Course Title: **Radiological Control Technician**
Module Title: **Air Sampling Program/Methods**
Module Number: **2.06**

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.

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.

INTRODUCTION

Inhalation of radioactive particles is the largest cause of internal dose. Airborne radioactivity measurements are necessary to ensure that the control measures are effective 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.

References:

1. Air Sampling/Survey Methods, General Physics Corp., Lesson 1003.
2. Cember, Herman, Introduction to Health Physics, 2nd Edition, Pergamon Press, New York, 1983.
3. Gollnick, Daniel, Basic Radiation Protection Technology, 2nd Edition, Pacific Radiation Corp., 1988.
4. Moe Harold, Operational Health Physics Training, ANL-88-26, Department of Energy, Argonne National Laboratory, Chicago, 1988.
5. Internal Radiation Dosimetry, Health Physics Society Summer School, 1994.
6. "Air Monitoring", Implementation Guide for Use with 10 CFR 835, "Occupational Radiation Protection".

INTRODUCTORY KNOWLEDGE

In order 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). (Refer to RCT lesson 1.12 sections 3 to 8).

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

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

The DAC is the average airborne concentration that a radiation worker may be exposed to for 40 hours/week, 50 weeks/year. When continuously exposed to this concentration, the resultant dose is either a committed effective dose equivalent of 5 rem or a committed dose equivalent to an organ or tissue of 50 rem (whichever one is more limiting). Since the DAC is a time-average concentration, as the concentration increases, the exposure time must decrease in order to maintain exposure below the ALI. This means that one could be exposed to concentrations significantly above the DAC for short periods of time and still be below the annual limit on intake, or ALI.

Example 2.06-1

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

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

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

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

PURPOSE AND OBJECTIVES OF AIRBORNE RADIOACTIVITY SAMPLING

Airborne radioactive contaminants are of concern to the radiological control organization due to the biological effects of the ionizing radiation emitted by those contaminants. The inhalation of radioactive airborne particles is one of the most important routes of entry of radionuclides into the human body. This represents a relatively complicated process that depends on particle size distribution of the airborne particles, their dynamical behavior in air, and the physical and chemical properties of the particles that control the radionuclide biokinetics after deposition in the respiratory tract. Air monitoring is performed to identify and monitor airborne radioactive material in order to control the intake of airborne radioactive material by workers.

Regulations govern the allowable or limiting effective dose equivalent to an individual. The total effective dose equivalent of an individual is determined by combining the external and internal dose equivalent values. Typically, airborne radioactivity levels are maintained well below allowable levels to keep the internal dose equivalent contribution to the total effective dose equivalent small. Confirmation that airborne radioactivity levels are maintained low is accomplished by the airborne radioactivity sampling program. It is important to note that the individual dose equivalent from internal sources is **not** normally determined from air sampling analysis data, unless other information, such as bioassay data, is unavailable, inadequate, or internal dose estimates based on air concentration values are demonstrated to be as or more accurate.

It is necessary to be aware that the air monitoring program is only one element of a comprehensive radiation protection program. Individuals involved with the air monitoring program should interact with personnel working in other elements of the radiation protection program, particularly with individuals involved in contamination control and internal dosimetry.

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
- to identify the type and physical characteristics of the radioactive contaminant
- to help evaluate the hazard potential to the worker
- to evaluate the performance of airborne radioactivity control measures
- to assess air concentration data in order 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

Allowable concentration values, such as derived air concentrations (DAC) 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.

Additionally, the air monitoring program must demonstrate that airborne radioactivity released to the general environment is maintained as low as reasonably achievable and below the allowable limits established by regulatory agencies.

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, such as derived air concentrations (DACs), 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 are:

- to establish the need for posting of airborne radioactivity areas and to determine the need for respiratory protection of workers

- to assess unknown hazards during maintenance on systems contaminated with radioactive material or when there is a loss of process controls

- to assist in determining the type and frequency of bioassay measurements needed for a worker

- to provide an estimate of worker exposures for situations where bioassay measurements may not be available or their validity is questionable

- to develop baseline airborne radioactivity levels and verify containment integrity as necessary during startup of a new facility or new operation within an existing facility

- where respiratory protection devices for protection against airborne radionuclides have been required

- real-time air monitoring shall be performed as necessary to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate inhalation of airborne radioactive material

2.06.02 Describe the three physical states of airborne radioactive contaminants.

THE NATURE OF AIRBORNE RADIOACTIVITY

Airborne radioactive contaminants are generally divided into three categories, based on the physical state of the contaminant.

- Particulates
- Gases
- Vapors

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

Particulates

Particulate contaminants are solid and liquid particles, ranging upward from molecular sizes (approximately 10^{-3} μm), suspended in the air. Solids may be subdivided into fumes, dusts, and smokes, which are distinguished mainly by their mode of generation. Liquids are subdivided into mists and fogs, depending on the dispersion of the liquid particulates. The term "aerosols" is used to collectively refer to relatively stable suspensions of either solid or liquid particles in a gaseous medium. Generally, particulates are more readily retained in the lungs than are gases, but retention of particulates is highly dependent on particle size and solubility in the lung. While this suggests that particulate airborne contaminant sampling should measure particle size, this is not practically accomplished on a routine basis. Certain sampling instruments utilize the characteristics of particle size to separate larger particles from smaller particles (e.g., impactors). This is an important factor in that the size range of particles retained in the respiratory tract is generally 1-10 µm.

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. For this reason the various chemical forms of radioactive particles are classified with respect to their potential solubility in the lungs. Specifically, these are:

- 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

Gases

Gases are substances that, under normal conditions of temperature and pressure, exist in the gaseous phase. The retention of the 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 the fission product gases, such as xenon and krypton, and naturally occurring radon. While the 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. Airborne vapor sampling is most commonly done for radioiodine and tritium. The contaminant may be dispersed in vapor form at abnormal conditions of temperature and pressure. However, 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 List the primary considerations to ensure a representative air sample is obtained.

REPRESENTATIVE AIR SAMPLES

To ensure that the 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.

- The airborne radioactivity concentration entering the sampling inlet must be representative of the airborne radioactivity concentration at the point of concern, or the air that is breathed, i.e., breathing zone.

When obtaining an air sample, care must be taken to ensure that the sample obtained is representative of the air around the sampling device. This is particularly important for sample lines that directly sample an air flow, such as a stack or duct monitor. Air flow into sampling lines needs to be balanced with respect to the flow of air around the probe or sample inlet. If there is not a relative balance between these velocities, particles may be thrown in or out of a sampling probe rather than being sampled in a representative fashion. To ensure 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.

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

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

If the velocities are not the same, or ***isokinetic***, then discrimination can occur for smaller or larger particles. This occurs because the inertia of the more massive particles prevents them from following an airstream that makes an abrupt directional change.

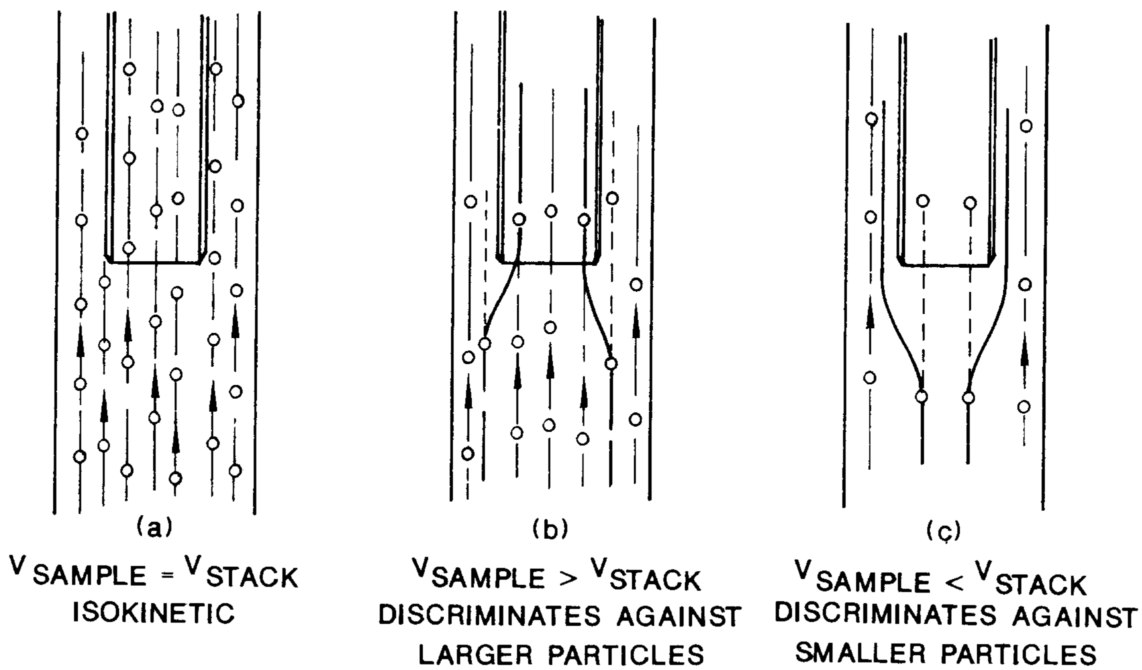

Figure 1 - Isokinetic Sampling

If the velocity of the sample airstream is > the velocity of the system airstream, then the larger particles can not make the abrupt change and are discriminated against in the sample, i.e., the smaller particles are collected more efficiently.

If the velocity of the sample airstream is < the velocity of the system airstream, then the small particles do make the abrupt change and are discriminated against in the sample, i.e., the larger particles are collected more efficiently.

To minimize particle losses, sampling lines should be as short (less than six feet preferred) and straight as possible to avoid sample deposition along the walls of the tube. When possible, sample lines should be vertical instead of horizontal to prevent gravimetric settling of large particles. Additionally, the sampling line should have no more than one bend and be made of conducting material.

There are other factors to consider for maximizing the efficiency of airborne radioactivity detection. Self-absorption losses, e.g., dust loading, should be minimized. This is especially critical for alpha radiation detection. Air in-leakage between the sample intake and the sample collection medium should be eliminated to the greatest degree possible by instrument design. Finally, the system and mechanisms within the instrument for sample collection should be designed and constructed to minimize deterioration and to facilitate decontamination. This is more critical in areas with corrosive atmospheres.

When obtaining an air sample, care must be taken to ensure that the sample obtained is representative of the air at the point of interest (the breathing zone). Depending on the source of the airborne contaminant, the concentrations within a work area can vary over several orders of magnitude. The sample taken should be representative of the air entering the nose and mouth of the individual workers since the data obtained may be used to estimate potential worker intakes. Obviously, the best sampling method then is to sample the air at the individual's nose and mouth. This sampling method may not always be practical and general work area sampling may be the alternative. Care must be exercised in the selection of the number and placement of the general area air samplers to ensure that the sample is as representative as possible.

BASIC SAMPLING METHODS

Basically, three types of samples are collected:

1. A volumetric sample 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.

2. An integrated sample which concentrates the contaminant on some collecting medium, providing an average concentration over the collection time. (Sometimes called a "grab" sample if collected in a short period of time.)

3. A continuous sample where 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 40 DAC-hr exposure in a year. Breathing zone 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 is typically used to verify containment or confinement integrity, documenting airborne radioactivity levels, and providing guidance on personnel protective measures (e.g., determining when respiratory protection is required).

Grab air sampling is used for temporary or nonroutine (e.g., emergency response) situations and as a backup for other types of air sampling in the event of equipment failure. Portable air sampling equipment is typically used for operations requiring a grab sample. Sample flow rates may vary depending upon the specific application, but should always allow collection of a sample volume adequate to ensure the minimum detectable activity of the sampling and counting system is no greater than 2% of an ALI.

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

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

- Filtration
- Volumetric
- Impaction/impingement
- Adsorption
- Condensation/ dehumidification
- In-line/flow-through detection

Filtration

Filter samplers employ filtration of the air as the method of concentrating the airborne radioactive particulate (aerosol) contaminants. Filtration is the most common sampling method employed for particulates because it is relatively simple and efficient, but is ineffective as a sampling method for gases and vapors. The filter sampling technique employs 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 analysis of the filter medium to determine the amount of radioactive material collected on the filter at the time of the sample, 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, pore size, the area of the filter, the background radioactive material of the filter, cost, self-absorption within the filter, and chemical solubility. A wide choice of filters is available.

The most common types are:

- Cellulose-asbestos filters

- Glass fiber filters

- Membrane filters 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 in-line enclosure for sampling through a sampling hose, with sample air flow drawn through a flow meter with a suitable air pump.

Volumetric

Volumetric samplers employ a sample container into which the sample is drawn, by some method, and isolated for analysis. Several methods are employed 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, such as a vacuum pump, may be employed at the sample location to draw a representative atmospheric sample into the container.

- The container could be filled with water, isolated and taken to the sample location. The water is poured out of the container, drawing the air sample into the container as the water pours out.

This method can be employed for particulates, gases, and vapors.

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

- Coating the collection surface with a **thin** layer of grease or adhesive.
- 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 utilize 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. Adsorption is the adhesion of a substance to the surface of another substance through chemical bonding. The adsorption medium is granulated or porous to increase the surface area available for trapping of the contaminant. The technique employs an air mover to draw and collect the sample through the adsorption media. Adsorbers, such as activated charcoal, silica gel, and silver zeolite, are commonly used to collect organic vapors and non-reactive gases and vapors. Some uses of each type are:

- Activated charcoal is used primarily for radioiodine sampling, but does trap 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.

Particulates would be "filtered" by the adsorption media and must be filtered out before the adsorption process to prevent interference during the analysis of the media.

Condensation/Dehumidification

Condensation or dehumidifier sampling devices employ a "cold trap" to condense water vapors in the sampled atmosphere and provide a liquid sample for further analysis. Some means, such as liquid nitrogen or a refrigeration unit is utilized to cool the condensation surface and cause condensation of the water vapor as it passes over the cold surface. The collected water is frequently analyzed using a liquid scintillation counter. 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 only applied for sampling tritium oxide vapor (HTO or T_2O).

In-Line/Flow Through Detection

In-line or flow-through samplers employ an air mover to direct the sample air flow through or past the detection device. This method is employed for radionuclides which are difficult to collect or detect by other means. Because the air flow passes directly outside the detector or actually through the inside of the detector, the air must be filtered for particulates or vapors that could accumulate on or in the detector. In-line detectors are used to measure gaseous activity after filtration and adsorption have been accomplished. Flow-through detectors are employed for radionuclides, such as tritium, which emit low-energy radiation, that could not otherwise pass through the detector window.

Multi-Purpose Samplers and Monitors

The various sampling methods described above may be combined into one sampler or monitor. Some samplers employ 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:

- One vacuum pump supplies the air flow for all the samples.

- All the samples are drawn at the same time to minimize the amount of time spent by the technician drawing samples.

In addition, 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 Describe the general considerations for selection of an air monitoring method.

SELECTION OF THE AIR SAMPLING METHOD

It is critical that the proper air sampling method and equipment be selected because:

- The data obtained must be meaningful and accurate to adequately assign radiological control measures

- Improper selection and use may incorrectly indicate a safe environment where an airborne radiological hazard exists or leads to unneeded postings where no hazard exists.

The general considerations for the selection of an air sampling method includes several factors.

- The environmental conditions in the area where the sample is to be obtained. Humid conditions may preclude the use of some methods, such as paper filtration devices or charcoal canisters, because water vapor loading of the medium will change the collection efficiency and flow rate. High temperature environments may cause some samplers to overheat if run for long periods of time. Explosive gases may be present which could present an explosion hazard for samplers with electric motors not designed for such environments. Dusty areas could cause excessive sample loading which will reduce sampler flow rates and potentially overheat the sampler. Corrosive environments may lead to the deterioration of the sampling device.

- The physical characteristics of the area in which the sample is to be obtained. An electrical outlet may not be available or close, and a battery powered sampler would be better suited. Close spaces or passages may preclude the use of movable CAMs or heavy samplers.

- The energy and type of radiation of the radionuclide being monitored. This will dictate the type of CAM or analysis equipment required to determine the airborne radioactivity concentration.

- The expected concentration level. This will determine the length of sample time and type of sampler required. Low-level concentrations will require large volumes to reduce statistical errors and meet minimum sensitivity levels of the analysis equipment. Large volume samples obtained over a long time period are best obtained by samplers designed to run for long periods. If immediate readout of information is needed, then collection and analysis are done at the same time. If not, then samples may be taken and removed to a central analysis location.

- The physical state of the airborne contaminant. Dependent upon whether the contaminant is either gas, vapor or aerosol, will dictate the type of sampler and sample medium that is required.

- The type of survey required. Specific methods, such as breathing zone samples, routine general area samples, general work area samples, general area trending over time, etc., also determines the type of equipment that is selected.

- Procedural requirements. This may dictate a particular type of sample method and/or sample medium for a given application. Prior to selection, one should check the appropriate procedures and ask supervision and experienced technicians for their input.

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

PRIMARY TYPES OF AIR SAMPLERS

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

Personal Air Samplers

Personal air samplers (PAS) provide an estimate of the airborne radioactivity concentration in the air the worker is breathing during the sampling period. PAS may also be used to determine if the protection factor for respiratory equipment is exceeded, to compare with other workplace air samples, and to verify the effectiveness of engineered and administrative controls.

PAS are small, portable battery-powered devices which sample the air in the breathing zone of the worker's environment, making allowances to eliminate interferences the samplers themselves may have on a worker's activities. Some characteristics are:

- The device contains a small battery-powered pump that is calibrated to a flow rate approximately 1/10 (2 liters per minute) 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 Samplers

High volume/flow rate samplers provide an estimate of the airborne radioactivity concentration at a particular location in a short period of time. Portable high flow rate samplers are used to collect airborne aerosols on a filter paper (filtration) or on a greased planchet (impaction). Portable high flow rate samplers can also be used to collect radioiodine samples using activated charcoal cartridges (adsorption) as long as the maximum flow rate of the cartridge is not exceeded or a correction factor is used. These samplers do not have installed detectors and the sample must be removed from the sampler and analyzed on separate analysis equipment. The high volume/flow rate samplers may be used to:

- Provide a routine "slice of time" 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 cubic feet per minute (cfm). Although these samplers are noisy and not intended for continuous duty, the shorter sample times allow for greater sensitivity.

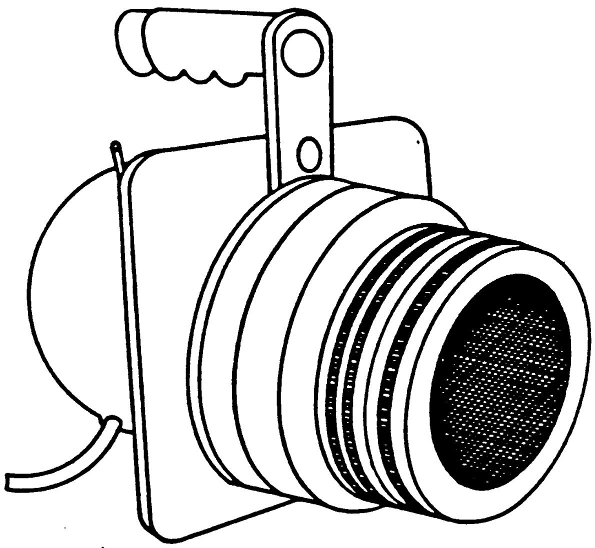

Figure 2 - High Volume Sampler

Low Volume/Flow Rate Samplers

Low volume/flow rate samplers provide an estimate of airborne radioactivity concentrations averaged over a longer period of time at a particular location. Portable low volume/flow rate samplers are used to collect samples for aerosols on filter paper (filtration) and radioiodine on an adsorption medium, such as an activated charcoal cartridge. 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 with 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.

Low volume samplers generally have flow rates set at approximately 20 lpm, 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.

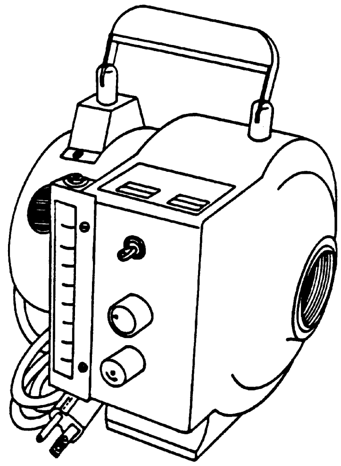

Figure 3
Low Volume Sampler

Portable Continuous Air Monitors

Portable continuous air monitors (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 (filtration), radioiodine activity (adsorption) and noble gas activity (volumetric chamber or in-line detector).

Portable CAMs can be utilized 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.

Installed Continuous Air Monitors

Installed continuous air monitoring systems (CAMs) 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
- Duct monitors

2.06.08 List the factors that affect the accuracy of airborne radioactivity measurements.

Factors affecting the accuracy of airborne radioactivity measurements include:

- Sample is not representative of the atmosphere being sampled
- Sample is not representative of the air being breathed by the worker
- Incorrect or improperly installed sampling media for the selected sampler, causing leak or improper flow rates
- Malfunctioning, miss-operated, or miscalibrated sampling device, causing errors in flow rate measurements
- Accuracy and operation of the timing device, causing errors in the time value
- Accuracy and operation of the flow rate measuring device, causing errors in the flow rate value
- Mishandling of the sample media causing cross-contamination or removal of sample material

- Changes in the collection efficiency of the medium due to sample loading, humidity and other factors

- Improper use or selection of analysis equipment

- Inherent errors in the counting process due to sample geometry, self-absorption, resolving time, backscatter and statistical variations

- Mathematical errors during calculations due to rounding of numbers and simple mistakes

- Incorrect marking of samples and inaccurate recording of data

It is important that the personnel performing the sample collection and analysis minimize the magnitude of these errors to ensure that accurate and reliable data is obtained for the assignment of internal exposure control methods.

BASIC AIR SAMPLE CALCULATIONS

Once the air sample is collected and analyzed, calculations must be performed to determine the amount of activity per unit volume.

The specific calculations for particular sampling methods are not covered in this lesson; however, some basics are necessary for each 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.

- This is especially true for short-lived radionuclides.

- This correction may not be necessary for very long-lived radionuclides.

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 as dpm/liter to µCi/cc.

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

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
- 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 the resulting data is as accurate as possible. Quality assurance that is applied to all phases of the air monitoring program will minimize many errors.

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.*

(Insert site specific material here)

SUMMARY

This lesson has addressed the primary objectives of an airborne radioactivity monitoring program, the physical states of the airborne contaminants, representative air sampling, the general sampling methods, the factors affecting the accuracy of sample collection and analysis, the primary types of samplers, and the proper selection of the air sampling method.

EXAMPLE SOLUTIONS

2.06-1

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

Solution: 1 DAC of tritium gas is 540 mCi/m^3, so 300 mCi/m^3 is 0.55 DAC. 0.55 DAC for 0.5 hours (30 min.) is .275 DAC-hours. One DAC-hr is 2.5 mrem, so .275 DAC-hr is .275 x 2.5, or ~ 0.7 mrem.

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

Solution: 1 DAC is 20 μCi/m^3, so 300 mCi/m^3 is 15,000 DAC for 0.5 hours (30 min.) which is 7,5000 DAC-hours. One DAC-hr is 2.5 mrem, so 7,500 DAC-hrs is 7,500 x 2.5, or 18,750 mrem, or 18.75 rem.

Key Points: Compare the dose received from HTO to the dose received from exposure to the same concentration of tritium gas in the previous exercise. The dose received for this exposure is 27,000 times worse.

Compare the DACs for tritium and plutonium. For Pu-239 the DAC is given in 10CFR835 as 2E-12 mCi/mL or 8E-2 Bq/m^3 List the reasons that inhaling plutonium is more hazardous than tritium.

Confirmation that airborne radioactivity levels are maintained low is accomplished by the airborne radioactivity sampling program. The individual dose equivalent from internal sources is not normally determined from air sampling analysis data, unless bioassay data are unavailable.