

Air Sampling Introduction

10/25/2010

Purpose of Air Sampling

1. Evaluate exposures to the public and workers.
2. Document measures used to control airborne concentrations.
3. Warn workers of unexpected releases.
4. Assist in materials balancing.
5. As part of a respiratory protection program.
6. Satisfy regulatory and/or license requirements.
7. Obtain data for use in potential litigation.

General Terminology

Form of Airborne Radioactive Material

The radioactive material being collected may be present in one of two forms.

1. Particulates (could be collected on a filter)
2. Gases and vapors (would not be collected on a filter)

Form of Airborne Radioactive Material

Particulates

A collective term describing airborne solids and liquid droplets. There are several ways to categorize particulates:

- a) Aerosol. This term is used in various ways, usually as a synonym for airborne particulate. Occasionally it only refers to particulates that are in a stable or quasi-stable suspension in air.
- b) Dusts. Particulates produced by the disintegration of material during mechanical processes such as grinding. Dusts are usually larger than one micron (μm) in size.
- c) Fumes. Particulates produced by chemical reactions, e.g., oxidation. They may condense from the gaseous state after the volatilization of melted substances. The typical size range for fumes would be 0.1 - 1.0 μm .

Form of Airborne Radioactive Material

Particulates

- d) Smoke. Small particulates (ca. 0.5 μm) resulting from the incomplete combustion.
- e) Mists and Fogs. Liquid droplets produced by condensation. In the 5 - 40 μm range the particulates are referred to as fog. Particulates above 40 μm in diameter are referred to as mists.

Form of Airborne Radioactive Material

Gases and Vapors

Gases can be defined as materials that under normal conditions exist in the gaseous phase.

Vapors are the gaseous phase of substances typically existing as a liquid or solid at room temperature.

Sampling vs. Monitoring

Sampling

“Air sampling” generally means a sample is collected over a finite period of time and sent to the laboratory for analysis.

A grab sample is collected in a short period of time (e.g., < 10 minutes) at a specific location. It is not used to determine an average concentration. Instead, it is usually collected to see if anything is there. In some cases repetitive grab samples might be used to evaluate temporal fluctuations of some sort.

Sampling vs. Monitoring

Monitoring

“Monitoring” usually indicates a “real time” analysis is being performed. In the DOE literature however, the term “monitoring” has no specific meaning.

Air sampling systems that perform a real-time analysis of airborne radioactive material are generally referred to as continuous air monitors (CAMs). Their primary purpose is to alert workers to unexpected releases rather than to make accurate measurements of the concentration. Most CAMs involve a “sampling” system of some sort.

Nuclide-Specific vs. Gross Activity Measurements

The concentration of airborne radioactive material might be determined:

1. For a specific radionuclide (e.g., I-131), or
2. As a gross alpha or beta concentration

Although gross beta and alpha measurements are more common, nuclide-specific (isotopic) analyses are preferred.

When gross alpha or gross beta measurements are performed, some method must be employed to correct for the contributions from the naturally occurring radon and thoron decay products.

Representative Sample

In some cases, the goal is to collect a representative sample, i.e., a sample whose characteristics are identical to the atmosphere being analyzed.

In most cases, this is accomplished if the concentration in the sampled air reflects the average ambient concentration.

Difficult Radionuclides to Assess

There are two general categories of radionuclides that are sufficiently difficult to collect and analyze, that we often make no attempt to do so:

- Noble gases (e.g., at nuclear power plants)
- Very short-lived nuclides (e.g., at accelerators)

One approach to “assess” such nuclides is to measure the ambient levels of gamma and/or beta radiation with detectors (e.g., GMs) or passive dosimeters (e.g., TLDs). In general, these methods cannot distinguish the device’s response to the radionuclides of interest from its response to background.

Characteristics of Airborne Radioactive Material that Affect Dose

Characteristics that Affect Dose

Three characteristics of the airborne radioactive material affect the dose due to inhalation:

1. Concentration
2. Particle size
3. Clearance class

Characteristics that Affect Dose

1. Concentration

The focus of air sampling is usually to quantify the concentration of the airborne radioactivity, e.g., uCi/ml, pCi/m³, Bq/m³.

In some cases, we simply want to determine if there has been an increase in the concentration rather than to quantify it.

Characteristics that Affect Dose

2. Particle Size

The dose depends on particle size because the size determines the region of the respiratory system that the particles are deposited in.

The size of radioactive particulates is usually expressed as their activity median aerodynamic diameter (AMAD). The AMAD describes the aerodynamic behavior of the particulates rather than their physical size. The term thermodynamic diameter (AMTD) rather than aerodynamic diameter (AMAD) is sometimes used to describe submicron particles whose deposition is due to diffusion rather than impaction or gravitational settling.

Characteristics that Affect Dose

2. Particle Size

For regulatory purposes in the U.S., the usual assumption is that airborne particulates have an AMAD of 1 μm .

The current ICRP recommendation is that a 5 μm size is assumed for particulates in the workplace and that 1 μm be assumed for the environment (public exposures).

In the workplace, 5 μm is probably a more realistic value than 1 μm .

Characteristics that Affect Dose

2. Particle Size

The AMAD does not describe a physical size of the particles, it describes their aerodynamic behavior. Furthermore, it only describes the radioactive particles.



AMAD means “Activity Median Aerodynamic Diameter”₁₈

Characteristics that Affect Dose

3. Clearance Class

Different chemical compounds are cleared from the lung at different rates. The rate at which they are cleared can be described in terms of a half time. On the basis of a compound's half time in the pulmonary region, ICRP 30 assigns it to one of three clearance classes:

Class D materials (half time less than 10 days) -
essentially equivalent to ICRP 60 class F

Class W materials (half time of 10 - 100 days) -
essentially equivalent to ICRP 60 class M

Class Y materials (half time longer than 100 days) -
essentially equivalent to ICRP 60 class S

Characteristics that Affect Dose

3. Clearance Class

This classification is based on chemistry and is independent of the radionuclides half-life. A radionuclide with a 5 minute half life can still be placed in clearance class Y.

In general, the longer the clearance half time the greater the dose and the lower the ALI.

Listings of the ALIs (e.g., 20 CFR 20, Federal Guidance Report 11) identify which radionuclides and compounds are assigned to the various clearance classes. If the chemical form of the radioactive material is not known, the most restrictive class is assumed.

Characteristics that Affect Dose

3. Clearance Class

Pt. 20, App. B

10 CFR Ch. I (1-1-09 Edition)

Atomic No.	Radionuclide	Class	Table 1 Occupational Values			Table 2 Effluent Concentrations		Table 3 Releases to Sewers
			Col. 1 Oral Ingestion ALI (μCi)	Inhalation		Col. 1 Air ($\mu\text{Ci}/\text{ml}$)	Col. 2 Water ($\mu\text{Ci}/\text{ml}$)	Monthly Average Concentration ($\mu\text{Ci}/\text{ml}$)
				Col. 2 ALI (μCi)	Col. 3 DAC ($\mu\text{Ci}/\text{ml}$)			
14	Silicon-31	D, all compounds except those given for M and Y	9E+3	3E+4	1E-5	4E-8	1E-4	1E-3
		M, oxides, hydroxides, carbides, and nitrates	-	3E+4	1E-5	5E-8	-	-
		Y, aluminosilicate glass	-	3E+4	1E-5	4E-8	-	-
14	Silicon-32	D, see ^{31}Si	2E+3	2E+2	1E-7	3E-10	-	-
		LLI wall (3E+3)	-	-	-	-	4E-5	4E-4
		M, see ^{31}Si	-	1E+2	5E-8	2E-10	-	-
	Y, see ^{31}Si	-	5E+0	2E-9	7E-12	-	-	

Where We Perform Air Sampling

Where We Perform Air Sampling

There are three locations where air sampling is performed:

1. Workplace
2. Stack (effluents)
3. Environment.

Where We Perform Air Sampling

Workplace

Fixed air samplers (FAS) are used if the concentration in the area frequently has the potential to become excessive, e.g., near glove boxes

Portable samplers are used to obtain short-term samples in areas that don't require continuous sampling, e.g., areas where radioactive material is occasionally handled.

General air (GA) samples estimate the average concentration in the room. Sampling near the room air exhaust grill is a good way to obtain a representative sample to calculate the average room concentration.

Where We Perform Air Sampling

Workplace

Breathing zone (BZ) samples are collected to determine the concentration in the air inhaled by the worker. This is usually higher than the room average concentration because the worker is typically close to the source of airborne contamination.

BZ samplers, might have the filter holder attached to the collar with the pump and flow meter attached to the belt. and. Such devices are referred to as personal air monitors (PAMs) or lapel air samplers.

Where We Perform Air Sampling

Workplace

Unfortunately, the sampling flow rates of these types of BZ samplers might be so low that there is no measurable collected activity.

Due to a lack of worker acceptance, they are rarely worn continuously.

Sometimes, a fixed air sampler is used to estimate the concentration in the “breathing zone.” When this is done, the sampling head is usually located in front of, and just above, the worker’s head.

Where We Perform Air Sampling

Workplace

Continuous air monitors (CAMs) are real-time monitors that warn the worker to leave the area in the event of an unexpected release. They are not used to calculate average concentrations.

False alarms caused by airborne radon decay products is a common problem with CAMs.

Improper placement of a CAM might cause accidental releases of airborne contaminants to go undetected. This is especially true with short-term “puff” releases (e.g., as opposed to gradual releases caused by a leak).

Where We Perform Air Sampling

Workplace



Continuous Air Monitor (CAM)

Portable Air Sampler



Where We Perform Air Sampling

Stack/Effluent

Stack sampling is usually (but not always) continuous with the samples analyzed on a daily or weekly basis.

One problem is ensuring that a representative sample of the particulates is collected on the filter. This can be difficult because of the highly dynamic flow of air in stacks which affects the distribution of particulates in the effluents.

The methodology employed for stack sampling is generally that described in Appendix A of ANSI N13.1 (1969). In some cases, it is necessary to employ the methodology in the latest version of ANSI N13.1 (1999).

Where We Perform Air Sampling

Stack/Effluent - ANSI N13.1 (1969)

Describes how to sample stacks.

Requires “isokinetic sampling” be performed for particulates. In isokinetic sampling, the velocity of the air/gas entering the nozzle is the same as it is at that point in the stack in the absence of sampling equipment.

In subisokinetic sampling the velocity entering the nozzle is lower than isokinetic. The theory is that we would overestimate the activity associated with the particulates, especially the large particulates.

Where We Perform Air Sampling

Stack/Effluent - ANSI N13.1 (1969)

In superisokinetic sampling the velocity entering the nozzle is faster than isokinetic. The theory is that we would underestimate the activity associated with the particulates, especially the large particulates.

The standard also recommends sampling probe be used with multiple withdrawal points.

Where We Perform Air Sampling

Stack/Effluent - ANSI N13.1 (1999)

Sets performance criteria, does not describes how to sample.

Does not require “isokinetic” sampling.

Recommends probes with single point extraction.

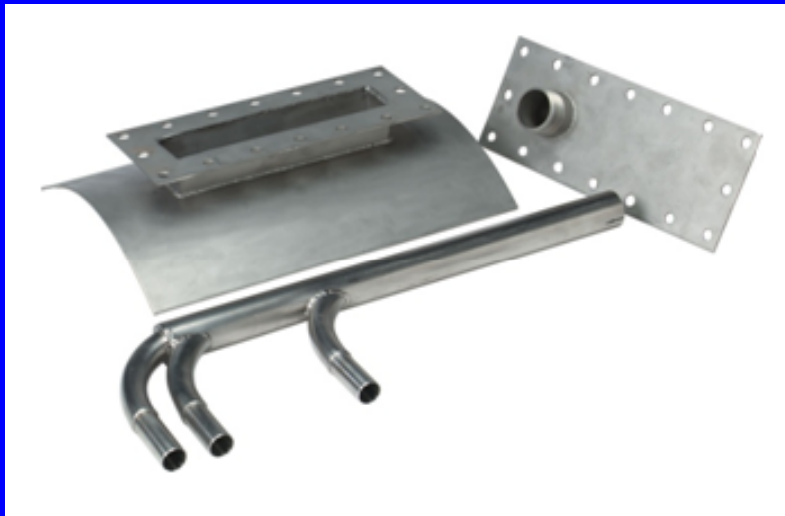
Requires flat air velocity profile at sampling point.

Requires tracer studies with gases and 10 um particulates to demonstrate complete mixing at sampling point.

Expensive to implement.

Where We Perform Air Sampling

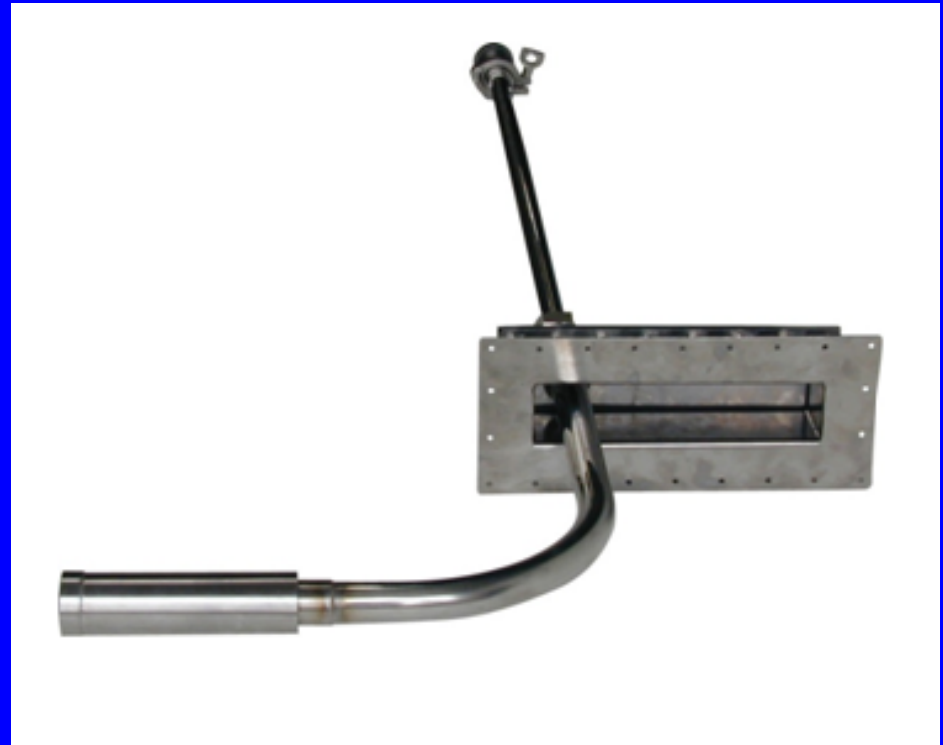
Stack/Effluent



Multi-point withdrawal
"rake"

ANSI N13.1 1969

Images courtesy of Hi-Q



Single-point withdrawal
"shrouded probe"

ANSI N13.1 1999

Where We Perform Air Sampling

Environment

Airborne concentrations in the environment are low. This requires long sampling times at high flow rates. The two most common approaches:

1. Gross alpha and/or beta analysis after sampling (low vol) for one week at 1 - 2 cfm through a 47 mm filter
2. Nuclide specific analysis after sampling for one week at 40 cfm (high vol) through an 8 x 10 inch filter

Problems can include the collection of large quantities of dust and other non-radioactive particulates, selecting appropriate sampling locations and maintaining equipment at remote sites.

Where We Perform Air Sampling

Environment – low vol sampler



Shelter for sampler known as a “dog house”

Where We Perform Air Sampling

Environment – high vol sampler



Solar powered systems are available.

Images courtesy of Hi-Q



How We Perform Air Sampling - Equipment

How We Perform Air Sampling - Equipment

Equipment Overview

A basic sampling system consists of an:

Air filter - to collect particulates

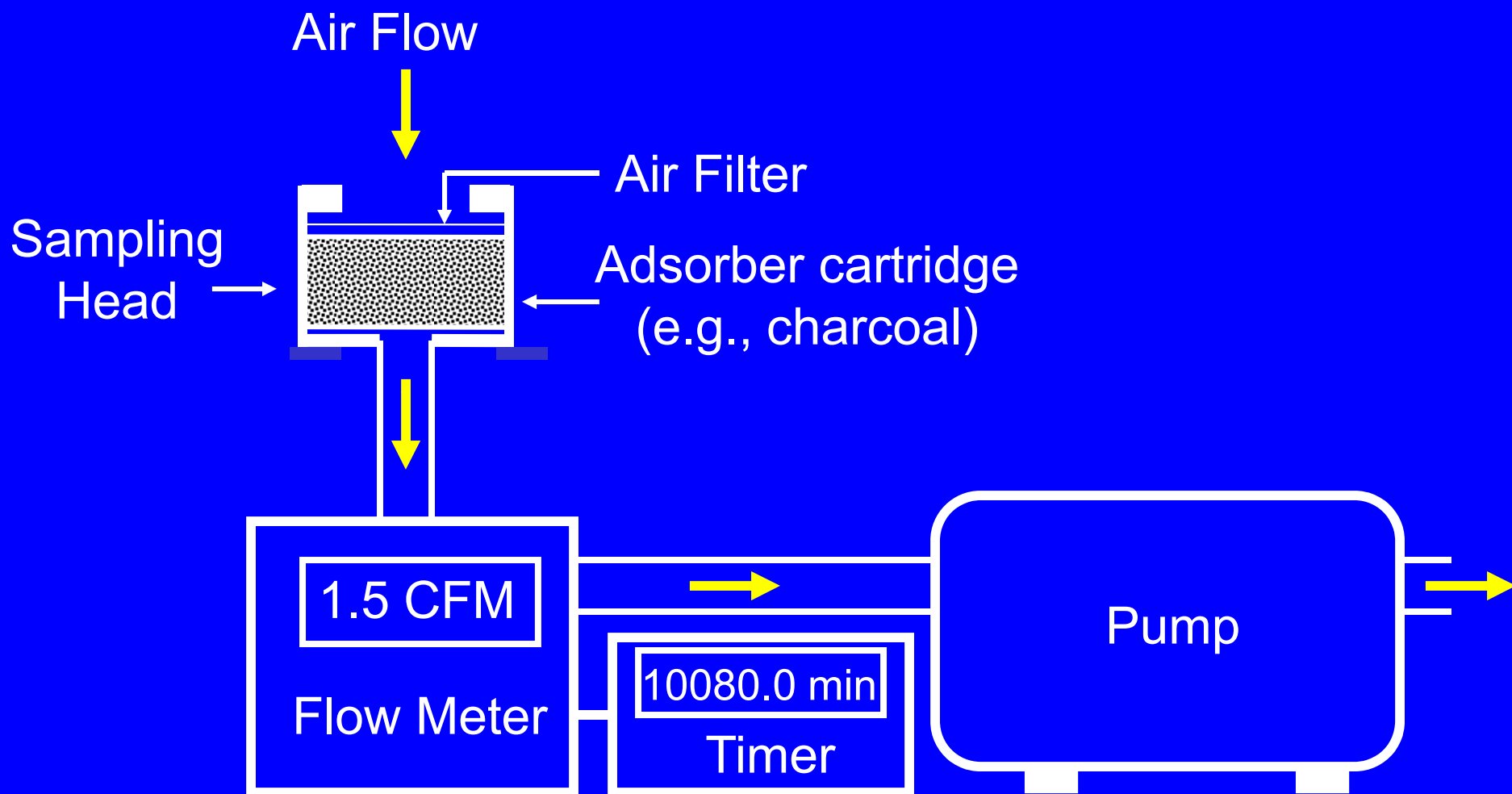
Flow meter - to determine sampling flow rate or volume,

Elapsed timer - to determine sampling duration

Pump – to move the air through the sampler

If it is necessary to collect gases or vapors, additional components are required, e.g., adsorber cartridge or bubbler.

How We Perform Air Sampling - Equipment



How We Perform Air Sampling - Equipment

Filters - General

A filter is the most common device employed to collect particulates.

Occasionally, a device known as an impactor is used instead.

The three major types of filters are:

- Membrane
- Glass fiber
- Cellulose

How We Perform Air Sampling - Equipment

Filters - Membrane Filter

- surface loading filter primarily used with alpha emitters
- typical pore sizes: 3 or 5 μm
- high collection efficiency not affected by flow rate
- easily digested
- goes transparent in LSC cocktail
- accumulation of dust results in increased resistance to air flow
- fragile

How We Perform Air Sampling - Equipment

Filters - Glass Fiber Filter

- the collection (up) side is irregular and wavy
- an accumulation of dust has minimal effect on the filter's resistance to air flow. This makes it useful in dusty atmospheres and it is often used for environmental sampling
- for most types of glass fiber filters, their collection efficiency is not affected by flow rate
- burial losses of alpha particles and low energy beta particles is minimal
- more rugged than membrane filters but still somewhat fragile
- very hard to digest for radiochemical analysis

How We Perform Air Sampling - Equipment

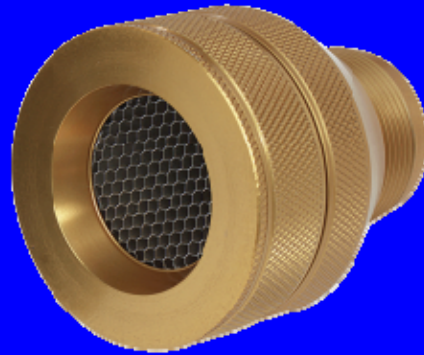
Filters - Cellulose Filter

- Whatman 41 is the most common cellulose filter used for sampling radioactive particulates although Whatman 42 might be a superior choice.
- rugged
- easily digested for radiochemical analysis
- particulates collected throughout depth of filter - burial losses of alpha particles and low energy beta particles are significant (e.g., 50%)
- accumulation of dust on the filter results in increased resistance to air flow
- collection efficiency is affected by flow rate - the filter face velocity should exceed 90 cm/s or so

How We Perform Air Sampling - Equipment

Open Face
Sampling Head

In-line Sampling



Open face
sampling head
with filter and
charcoal
cartridge



Images courtesy of Hi-Q

How We Perform Air Sampling - Equipment

Cassette for 8" x 10" air filters used in high volume air sampling

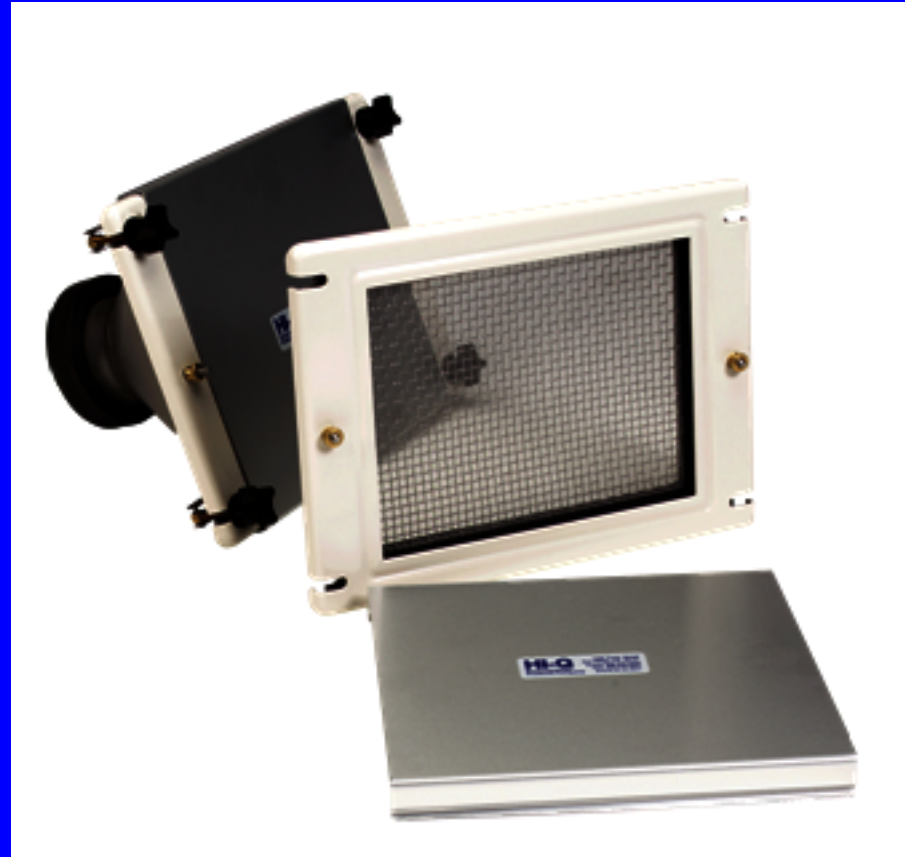


Image courtesy of Hi-Q

How We Perform Air Sampling - Equipment

Collecting Gases/Vapors

The primary methods used to collect gases and vapors:

- Adsorption
- Absorption
- Condensation

How We Perform Air Sampling - Equipment

Collecting Gases/Vapors - Adsorbers

Adsorbers are solid granules with large surface areas that are packed in cartridges or tube.

Examples: Indicating silica gel for tritiated water vapor

 Molecular sieve for tritiated water vapor

 Activated charcoal for iodine

 Silver zeolite for iodine

How We Perform Air Sampling - Equipment

Collecting Gases/Vapors - Adsorbers

Typical adsorber cartridges – note arrow indicating air direction



How We Perform Air Sampling - Equipment

Collecting Gases/Vapors - Absorbers

Absorbers are liquids that preferentially dissolve the gas/vapor of interest when the sampled airstream is bubbled through the solution. The “containers” used to hold the absorbing solutions are known as bubblers and impingers.

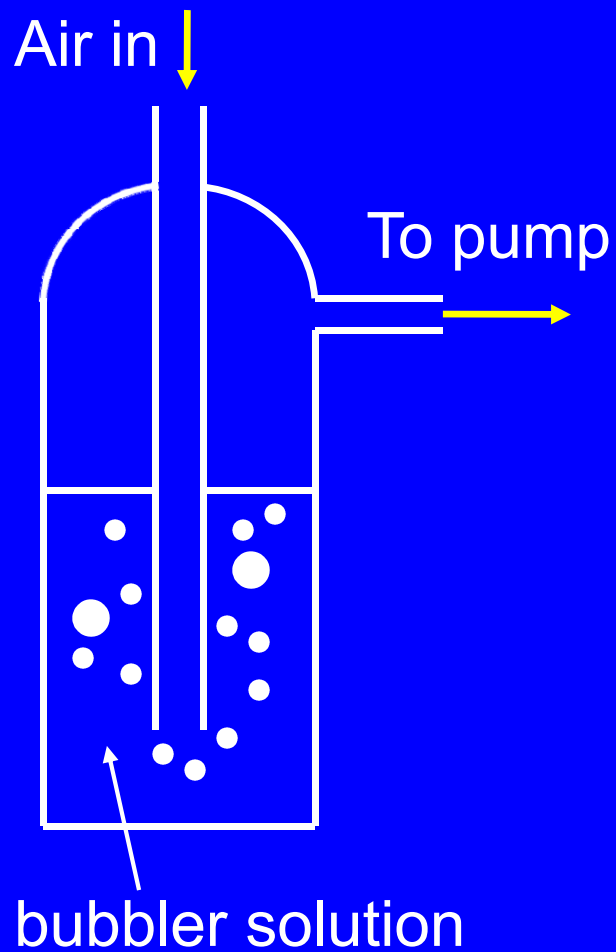
Examples of absorbing solutions:

- Distilled water for tritiated water vapor (HTO)
- Ethylene glycol for tritiated water vapor (HTO)
- Hydrogen peroxide for sulfur dioxide (e.g., S-35)
- Sodium hydroxide for carbon dioxide (e.g., C-14)

Analysis usually involves counting one ml of the solution by LSC.

How We Perform Air Sampling - Equipment

Collecting Gases/Vapors - Absorbers



How We Perform Air Sampling - Equipment

Flow Meter - General

The flow meter measures the volumetric flow rate of the sampler (e.g., cfm, lpm, ml/min), and/or the total volume of the sample (e.g., cubic feet, liters, mls, m³).

The most commonly employed flow rate meters are the rotameter and a very similar device, the by-pass rotameter

Another method to determine the flow rate is to measure the pressure drop across a constriction in the sample line (e.g., venturi or orifice meter).

How We Perform Air Sampling - Equipment

Flow Meter - Rotameters



Standard rotameter



By-pass rotameter
Image courtesy of Hi-Q

How We Perform Air Sampling - Equipment

Flow Meter - Total Volume Meter

The most commonly employed total volume meter is the dry gas meter, sometimes used in combination with a flow rate meter.

At some facilities, a total volume meter is used to measure the flow rate at the beginning and end of sampling. This is done by measuring the time it takes for a given volume of air to be sampled. To calculate the flow rate (e.g., 2.5 cfm), the volume of air (e.g., 5 cubic feet) is divided by the time it took to collect that volume (e.g., 2 minutes).

How We Perform Air Sampling - Equipment

Flow Meter - Mass Flow Meter

The mass flow meter is an electronic device that can be used to simultaneously measure flow rate and the total volume of air that has been sampled.

The mass flow meter has the advantage that it measures the flow rate and volume at standard temperature and pressure (e.g., scfm, slpm, etc.) conditions.

How We Perform Air Sampling - Equipment

Flow Meter – Calibration

Flow meters must be calibrated at least once per year and after any maintenance or adjustment that might affect the flow meter response. This involves relating the instrument read out (e.g., cfm, lpm, inches of water) to the actual flow rate.



Images courtesy of Hi-Q

How We Perform Air Sampling - Equipment

Elapsed Timer

Air sampling systems used for short periods (e.g., 10 minutes) might not employ an elapsed timer - the sample time might be measured a watch. Systems operating unattended for long periods require an elapsed timer.

Discrepancies in the clock time and the elapsed timer time should be explained. The DOE *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE 0173T)* indicates that an elapsed timer is not required if a total volume meter is employed.

How We Perform Air Sampling - Equipment

Elapsed Timer

The elapsed timer might be resettable or non-resettable, and mechanical or electronic. With a resettable timer, the reading is set back to zero at the beginning of each sampling period. This reduces the chance that the timer will be misread and eliminates the need for a mathematical calculation (subtraction). Unfortunately, the time indicated by a resettable timer can be erased accidentally.

Almost all new timers are electronic. In general, they are more prone to failure than the older mechanical designs, especially in extreme temperatures.

How We Perform Air Sampling - Equipment

Elapsed Timer

Periodic accuracy checks need to be performed on the timers. Regulatory Guide 8.25 recommends that the timer's error be under 1% (approximately 14 minutes/24 hrs) while DOE recommends that the timer reading be correct within two minutes/24 hours. For such calibrations, the signals from the NIST atomic clock in Colorado could be employed.

It is useful to have some means of alerting people when the sampling system has shut down. This might be done with a warning light or a more elaborate system whereby a signal is sent to some monitoring location or cell phone number.

How We Perform Air Sampling - Equipment

Pump

There are two major categories of “pump”:

Positive Displacement Pump (low volume sampler)

Centrifugal Blower/Fan (high volume sampler)

To maintain a constant flow rate during the sampling period, many air sampling systems incorporate an air flow controller.

How We Perform Air Sampling - Equipment

Positive Displacement Pump

For low volume (Low Vol) sampling e.g., < 2 cfm

Continuous sampling (e.g., in workplace, environment and in stacks) and sometimes short term sampling.

Positive displacement pumps require little maintenance and can move air against significant resistance.

Common types:

- rotary vane pump (self-lubricating)
- rotary vane pump (oil-lubricated)
- diaphragm pump
- piston pump
- rotary lobe pump

How We Perform Air Sampling - Equipment

Centrifugal Fan/Blower

For high volume (hi vol) sampling e.g., > 5 cfm

Centrifugal fans are used for hi vol continuous sampling (e.g., the environment) and short term sampling (e.g., workplace, emergency response).

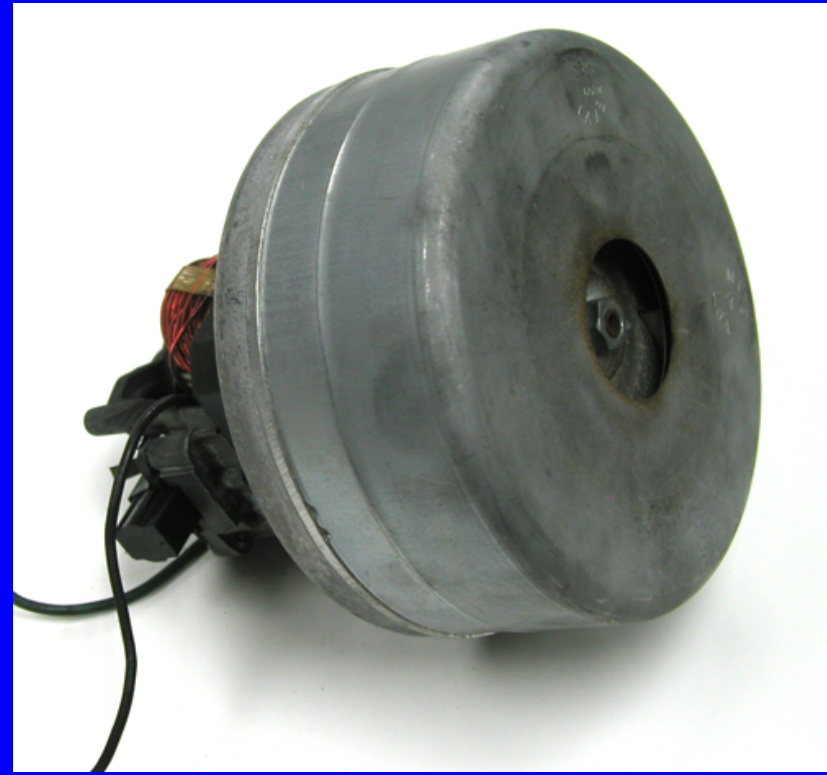
Centrifugal fans that use electrical contacts called brushes require considerable maintenance if they are run continuously.

Brushless hi vol systems, although more expensive, are almost maintenance-free and are generally preferred.

How We Perform Air Sampling - Equipment



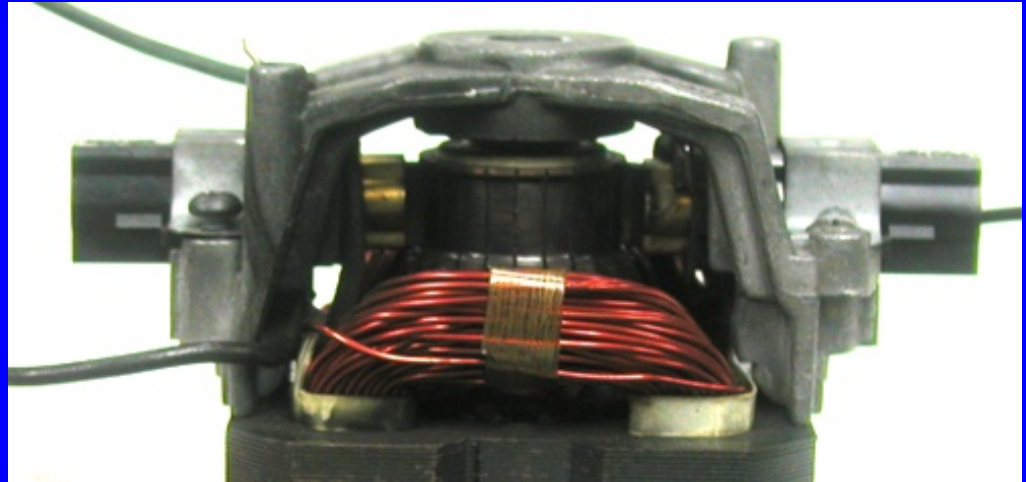
Self-lubricating (carbon vane) rotary vane pump with flow controller



Centrifugal fan/blower with brushes

How We Perform Air Sampling - Equipment

Side view showing brushes on opposite sides of commutator



Worn brush in need of replacement



How We Perform Air Sampling - Equipment

Class Exercise

A radionuclide might be present in the air as both a gas and a particulate.

Nevertheless, in the following table indicate the most likely form of the specified radionuclides and identify one or more collection devices that would be suitable.

Nuclide	Gas/Vapor	Particulate	Possible Collection Device
H-3			
C-14			
P-32			
S-35			
Co-60			
Kr-85			
Sr-90			
Tc-99			
I-131			
Xe-133			
U-238			
Pu-239			

Appendix

ICRP 30 and 66 Models of the Respiratory System

ICRP 30 Respiratory System

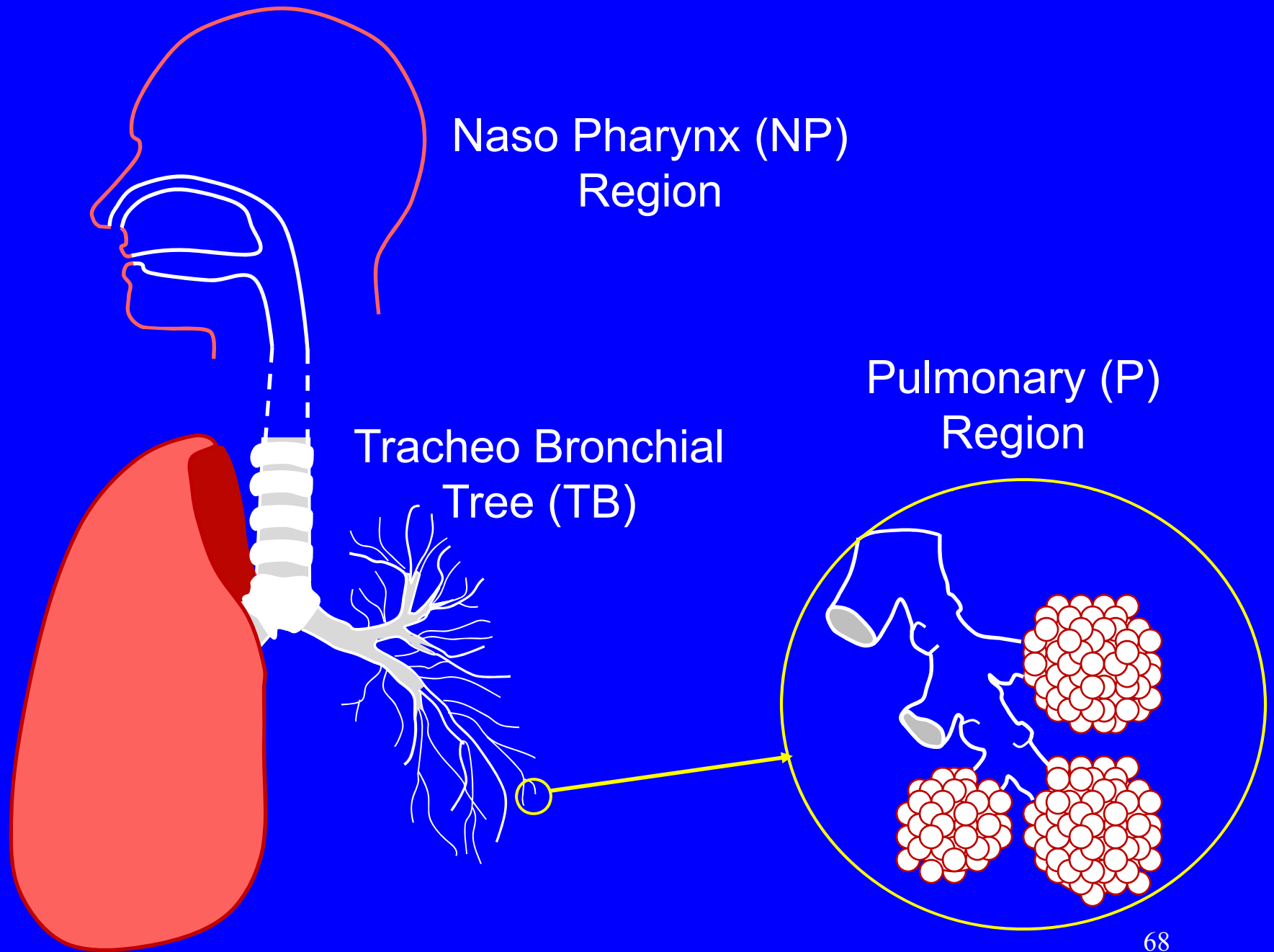
Regions of the Respiratory System

The ICRP 30 model, still the basis for most regulations in the U.S. divides the respiratory system into three parts:

Nasopharynx (N-P)

Tracheobronchial Tree (T-P)

Pulmonary Region (P)



Regions of the Respiratory System

ICRP 30 Respiratory System

Inspirable Mass Fraction

Fraction of the aerosols that are inspirable. Inspirable particles can be inhaled and therefore can reach the nasopharynx. Their 50% cut point is 30-40 μm .

Thoracic Mass Fraction

Fraction of the particulates that penetrate into the thoracic region (tracheo-bronchial tree). Their 50% cut point is 10 μm .

Respirable Mass Fraction

Fraction of the particulates that penetrate into the pulmonary region. Their 50% cut point is typically 2.5 - 5 μm .

ICRP 30 Respiratory System

Respirable Particles

The definition of respirable particles varies considerably.

Sometimes it refers to particles less than 10 μm , i.e., those that can get into the tracheo-bronchial tree.

The more “official” definitions define respirable particles as those that can get into the pulmonary region/alveoli. The most common “official” 50% cut point is 3.5 – 4 μm , however it might be as low as 2.5 or as high as 7 μm .

ICRP 30 Respiratory System

Particle Deposition

Inhaled particulates are not necessarily deposited - they may be exhaled. Those that are deposited can be cleared.

The clearance mechanisms for particles deposited in the pulmonary and tracheobronchial tree regions differ. As such, the hazards associated with particles deposited in these regions differ.

Dichotomous samplers collect the respirable and thoracic mass fractions separately.

ICRP 30 Respiratory System

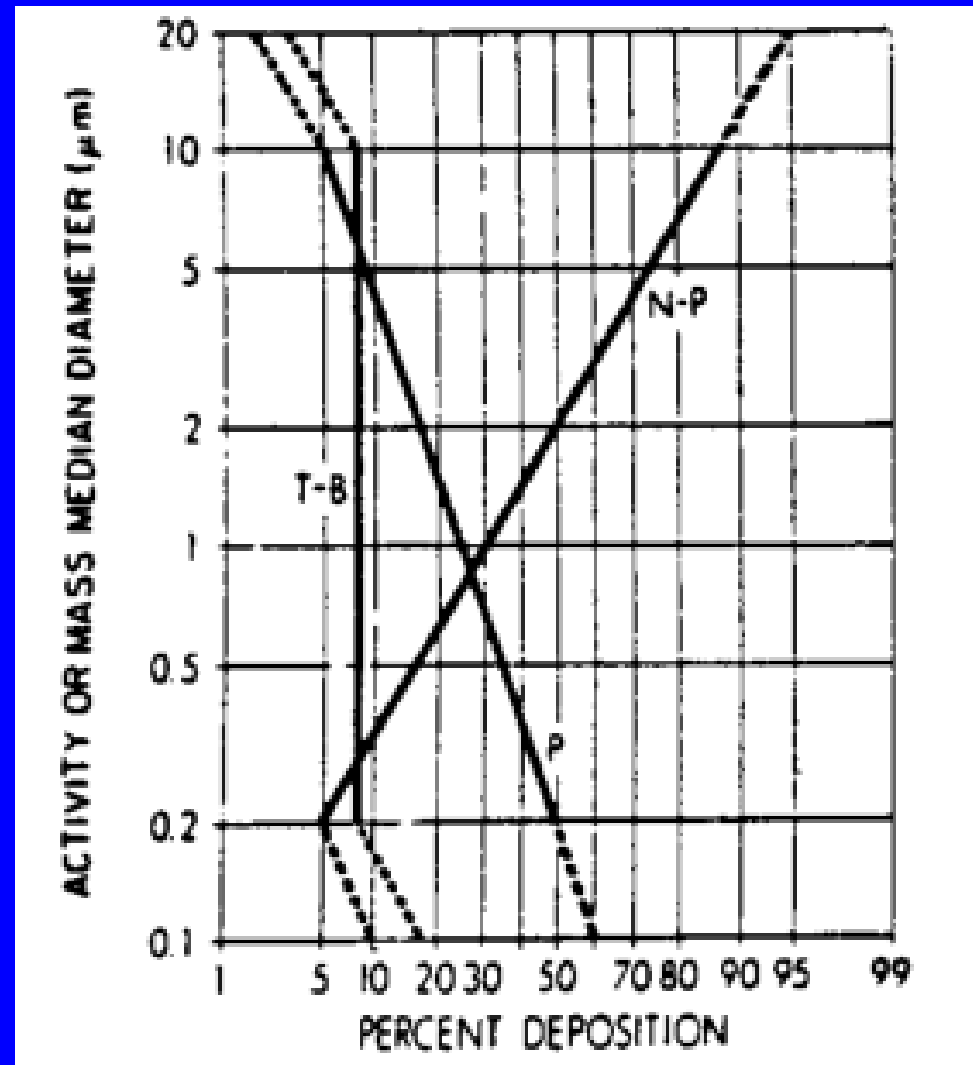
Particle Deposition

This graph gives an idea as to how different particle sizes will be deposited. The lowest percent deposition in the respiratory system occurs for 0.3 μm particles.

Nasopharynx (N-P)

Tracheobronchial Tree (T-P)

Pulmonary Region (P)



ICRP 66 Respiratory System

The ICRP 66 lung model, officially known as the human respiratory tract model (HRTM), is sufficiently complex that dose calculations require the use of computer codes.

Regions of the Respiratory System

The respiratory system is divided into the:

1. Extrathoracic (ET) airways of the head and neck
2. Thoracic airways, i.e., the lungs

Lymph nodes are associated with both the extrathoracic (LN_{ET}) and thoracic components (LN_{TH})

ICRP 66 Respiratory System

Regions of the Respiratory System

1. Extrathoracic (ET) airways of the head and neck

ET₁ anterior nasal passage (front of nose)

ET₂ posterior nasal and oral passages (pharynx and larynx)

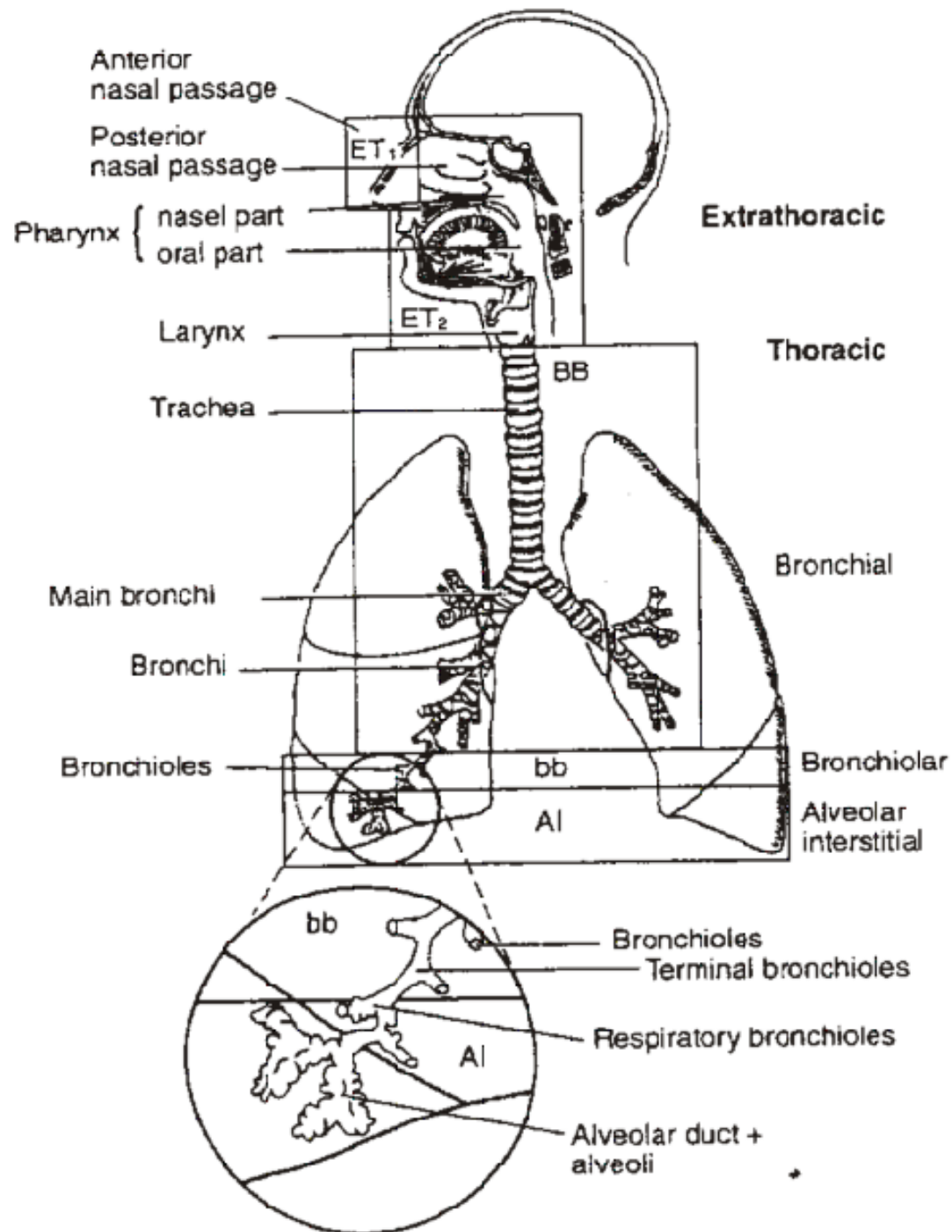
2. Thoracic airways, i.e., the lungs

BB bronchial passages (trachea, generations 0 - 8)

bb bronchiolar (generations 9 - 15)

Al alveolar (gas exchange region).

ICRP 66 Respiratory System



ICRP 66 Respiratory System

Regional Deposition of Inhaled Particulates in Reference Workers

The default particle size for the workplace is 5 μm .

Region	% Deposition for 5 μm Particles
ET1	33.85
ET2	39.91
BB	1.78
bb	1.10
Al	5.32
Total	81.96

ICRP 66 Respiratory System

Regional Deposition of Inhaled Particulates in Members of the Public

The default particle size for the general public is 1 μm . Different reference values are employed for the following ages: 3 months, 1 year, 5 years, 10 years, and adult.

Region	% Deposition for 1 μm Particles					
	3 month	1 y	5 y	10 y	15 y Male	Adult Male
ET1	20.97	21.07	17.39	17.75	13.91	14.89
ET2	27.20	27.30	22.32	22.86	18.13	18.97
BB	1.04	1.04	1.03	1.17	1.69	1.29
bb	2.05	1.71	1.85	1.70	2.00	1.95
AI	8.56	9.64	9.85	9.51	10.65	11.48
Total	59.82	60.76	52.44	52.99	46.38	48.58

ICRP 66 Respiratory System

Clearance

Clearance of deposited material occurs by two processes:

- Particle transport to the GI tract and lymph nodes (the same for all materials).
- Absorption into the blood. This depends on the chemical form of the material. Absorption rates are classified as:

Fast (F)

Moderate (M)

Slow (S)

F, M and S are essentially equivalent to the ICRP 30 D, W, and Y classifications.

ICRP 66 Respiratory System

Dosimetry – target cells

The target cells for cancer induction and dosimetry:

Extrathoracic airways (ET): basal cells of the epithelium

Bronchial passages (BB): basal cells and secretory cells

Bronchiolar region (bb): secretory cells

ICRP 66 Respiratory System

Dosimetry – tissue weighting factors

1. Extrathoracic (ET) airways of head and neck ($w_T = 0.025$)

Extrathoracic airways are treated as a “remainder tissue.” The assigned fraction of w_T attributed to ET_1 is 0.001. The assigned fraction attributed to ET_2 is 0.998.

2. Thoracic airways, i.e., the lungs ($w_T = 0.12$)

The assigned fractions of w_T attributed to the bronchial region (BB), the bronchiolar region (bb) and the alveolar-interstitial (AI) regions are 0.333, 0.333 and 0.333.