Air Sampling in the Workplace

Reg Guide 8.25

NUREG 1400

Learning Objectives

- Describe the principles and practices of air monitoring in the workplace
- Identify the advantages and disadvantages of different sampling devices
- Explain the use of air sampling to demonstrate regulatory compliance

Objectives

- Discuss the *placement* of air sampling equipment in the workplace.

- Discuss methods of determining that sampling is *representative* of inhaled air.

Introduction

Air sampling in the workplace might be performed for one or more of the following reasons:

- To *measure the concentrations* of radioactive material.
- To determine *posting* requirements.
- To determine *effectiveness of engineered controls.*

Introduction

- To *select* appropriate protective *equipment* and measures.
- To *provide warnings* of significantly elevated levels of airborne radioactive materials.
- To *estimate intake* of radioactive materials by workers.
- To meet *regulatory requirements.*

Primary Dose Limits

Population	Dose Limit
Adult Worker	5 rem TEDE 50 rem TODE 15 rem eye dose equivalent
Minor Worker	500 mrem TEDE 5 rem TODE 1.5 rem eye dose equivalent
Member of the Public	100 mrem, with only 10 mrem from airborne emissions
Embryo/fetus of Declared Pregnant Worker	500 mrem during gestation period

Secondary Derived Limits

There are two *secondary* derived limits that are useful for individual dose control and determining compliance with primary dose limits.

- Annual Limit on Intake (*ALI*)
- Derived Air Concentration (*DAC*)

Annual Limit on Intake (ALI)

- The amount of a single radionuclide that if inhaled or ingested would deliver a committed effective dose equivalent (CEDE) of 50 mSv (5 rem) or a CDE 500 mSv (50 rem).

- Values are listed in:
  - NRC regulations: 10 CFR 20, Appendix B.
  - ICRP 30.
  - Federal Guidance Report No. 11.

Derived Air Concentration (DAC)

- The concentration of a single radionuclide in air that if breathed by reference man for a *full working year (2000 hours),* would result in an intake of one ALI.

- Tables of DACs can be found in:
  - NRC regulations: 10 CFR 20, Appendix B.
  - ICRP 30.
  - Federal Guidance Report No. 11.

10 CFR 20, Appendix B

Cobalt-60

			Table 1 Occupational Values			Table 2 Effluent Concentrations		Table 3 Releases to Sewers
			Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	
			Oral Ingestion	Inhalation				
Atomic No.	Radionuclide	Class	ALI (µCi)	ALI (µCi)	DAC (µCi/ml)	Air (µCi/ml)	Water (µCi/ml)	Monthly Average Concentration (µCi/ml)
27	Cobalt-60	W, see ^{55}Co	5E+2	2E+2	7E-8	2E-10	3E-6	3E-5
		Y, see ^{55}Co	2E+2	3E+1	1E-8	5E-11	-	-

10 CFR 20, Appendix B

Iodine-131

Atomic No.	Radionuclide	Class	Table 1 Occupational Values Col. 1 Oral Ingestion ALI (µCi)	Table 1 Col. 2 Inhalation ALI (µCi)	Table 1 Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations Col. 1 Air (µCi/ml)	Table 2 Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers Monthly Average Concentration (µCi/ml)
53	Iodine-131	D, all compounds	3E+1 Thyroid	5E+1 Thyroid	2E-8	-	-	-
			(9E+1)	(2E+2)	-	2E-10	1E-6	1E-5

Secondary Derived Limits

ALI and DAC values may be used to *determine the individual's dose* and to *demonstrate compliance* with the occupational dose limits. (20.1201(d))

ALI

- Stochastic ALI:

$$\frac{\text{Intake Amount}}{\text{ALI}}(5\text{ rem}) = \text{Dose}$$

- Non-stochastic ALI:

$$\frac{\text{Intake Amount}}{\text{ALI}}(50\text{ rem}) = \text{Dose}$$

Example

If a worker inhaled 100 μCi of Co-60 metal, what is the CEDE?

$$\frac{100\ \mu Ci}{200\ \mu \text{Ci}}(5\ \text{rem}) = 2.5\ \text{rem}$$

Example

If a worker inhaled 100 μCi of I-131, what is the CDE to the thyroid?

$$\frac{100\ \mu Ci}{50\ \mu\mathrm{Ci}}(50\ \mathrm{rem}) = 100\ \mathrm{rem}$$

DAC

- The *DAC fraction* is also used to control and assess dose.

- It is calculated by the following formula:

  DAC fraction = airborne concentration/DAC

  DAC fraction x stay time (hr) = DAC-hrs

  2000 DAC-hrs = 1 ALI

DAC

- The product of the DAC fraction and the exposure (stay) time in hours is *DAC-hrs*.

- Dose is easily determined by multiplying DAC-hrs by:
  - *2.5 mrem/DAC-hr* for a stochastic DAC value, or
  - *25 mrem/DAC-hr* for a nonstochastic DAC value

DAC

Stochastic DAC:

$$\text{Dose} = \left(\frac{\text{Airborne Concentration}}{\text{DAC}}\right)(\text{Stay Time (hrs)})\left(\frac{2.5\text{ mrem}}{\text{DAC} - \text{hr}}\right)$$

Non-stochastic DAC:

$$\text{Dose} = \left(\frac{\text{Airborne Concentration}}{\text{DAC}}\right)(\text{Stay Time (hrs)})\left(\frac{25\text{ mrem}}{\text{DAC} - \text{hr}}\right)$$

Example

A worker is in a room for 4 hours at a concentration of 6 x 10^{-6} μCi/ml I-131. What is the CDE to the thyroid?

$$\left(\frac{6 \text{ x } 10^{-6}\ \mu Ci/ml}{2 \text{ x } 10^{-8}\ \mu Ci/ml}\right)(4 \text{ hrs})\left(\frac{25 \text{ mrem}}{\text{DAC} - \text{hr}}\right) = 30{,}000 \text{ mrem}$$

Determining the Need for Air Sampling

- *Monitoring* of a worker's intake is required if the intake is likely to exceed *10% of the ALI.* (10 CFR 20.1502)

- For many workers, intakes will never approach 10% of the ALI.

- To meet this requirement, licensees have to estimate whether *projected airborne concentrations* may be high enough that workers are likely to exceed 10% of an ALI.

Determining the Need for Air Sampling

- If possible, estimates of potential intakes should be based on historical air sampling and bioassay data.

- Reg. Guide 8.25 and NUREG 1400 recommend a method to determine the need for air sampling when that data is not available.

Determining the Need for Air Sampling

- First the *total quantity Q* of unencapsulated radioactive material is estimated.

- All potential radionuclides and amounts that may be used are to be considered in the estimate.

Determining the Need for Air Sampling

- If more than one radionuclide is present, the *"sum of the fractions"* method can be used.

- Reg. Guide 8.25 recommends that licensees who handle quantities of unsealed radioactive materials > *10,000 times the ALI for inhalation* evaluate the need for air sampling.

Determining the Need for Air Sampling

- Next, an estimate of the *potential intake* (I_p) by a particular worker or group of workers is completed.

- NUREG 1400 suggests that the potential (I_p) intake be estimated at *one millionth* (1×10^{-6}) of the amount of unencapsulated radioactive material in the work location during 1 year or $Q \times 10^{-6}$.

Air Sampling Recommendations

Recommendations are then based on the ratio of the potential intake to the inhalation ALI or *intake fraction* (I_f).

Example: (unmodified)

- A lab technician makes up I-125 injections in a fume hood.

- The maximum activity that is prepared at one time, and on average, once per week is 10 mCi.

Example: Unmodified

$$Q = (10\ \text{mCi})\ (50\ \text{weeks})(\frac{1\ \text{Ci}}{1000\ \text{mCi}}) = 0.5\ \text{Ci of I-125}$$

$$I_p = 0.5\ \text{Ci x}\ 10^{-6}$$

$$\text{ALI}_{\text{I-125}} = (60\ \mu\text{Ci})(\frac{1\ \text{Ci}}{1\ \text{x}\ 10^{6}\ \mu\text{Ci}}) = 6\ \text{x}\ 10^{-5}\ \text{Ci}$$

$$I_f = \frac{0.5\ \text{Ci x}\ 10^{-6}}{6\ \text{x}\ 10^{-5}\ \text{Ci}} = 0.0083$$

From Reg Guide 8.25, pg. 3

Air Sampling Recommendations Based on Estimated Intakes and Airborne Concentrations		
Worker's estimated annual intake as a fraction of the ALI	Estimated airborne concentrations as a fraction of DAC	Air Sampling Recommendations
<0.1	<0.01	Air sampling is generally not necessary. However, monthly or quarterly grab samples or some other measurement may be appropriate to confirm that airborne levels are indeed low.

Determining the Need for Air Sampling

The potential intake (I_p) can be *modified by factors* such as:

- The *release fraction, R* based on the physical form and use.
- The *type of confinement, C* for the material.
- The *dispersibility, D* of the material.

Determining the Need for Air Sampling

- The modified potential intake I_p will then be:

$$I_p \text{ (unmod) } x \text{ R } x \text{ D } x \text{ C}$$

- Release fractions, confinement factors and dispersibility factors are available in NUREG 1400.

Release Fractions

Physical Form	Release Fractions
Gases or volatile material	1.00
Non volatile powders	0.01
Solids (uranium fuel pellets, cobalt, or iridium metal)	0.001
Liquids	0.01
Encapsulated material	0

Confinement Factors

Type of confinement	Confinement Factors
Glovebox	0.01
Well-ventilated hood	0.1
Open work area	1.0

Dispersibility Factors

Process	Dispersibility Factors
Cutting	10
Grinding	10
Heating	10
Chemical Reactions	10

Determining the Need for Air Sampling

Therefore, the potential intake for a nonvolatile powder (R = 10^{-2}) that is being ground (D = 10) in a glovebox (C = 10^{-2}) would be: 10^{-3} of that for a non-volatile material in an open work area

Example: Modified

- In the manufacturing of uranium fuel, sintered pellets of U_3O_8 are ground to a uniform diameter.
- The grinding is mostly an automated dry process.
- The apparatus is contained in a well-ventilated shroud, but not glovebox tight.

Example: Modified

- Annual throughput for a grinding station = 170 Ci
- $ALI_{U\text{-}238}$ = 0.04 µCi
- R = 10^{-3} (solid fuel pellets)
- C = 10^{-1} (hood value)
- D = 10 (grinding)

Example: Modified

$$Q = 170\ \text{Ci of } U_3 0_8$$

$$I_p = (170\ \text{Ci x } 10^{-6})(10^{-3})(10^{-1})(10) = 1.7\ \text{Ci x } 10^{-7}$$

$$ALI_{U_3 0_8} = (.04\ \mu\text{Ci})(\frac{1\ \text{Ci}}{1 \text{ x } 10^{6}\ \mu\text{Ci}}) = 4 \text{ x } 10^{-8}\ \text{Ci}$$

$$I_f = \frac{1.7\ \text{Ci x } 10^{-7}}{4 \text{ x } 10^{-8}\ \text{Ci}} = 4.25$$

From Reg Guide 8.25, pg. 3

Air Sampling Recommendations Based on Estimated Intakes and Airborne Concentrations		
Worker's estimated annual intake as a fraction of the ALI	Estimated airborne concentrations as a fraction of DAC	Air Sampling Recommendations
>0.1	>0.3	Monitoring of intake by air sampling or bioassay is required by 10 CFR 20.1502(b). A demonstration that the air samples are representative of the breathing zone air is appropriate if (1) intakes of record will be based on air sampling and (2) concentrations are likely to exceed 0.3 DAC averaged over 40 hours.

Types of Air Samplers

- Lapel Samplers
- Portable Samplers
  - Low Volume
  - High Volume
- Fixed Location Samplers
- Air Monitors

Lapel Samplers

Lapel samplers are worn by the worker, with the filter holder worn on or near the shirt collar and the battery powered vacuum pump worn on the belt.

From Gillian

Lapel Samplers

From F&G Speciality Products

Lapel samplers may be the best method of estimating *breathing zone concentrations* because they are located close to the worker's nose and mouth.

Lapel Samplers

- A primary problem is that they have a *low flow rate (2 L/min),* which may make them unsuitable for airborne radioactivity areas.

- The low flow rate problem can be overcome by:
  - Collecting the sample for a longer time.
  - Using a more sensitive counting system.

Lapel Samplers

- Other problems with lapel samplers included:
  - Problems with contamination
  - Expense
  - Worker acceptance

- In spite of the problems, lapel samplers still may be the best method for determining intakes.

Lapel Samplers

The most common causes for failures include:

- Battery failure (improper charging)
- Debris
- Leakage caused by vibration
- Fatigue in valve diaphragms
- Mechanical failures (rotary vane, pump, or motor)

Portable Samplers

- *Portable air samplers* are usually used in facilities where the *location of airborne radioactivity changes* frequently, such as nuclear power plants.

- Because they are portable, they can be located *close to the worker.*

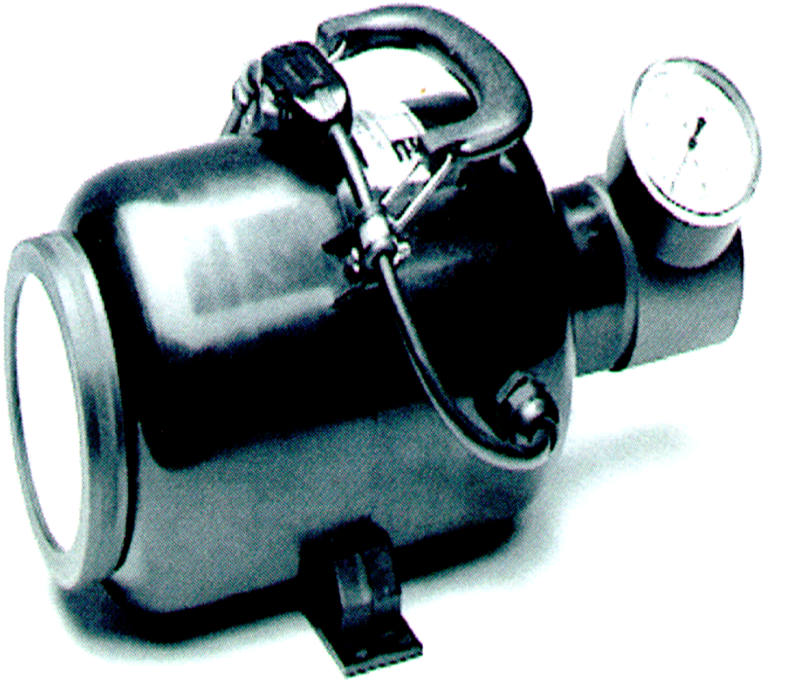
Portable Samplers

Portable air samplers are available as:

- Rugged AC samplers.
- Battery powered air samplers with air volume totalizers.
- Constant airflow samplers on goosenecks.

Portable Samplers

Portable samplers are categorized by their airflow rates as *low-volume or high volume* samplers.



Portable Samplers

LV-14M
Breathing Zone Air
Samplers

For *breathing zone* sampling, *low-volume samplers* are used, with flow rates from 28 to 56 L/min.

Fixed Location Samplers

Fixed location samplers or *general air samplers* are used for various purposes (detect release, intakes) and can be used to collect continuous or grab samples.

Air Monitors

- *Air monitors* are designed to prevent workers exposure to *higher than expected* levels of airborne radioactive materials.

- The *early warning* is provided by:
  - Prompt sample analysis.
  - Continuous monitoring in real time.

Types of Air Samples

- Air sampling may be *continuous or intermittent* (grab samples).

- Continuous samples are typically *exchanged on a weekly basis*.

Types of Air Samples

- *Grab sampling* for continuous processes may be collected on a *weekly basis*, or less frequently if concentrations are extremely low.

- Grab sampling is also performed for intermittent processes.

Location of Air Samplers

- The *purpose* of the air sample and *airflow patterns* will dictate the location of the air sampler.

- In general, air samples should be collected in airflow pathways *downstream* of release points.

Location of Air Samplers

- To verify the *effectiveness of confinement* or to provide warning of elevated concentrations, the sampling point should be located in the airflow *near the release point.*

- More than one sampler may be necessary.

Location of Air Samplers

- To determine release of material *outside the laboratory*, the sampler should be located *near the exhaust point.*

- Air samplers may be installed slightly *above head height* and *in front of the worker* on the *front face of a hood.*

Purpose of Sampling	General Placement of Sampler
Estimate worker’s intake	Sampler in BZ
Identify area needing confinement control	Sampler in airflow pathway near release
Provide early warning	CAM between workers and release
Test for leakage from sealed confinement	Samplers downstream of confinement
Determine total concentration from many release points	Downstream at exhaust point
Determine airborne radioactivity area	Samplers at workers’ locations
Special purpose (particle size)	Case by case, depending on airflow

Using Air Concentrations (Reg Guide 8.25)

- If air sampling is to be used to *assess worker intakes,* then each frequently occupied work location should have its own air sampler.

- The air samplers should be placed *as close to the breathing zone (BZ)* of the worker as practical.

Using Air Concentrations (Reg Guide 8.25)

- The *breathing zone* is the area about *12 inches around the head.*

- When air sampling results will be used to determine the intake and *dose of record,* the licensee may have to demonstrate that the sampled air *represents* the worker's BZ air.

Using Air Concentrations (Reg Guide 8.25)

If *all* of these conditions are met, the licensee *should demonstrate that the sampled air is representative* of the BZ:

- Monitoring is required
- Annual intake is likely to exceed 0.1 ALI
- Intake of record will be based on air sampling
- Exposure is in an airborne radioactivity area likely to exceed 12 DAC-hours/wk
- Lapel samplers are *not* used

Using Air Concentrations (Reg Guide 8.25)

Representativeness can be demonstrated by comparing air sampling results with:

- Lapel sampler results.
- Bioassay results.
- Multiple air samples near the BZ.
- Quantitative air flow studies.

Using Air Concentrations (Reg Guide 8.25)

- If results show that the sampled air is *not* representative of the worker's BZ, the licensee may need to:
  - Relocate samplers.
  - Switch to lapel sampling.
  - Use bioassay to assess intake.

- *Corrections* should be made to intake estimates made within the last year and subsequent to the previous demonstration of representativeness.

Using Air Concentrations (Reg Guide 8.25)

- The licensee may use the specific physical and biochemical properties of the radionuclides taken into the body to calculate CEDE, but shall document that information in the individual's dose record. 20.1204 (c).

- The licensee may request (prior) approval from the NRC to adjust ALI and DAC values to reflect actual physical and chemical characteristics of airborne radioactive material (e.g. aerosol size distribution, solubility) 20.1204 (c)(2).

References

- NUREG 1400, Air Sampling in the Workplace, US Nuclear Regulatory Commission, Washington, DC, 1993.
- Reg Guide 8.25, Air Sampling in the Workplace, US Nuclear Regulatory Commission, Washington, DC, 1992.
- 10 CFR Part 20, Standards for Protection Against Radiation, US Nuclear Regulatory Commission, Washington, DC, 1998.