 E + 09	9 E + 09
Co-60	-	7 E−08	3 E−08	-	2 E + 03	1 E + 03
Sr-90	1 E−08	-	7 E−09	4 E + 02	-	2 E + 02
Y-90	-	3 E−07	3 E−07	-	1 E + 04	1 E + 04
Cs-137	8 E−08	-	-	3 E + 03	-	-
Th-232	-	3 E−12	4 E−11	-	1 E−01	1 E + 00
U-234	5 E−10	2 E−10	7 E−11	1 E + 01	9 E + 00	2 E + 00
U-235	5 E−10	3 E−10	8 E−11	1 E + 01	1 E + 01	3 E + 00
U-238	5 E−10	3 E−10	8 E−11	2 E + 01	1 E + 01	3 E + 00
U-239	1 E−05	9 E−06	9 E−06	5 E + 05	3 E + 05	3 E + 05
Pu-238	-	6 E−12	5 E−11	-	2 E−01	1 E + 00
Pu-239	-	5 E−12	6 E−11	-	2 E−01	2 E + 00
Pu-240	-	5 E−12	6 E−11	-	2 E−01	2 E + 00
Pu-241	-	2 E−10	2 E−09	-	1 E + 01	1 E + 02
Pu-242	-	5 E−12	6 E−11	-	2 E−01	2 E + 00
Am-241	-	5 E−12	-	-	1 E−01	-

2.06.09 – LANL Air Monitoring Program

Procedure RP-1-DP-018, *Air Monitoring* provides methods and techniques for performing air monitoring to identify and control airborne radioactivity.

Procedure RP-SOP-031, *Planning Routine Radiological Monitoring* governs the planning and development of routine monitoring instructions (RMIs) and provides the justification and monitoring frequencies for surveys for LANL facilities.

RP procedure RP-SOP-014, *Responding to CAM Alarms,* states the necessary actions that RCTs must take when responding to a workplace CAM alarm.

2.06.09 – LANL Air Monitoring Program

Radiation Protection (RP) Staff Responsibilities

- Staff Health Physicists and Radiological Engineers:
  - Perform air monitoring determination calculations and verify the correct placement of air monitoring equipment.
- Health Physics Field Coordinators (HPFCs)
  - Provide assistance and guidance to RCTs in supporting air-monitoring equipment.
- Radiological Control Technicians (RCTs)
  - Perform filter changes on CAMs and other air monitoring installations.
  - Verify air-monitor flow rates and adjust where needed.

2.06.09 – LANL Air Monitoring Program

Determining the need for air monitoring

- Air sampling and monitoring commensurate with the hazards of the activities planned for the area must be performed to ensure that airborne radioactivity is characterized. Air sampling and monitoring equipment (e.g., portable and fixed air samplers, CAMs, or lapel samplers) must be selected according to the specific job being monitored.
- Air-sampling equipment must be used where an individual is likely to receive an exposure of 40 or more DAC-hours in a year.

2.06.09 – LANL Air Monitoring Program

Determining the need for air monitoring *(continued)*

- Note: A 40 DAC-h exposure would result in a CED to an individual of approximately 0.1 rem.
- Real-time air monitoring must be performed as necessary to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate inhalation of airborne radioactive material. These real-time air monitors must have alarm capability and enough sensitivity to alert potentially exposed individuals that immediate action is required to minimize or terminate inhalation exposures.

2.06.09 – LANL Air Monitoring Program

Determining the need for air monitoring *(continued)*

Table 4. Available Air Monitoring Equipment

Type	Available Instruments
Alpha Continuous Air Monitors	Alpha 7, Alpha 6, ASM 1000/AS1700, TA-55CAM and others
Beta Continuous Air Monitors	AMS-3, AMS-3A, AMS-4
Tritium Continuous Air Monitors	Femto-Tech U24/U24-D, Overhoff T301
Fixed-Head Air Sampler (FAS)	Multiple available
Giraffe or Other Portable Air Sampler	HI-Q MRV series
High Volume Air Sampler	Multiple available
Lapel Air Sampler	Multiple available

From RP-1-DP-018, *Air Monitoring*

2.06.09 – LANL Air Monitoring Program

Determining the need for air monitoring *(continued)*

- Guidance from NUREG-1400, *Air Sampling in the Workplace*, included in RP-1-DP-018, is used to determine the need for retrospective and real-time air monitoring .
- The HI is the potential intake expressed as a percent of the amount of material that, if inhaled, could result in a CED of 5 rem (for stochastically limited nuclides) or 50 rem (for deterministically limited nuclides).

$$HI = \frac{Q \times 1 \times 10^{-6} \times R \times C \times D \times 100}{DAC \times 2400}$$

2.06.09 – LANL Air Monitoring Program

Hazard Index

$$HI = \frac{Q \times 1 \times 10^{-6} \times R \times C \times D \times 100}{DAC \times 2400}$$

- Q = the amount of radioactive material (in curies).
- R = the release fraction of the material.
- DAC = the derived air concentration value in units of µCi/ml.
- C = the confinement factor.
- D = the dispersibility and other modifying factors.

2.06.09 – LANL Air Monitoring Program

Hazard Index *(continued)*

Table 9. Recommended Air Sampling

HI	Air Monitoring Needed
< 2	Very low level of hazard from airborne radioactivity. Air sampling is generally not necessary; however, monthly or quarterly grab samples may be appropriate in some situations to confirm that airborne levels are indeed low.
2 to 10	Fairly low level of hazard from airborne radioactivity. A HI of 2 corresponds to 40 DAC-h which is the level at which air sampling is required.
> 10	Potential for moderate hazard from airborne radioactivity. In addition to general air sampling, evaluate the need to determine intakes by either breathing zone air sampling or bioassay measurements. Note that facility-specific dosimetry enrollment criteria in DES and RP-SVS technical basis documents specifying bioassay enrollment must be followed.
> 100	Potential for relatively high level of hazard from airborne radioactivity. In addition to general or breathing-zone air sampling, early warning air monitoring is required For example, continuous air monitoring using CAMs.

From RP-1-DP-018, *Air Monitoring*

2.06.09 – LANL Air Monitoring Program

Determining Placement of Air Monitors

- After determining which areas require air monitoring, determine the placement of air monitors.
- Consider the following when selecting the location and number of air monitors:
  - The size of the area or facility
  - The type of operations conducted at the facility
  - The contamination levels and potential for contamination
  - The traffic and airflow patterns
  - The specific facility features (such as the location of ventilation intake and exhaust registers)
  - The locations having high source-term potential
  - Any available historical air monitoring results

2.06.09 – LANL Air Monitoring Program

Determining Placement of Air Monitors *(continued)*

- Consider breathing zones when placing air monitors:
  - Position air monitors to measure air concentrations to which people are exposed.
  - Place the air sample inlet approximately 6 feet above the floor and either between any workers and the potential point of release or so that the air sample is representative of the air breathed by the workers.
  - Initiate a program of personal breathing-zone air monitoring if proper placement of air monitors is not achieved.
- Document the placement of air samplers and air monitors.

2.06.09 – LANL Air Monitoring Program

Air Monitoring Frequency

- Procedure RP-SOP-031, *Planning Routine Radiological Monitoring* governs the planning and development of routine monitoring instructions (RMIs) and provides the justification for surveys and frequency for LANL facilities.
- Per RP-SOP-031, air filters are *typically* changed weekly and counted after allowing for the decay of radon and thoron daughters.

2.06.09 – LANL Air Monitoring Program

RP-SOP-014, *Responding to CAM Alarms*

- RCTs should be aware that a prompt and appropriate response to CAM alarms is necessary to minimize exposure of personnel to airborne radioactive material and internal intake of airborne radioactive material by personnel.
- A CAM alarm must be treated as a true CAM alarm until proven otherwise. The immediate response to a CAM alarm should always be to leave the area. (This does not apply if a CAM alarms while it is undergoing testing by Health Physics personnel.)

2.06.09 – LANL Air Monitoring Program

RP-SOP-014, *Responding to CAM Alarms (continued)*

- When a CAM alarms, personnel must evacuate the area and contact an RCT.
- The RCT must:
  - Notify the HPFC and request assistance if needed.
  - Check personnel for contamination.
  - Control the area and ensure entry and exit controls are appropriate.
  - Perform nasal swipe surveys, if required.
  - Attempt to determine the possible cause of the CAM alarm.
  - Develop a reentry plan, if needed.

2.06.09 – LANL Air Monitoring Program

RP-SOP-014, *Responding to CAM Alarms (continued)*

- A reentry plan may need to be developed, depending on the cause of the alarm.
- A reentry plan may include :
  - Using facility-specific procedures
  - Using appropriate PPE and respiratory protection
  - Acquiring Team Leader approval for > 50 DAC
  - Checking the CAM – stopping or resetting the alarm and determining if CAM is malfunctioning
  - Performing direct/LAS surveys and attempting to determine the source of the alarm
  - Replacing the CAM filter

2.06.09 – LANL Air Monitoring Program

Radon Determination

- When counting CAM filters:
  - Count the CAM filter on a locally available sample counter, such as a Berthold, SAC-4, or Ludlum 2929/3030/3030E.
  - Repeat the CAM filter sample count after at least 20 minutes.
  - If the activity is caused by radon daughters, the second count will be less than 70% of the first count.