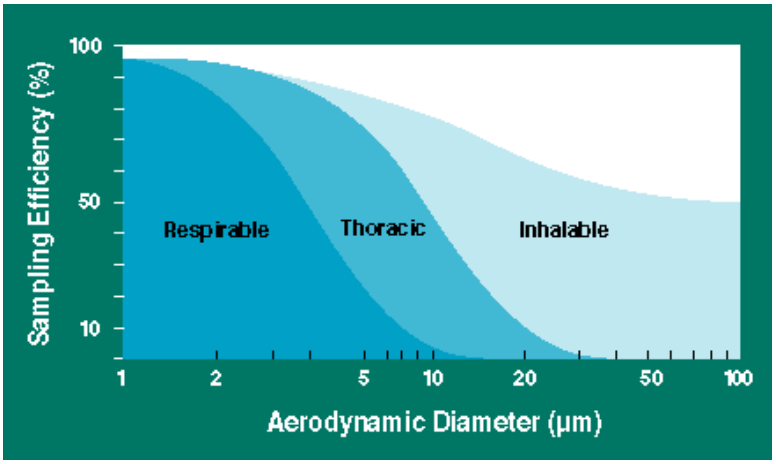
HEALTH-BASED PARTICLE-SIZE-SELECTIVE SAMPLING

APPLICATION NOTE ITI-050



For particle monitoring in the workplace to be meaningful, sampling should be based on the nature of exposure to humans. Many occupational diseases are associated with the location where inhalable hazardous airborne particles are deposited. Therefore, health-based particle sampling should reflect how particles penetrate and deposit in the various regions of the human respiratory system.

In the 1980's and early 1990's, committees from the International Organization for Standardization (ISO), the American Conference of Governmental Industrial Hygienists (ACGIH), and the Comit Europen de Normalisation (CEN) developed an internationally accepted definition of what the sampling criteria should be. These committees agreed that health-related sampling should be based on one or more of three progressively-finer size fractions: inhalable, thoracic, and respirable.

Inhalable

The curve for the inhalable fraction represents particles that enter the respiratory system via the nose or mouth (D_{50} = 100 µm). The total area below this curve is the inhaled fraction of total suspended particles.

$$I(d) = 0.5\ (1 + e^{-0.06d}) \text{ for } 0 < d \pm 100\ \mu m$$

where:

I(d) = sampling efficiency of inhaled particles as a function of aerodynamic particle diameter (d) in micrometers

D_{50} = particle diameter corresponding to 50% sampling efficiency

Thoracic

The thoracic fraction is that portion of the inhalable particles that pass the larynx and penetrate into the conducting airways (trachea, bifurcations) and the bronchial region of the lung (D_{50} = 10 µm).

$$T(d) = I(d)[1-F(x)]$$

where:

$x = \ln(d / 11.64\ \mu m) / \ln(1.5)$

F(x) = the cumulative lognormal function with a median diameter of 11.64 µm and geometric standard deviation of 1.5

T(d) = sampling efficiency of thoracic particles as a function of aerodynamic particle diameter

Respirable

The respirable fraction is the portion of inhalable particles that enter the deepest part of the lung, the non-ciliated alveoli (D_{50} = 4 µm). The curve is different from previous definitions used in the United States and Europe and represents an international harmonization of the older standards.

$$R(d) = I(d)[1-F(x)]$$

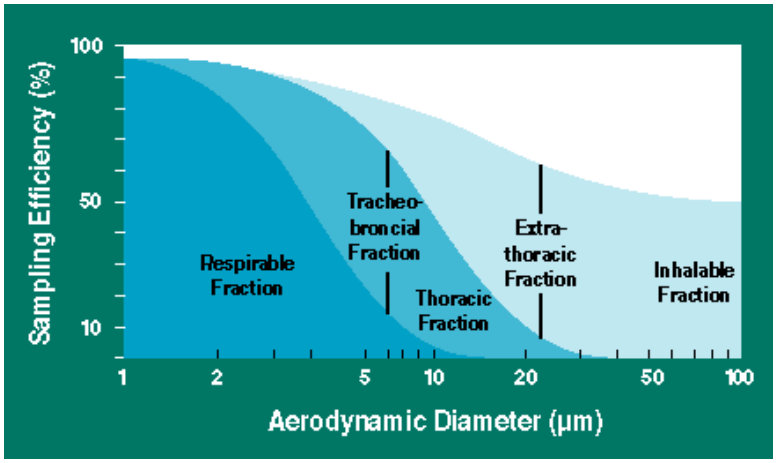
where:

$x = \ln(d / 4.25\ \mu m) / \ln(1.5)$

F(x) = the cumulative lognormal function with a median diameter of 4.25 µm and geometric standard deviation of 1.5

R(d) = sampling efficiency of respirable particles as a function of aerodynamic particle diameter

From these three curves we can identify two additional size fractions: Extrathoracic and Thracheobronchial.



Extrathoracic

The extrathoracic fraction of inhaled particles are those that fail to penetrate beyond the larynx. The extrathoracic fraction is obtained by subtracting the thoracic fraction from the inhalable.

Extrathoracic = Inhalable - Thoracic

Tracheobronchial

The tracheobronchial fraction of inhaled particles are those that penetrate beyond the larynx but fail to reach the alveoli. The tracheobronchial fraction is obtained by subtracting the respirable fraction from the thoracic.

Tracheobronchial = Thoracic - Respirable

It is important to note that these size conventions are only approximations to the behavior of particles in the human respiratory tract of healthy adults. Actual particle penetration and deposition will depend on the wind speed and direction, physical variations in individuals, breathing rate, and on whether one is breathing through the nose or mouth.

Threshold Limit Values

In the United States, the Chemical Substances Committee of the ACGIH is re-examining and recommending Threshold Limit Values (TLVs) based on these size fractions with the objective of defining: 1) the size fraction most closely associated with the health effect of concern for each material, and 2) the mass concentration within that size fraction which should be the TLV.

Inhalable Particle Mass TLVs are for those substances that are hazardous no matter where they are deposited in the respiratory tract. For example, biologically active particles such as pollens and fungi that deposit in the extrathoracic airways may cause allergic reactions. Other particles deposited in a similar location may cause nasal cancer or be swallowed and cause stomach ailments.

Thoracic Particle Mass TLVs are for those substances that are hazardous when deposited in the lung airways and gas-exchange region. Particles deposited in the tracheobronchial region may cause chronic bronchitis or bronchial carcinomas.

Respirable Particle Mass TLVs are for those substances that are hazardous when deposited in the non-ciliated gas-exchange regions of the lung. Diseases of the alveolar regions include pneumoconiosis and emphysema.

In the 1996 ACGIH TLV and BEI Handbook, you will still find TLVs expressed in terms of "total" particulate. This term is ill-defined since no sampling method has 100% sampling efficiency. These TLVs will eventually be replaced with one of the above internationally accepted terms: inhalable, thoracic or respirable. Publications showing side-by-side comparisons of older "total" samplers with newer inhalable, thoracic and respirable samplers will aid in the development of appropriate new TLVs.

In the United Kingdom, the Health and Safety Executive (HSE) have already taken the step to change all occupational exposure standards (OESs) from the old "total" term to "inhalable". Similarly, the German Commission specifying maximum workplace concentrations (MAK) have adopted the respirable and inhalable criteria.

Sampling Methods: Area and Personal

The concentration of airborne particles can be measured using either a stationary area sampler or a personal sampler worn in the breathing zone of the worker. In static area measurements, a sampler is located in the workplace atmosphere to assess the exposure of ambient aerosols to a group of workers. To assess a given individual's exposure, a personal sampler is mounted on the torso and travels with the worker at all times.

Considerable debate exists about which of the two alternatives is preferable. Comparison studies have shown that in most cases, personal sampling consistently gives higher aerosol concentration measurements than area sampling. The higher concentrations surrounding a worker may be a result of aerosols generated from the work activity or particles released from clothing, hair, skin, and body fluids. Area sampling has the advantage of requiring fewer samplers. The samplers are less intrusive to the work activity and do not require worker cooperation. It can be a simple and cost-effective way to monitor the work atmosphere of a large workforce. Area sampling can also be used to identify sources of particles and to evaluate engineering controls.

Personal sampling is generally accepted as the best way to assess the true exposure of an individual worker. Personal sampling requires a separate sampler for each exposed worker and thus more time is needed to prepare and analyze an increased number of samples. Obtaining a valid sample requires cooperation from the worker and care must be taken that the sampler and pump do not interfere with the work activity.

Sampling with the RESPICON™ Model 8522

TSI's patented RESPICON Particle Sampler Model 8522 was specifically designed to meet the new internationally accepted size-selective sampling criteria. The RESPICON measures all five particle-size fractions simultaneously. Particles that fall in the inhalable, thoracic and respirable fractions are collected directly on the filters. From these measurements, the extrathoracic and thracheobronchial fractions are calculated.

An optional inlet module is designed to give a 2.5-µm cut in place of the 4-µm cut. The 2.5-µm size cut corresponds to the size frequently measured for outdoor ambient air quality studies. The optional 2.5-µm module does not effect the inhalable or thoracic measurement.

The collected particles can be analyzed using conventional methods: gravimetric weighing, chemical analysis or microscopic observation. The mass of the particles is determined by weighing the filters before and after sampling. The mass concentration within each fraction is easily calculated by hand or by using a computer spreadsheet template.

The RESPICON sampler can be used for both personal and area monitoring. For personal breathing-zone measurements, the compact sampler easily attaches to a chest harness. For area monitoring, the sampler is placed on a flat surface or thread-mounted onto a tripod.

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