Size-selective Sampling for Particulates

Occupational lung disease continues to be one of the most frequent work-related illnesses in the United States. The latest NIOSH Work-related Lung Disease Surveillance Report at www.cdc.gov/niosh/docs/2008-143/ provides extensive information on the incidence of lung disease and exposure sources in our country. In the public health arena, asthma is the number one reason children miss school. Lung disease can result from exposures to particulate contaminants in the form of dusts, fumes, mists, and smokes. The ultimate health effects from these exposures are determined by several factors:

1. Chemical composition
2. Mass concentration
3. Particle size

For professionals to properly evaluate particulate exposures, the sampling method chosen must provide information relevant to these three factors. This training article provides information on particle size and particle size-selective sampling options. *Note that asbestos and other fibers are a special class of particulates and are not covered in this article.*

Particle Size

Particle size determines the deposition site within the human body and the resulting health effect. The smaller the particle, the deeper it will penetrate within the respiratory system ultimately reaching the gas-exchange region of the lung. Therefore, exposure limits and sampling methods have historically been issued for different particle sizes. It is important that health and safety professionals choose a sampling method that is appropriate for (a) the particulate size fraction and (b) the regulatory standard or guideline being addressed. Occupational and environmental agencies have similar, but different definitions and methodologies for assessing particulates in air.

Occupational Size-selective Criteria and Samplers

Occupational health and safety professionals have traditionally sampled for two particulate size fractions: total or respirable.

- *Total particulate* includes both respirable and non-respirable particles that are collected onto a closed-face 37-mm filter cassette loaded with the appropriate filter.
- *Respirable particulate* includes only the smaller particles than can penetrate to the alveolar or gas-exchange region of the lung. Respirable particles are usually separated from non-respirable particles by placing a cyclone on the inlet of a filter cassette loaded with the appropriate filter. The cyclone will scrub out the large particles and collect them into a grit pot on the bottom of the device for disposal. The smaller respirable particles will be trapped onto the filter for analysis.

At this time, U.S. OSHA and MSHA still use total and respirable particulate size fractions for regulatory standards and compliance monitoring.

Over the last 25 years, however, occupational hygienists around the world have been considering new size-selective criteria for particulates to better assess exposures and to provide worldwide consistency in exposure measurements. Many countries and several international agencies have adopted new size-selective criteria for particulates. At this time, the International Standards Organization (ISO®), the Committee for European de Normalisation (CEN), the American Conference of Governmental Industrial Hygienists (ACGIH®), and ASTM® International have adopted three size fractions: inhalable, thoracic, and respirable.

- *Inhalable particulate* includes particles that are hazardous when deposited anywhere in the respiratory system, including the nose and mouth.
- *Thoracic particulate* includes particles that are hazardous when deposited within the lung airways and the gas-exchange region
- *Respirable particulate* includes particles that are hazardous when deposited within the gas-exchange (alveolar) region of the lung.

New sampling devices that meet precise sizing requirements have been developed to collect the particles in each of these size fractions. To choose an appropriate sampler, occupational health and safety professionals should first review the occupational exposure limit (OEL) or guideline for the contaminant of interest to determine which particulate size fraction they need to collect. For example, ACGIH TLVs® for individual particulate contaminants are issued for inhalable, thoracic, or respirable particulate mass. After determining the appropriate size fraction, professionals should then select a sampling device that is designed to collect that size fraction, taking note of the designated flow rate. Flow rate is critical because it impacts the size of particulate matter collected. Users should not deviate from the specified flow rate for a given device when performing size-selective sampling.

Inhalable Samplers are designed to aspirate the same measured dust concentration and size distribution as that inhaled by the wearer. They have a 50% (or median) cut-point of 100 microns (µm). This specification means that inhalable samplers trap 100-µm particles with a collection efficiency of 50%. As the particles get smaller, samplers trap particles with efficiency greater than 50%. As the particles get larger, samplers trap particles with efficiency less than 50%. When compared to the traditional closed-faced 37-mm filter cassette, inhalable samplers are more efficient at capturing large particles such as wood dust. In addition, inhalable samplers do not evidence the wall losses that are seen with traditional filter cassettes. Wall losses occur when particles stick to the sides of the cassette and are not included in the analysis.

There are several devices available for inhalable sampling. The IOM Sampler was the first inhalable sampler and is the most commonly used at this time. The IOM Sampler consists of a sampling head, reusable cassette, and 25-mm filter appropriate for the contaminant of interest. See www.skcinc.com/prod/225-70.asp. The IOM is connected to a pump calibrated to a flow rate of 2 L/min. Gravimetric or chemical analysis can be performed on the collected sample.

The Button Sampler for inhalable particulate is similar in design to the IOM. The Button Sampler, however, features a screen over the inlet to keep large, non-inhalable particles from being projected onto the filter by blasting operations or other workplace activities. See www.skcinc.com/prod/225-360.asp. A 25-mm filter is placed onto a stainless steel support screen for sample collection at 4 L/min.

Other inhalable samplers have been developed and are more commonly used in Europe rather than in the U.S. For example, the seven-hole head is a traditional European method using a 25-mm filter and cassette inside a sampling head that has seven equally spaced inlet holes. Other inhalable samplers include the Conical Inhalable Sampler (CIS) and CIP-10.

Thoracic Samplers that have a 50% cut-point of 10 microns are now available to collect particulates in this size fraction. As of 2010, ACGIH has issued only one TLV as thoracic particulate mass; it was for sulfuric acid. NIOSH has published one method that specifies a thoracic sampler as a sampling option; NIOSH Method 5524 is for metalworking fluids.

SKC has developed an impactor for the collection of thoracic particulate. The Parallel Particle Impactor (PPI) has four inlet holes, each with a different 50% cut-point, arranged in parallel that allow for collection of the thoracic-size fraction onto a final filter at 2 L/min. See www.skcinc.com/prod/225-380.asp. As with traditional filter cassettes, the user can load the device with any filter suitable for collection of the target compound. For sulfuric acid, an MCE filter should be used for analysis following OSHA Method ID 113. Another sampling option for this size fraction is a thoracic cyclone manufactured by another company.

Respirable Samplers used for occupational sampling have traditionally been cyclones. Cyclones function on the same principle as a centrifuge. Smaller respirable particles are whirled up onto a filter for collection and analysis. Larger non-respirable particles fall into a grit pot and are discarded. There is a variety of cyclone designs commercially available and each specifies a different flow rate.

In recent years, SKC has also developed impactors for the collection of respirable dust. Similar to the thoracic PPI samplers mentioned above, SKC has PPI samplers specifically designed for respirable dust. PPI respirable samplers allow for higher flow rates so a more relevant sample mass can be obtained for compounds with low OELs.

Throughout the history of occupational hygiene and worldwide, there has been disagreement on the performance criteria for respirable dust samplers. U.S. compliance agencies, including OSHA and MSHA, specify a 50% cut-point of 3.5 microns. Most other organizations around the world, including NIOSH and ACGIH, now specify a 50% cut-point of 4 μm. Health and safety professionals must determine the criteria they need to meet and then operate the specific cyclone at the designated flow rate. Not all cyclones are created equal! Operating a cyclone at the wrong flow rate will render your data meaningless.

Environmental Size-selective Criteria and Samplers

For Ambient Air

The U.S. Environmental Protection Agency (EPA) first established the national ambient air quality standard for particulate matter in terms of total suspended particulates or TSP. TSP is defined as particulate matter with a particle size less than 100 μm collected with a high-volume sampler onto a filter. Beginning in 1987, the EPA replaced the TSP standard with PM10 and PM2.5. These new standards define particulate matter as having an aerodynamic diameter less than or equal to 10 μm or 2.5 μm, respectively. In recent years, there has been some discussion about another criterion called PM coarse. PM coarse is defined as PM10 minus PM2.5. Currently, PM coarse continues to be under study by regulatory agencies.

Sampling options for compliance monitoring of PM10 and PM2.5 fall into two categories: reference methods and equivalent methods. Reference methods specify the use of a dichotomous sampler operating at a flow rate of 16.7 L/min where particles are drawn through an inlet, separated into PM10 and PM2.5, and collected onto filters for analysis. Equivalent methods include direct-reading instruments such as a beta-radiation or oscillating pendulum. These instruments are costly and require significant technical expertise.

SKC offers less complex and less costly instruments for assessing particulate levels in ambient air. The SKC Deployable Particulate System (DPS) includes the Leland Legacy pump for PM10 or PM2.5 sample collection at 10 L/min onto filters. See www.skcinc.com/prod/100-3901.asp. This system has been validated and is used by the U.S. Department of Defense to monitor deployed troops. Real-time direct-reading devices are also available that measure particulate levels using the principle of light scattering. See the EPAM from SKC at www.skcinc.com/prod/770-203.asp. These instruments provide reliable assessments for users, but they have not undergone the rigorous testing protocol required for EPA compliance monitoring by government agencies.

For Indoor Air

Currently, there are no U.S. government standards for particulate matter in indoor air. However, various professional groups have published guidelines for particulates in indoor air. For example, the U.S. Green Building Council specifies an indoor air limit of 50 $\mu g/m^3$ as PM10. See www.usgbc.org.

Sampling the indoor environment for particulates poses some unique challenges for professionals. Since the contaminant levels are low, the equipment must have the high power necessary to collect a measurable, relevant sample. At the same time, the equipment must be small and quiet enough for personal monitoring of the indoor environment.

In recent years, personal impactors have been developed for measurement of PM10 and PM2.5 in indoor air. The SKC PMI samplers are designed for use at 3 L/min with sample

collection onto filters. See www.skcinc.com/prod/225-352.asp. Alternatively, SKC offers PEM samplers for PM10 or PM2.5 sampling at various flow rates. See www.skcinc.com/prod/761-200.asp. SKC AirChek® XR5000 pumps with new lithium-ion batteries will provide high flow rates and long run times for indoor air particulate sampling. For more information on the SKC AirChek XR5000 see www.skcinc.com/pumps/210-5000.asp.

A new personal cascade impactor has also been developed for simultaneous measurement of PM 10, PM2.5, and smaller size fractions at a flow rate of 9 L/min. See www.skcinc.com/prod/225-370.asp. The Sioutas Personal Cascade Impactor is typically partnered with the Leland Legacy pump for 24-hour sample times. See www.skcinc.com/pumps/100-3000.asp. Performance of the Sioutas Impactor with the Leland Legacy® Sample Pump has been verified by the EPA Environmental Technology Verification (EPA-ETV) Program. See www.epa.gov/nrmrl/std/etv/vt-ams.html - pcis.

Conclusion

The recognition, evaluation, and control of particulate matter is clearly a priority for health and safety professionals. Lung disease, including asthma, continues to be a major occupational and public health issue. The development of new size-selective samplers and pump technology has enhanced the ability to evaluate particulate exposure levels based on new occupational size-selective criteria. Professionals should be educated in the selection and application of this new equipment to properly evaluate the environment under study.