ENGINEERED NANOPARTICLES AND PARTICULATE RESPIRATORS

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ABSTRACT

Engineered nanoparticles generally refer to designed structures approximately 1-100 nanometer (nm) in size. Much work needs to be done regarding toxicology of engineered nanoparticles. To date there are no published exposure limits for nanoparticles. However, a hierarchy of control measures may be used to help reduce exposure. These include enclosing the source, local exhaust ventilation, limiting the duration of worker exposure, and personal protective equipment such as respirators. Filtration theory predicts that particles less than 500 nanometers (0.5 micrometers) are primarily filtered by diffusion and electrostatic attraction. Many authors have shown that particulate filters and particulate respirators may be used to filter nanoparticles. Respirators must be selected according to their nominal or assigned protection factor and used in conjunction with a complete respiratory protection program.

INTRODUCTION

One of the emerging topics in industrial hygiene today is nanotechnology and engineered nanoparticles. Engineered nanoparticles generally refer to structures approximately 1-100 nanometer (nm) in size that have novel properties and functions because of their nanometer scale dimensions. It should be noted that particles in this size range are also unintentionally produced by certain industrial processes (e.g. welding) or combustion and occur naturally in the atmosphere.

At this time there are no published exposure limits for engineered nanoparticles. More research needs to be done to determine the best way to measure worker exposure, and what specific health effects may result, if any, from exposure.

According to industrial hygiene principles, a hierarchy of control measures may be used to help reduce worker exposure. These include enclosing the process, local exhaust ventilation, and personal protective equipment (PPE) such as particulate respirators.

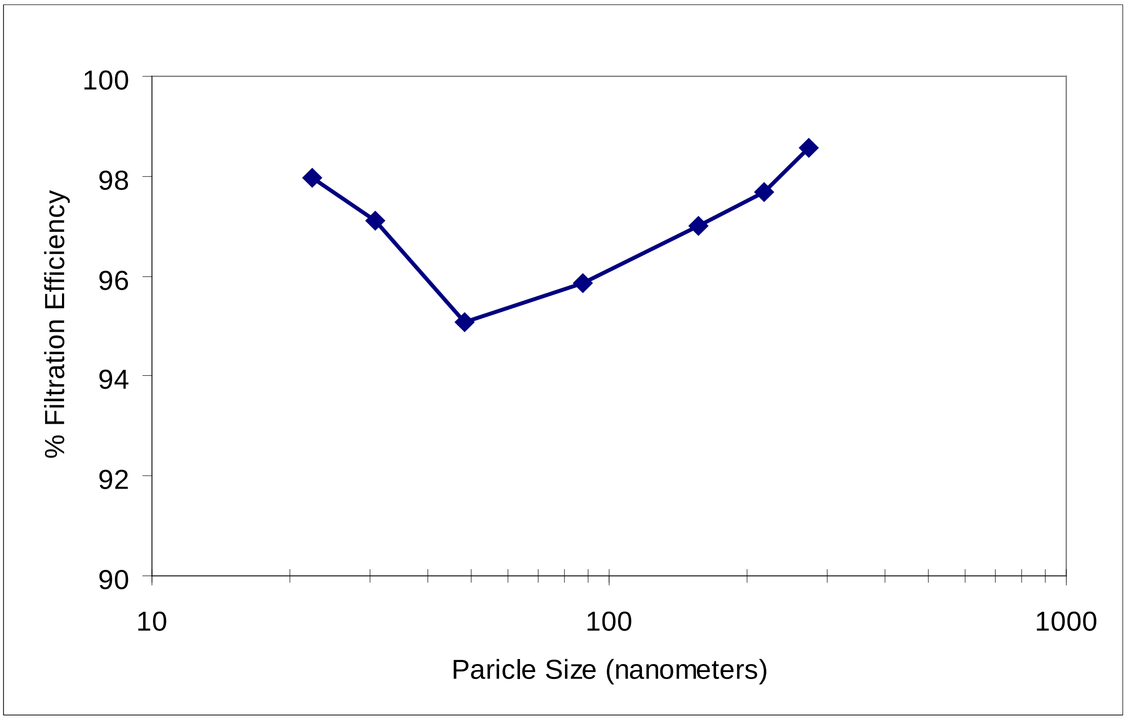
PARTICULATE FILTRATION

Some have asked if particulate respirators can filter very small particles such as nanoparticles. To answer this question, one must first understand particle filtration mechanisms.

Particulate filters used in respirators do not work like a sieve. Particles may be much smaller than the spaces between fibers in the filter. However, particles need to pass through multiple layers of fibers to get through the filter. Larger particles may impact or are intercepted by the fibers as they move through the filter. Particles in the 1-100 nm range collide with air molecules and are thus forced to move in a random motion called Brownian diffusion. This diffusive motion may cause particles to contact a fiber in the filter. Once the particle is collected onto a fiber, it will adhere to the filter fiber due to Van der Waals forces. Many current respirators also use electrostatically charged fibers to increase filtration efficiency.

Filtration efficiency will depend on several factors, including the filter, particle size, flow rate, measurement device, etc. Figure 1 shows test results from six different models of N95 filtering facepiece respirators that were commercially available from various manufacturers in 2006. (The US NIOSH N95 class is similar to P2 filters under AS/NZS 1716.) Filtration efficiency was measured at seven different particle sizes using a sodium chloride (NaCl) aerosol at a flow rate of 85 liters per minute. Ten samples of each model were tested.

Figure 1: Averaged Results from Six Models of N95 Filtering Facepiece Respirators from Various Manufacturers



Filtration efficiency varied between models and within the ten samples of each model. However, the shape of the filtration efficiency curve was similar for all tests, with the most penetrating particle size (MPPS) being between 40 and 100 nm. Figure 1 clearly illustrates that "smaller" particles are not necessarily more difficult to capture thanks to diffusion and electrostatic attraction. Engineered nanoparticles can be filtered by particulate respirators.

It should be noted that most particulate respirator certification testing (such as described in AS/NZS 1716) is done with an aerosol that contains a range of different sized particles. Filtration efficiency is determined by measuring the particle concentration before and after the filter. This gives a single measurement of filtration efficiency for the entire aerosol as opposed to filtration efficiency according to particle size as shown in figure 1. However, correlations may be developed between the two methods and both may be used to assess respirator performance against nanoparticles.

FACIAL FIT

Some individuals have speculated that face fit is even more critical for nanoparticles because of their small size. However, the fit test methods in use today have been widely used to fit respirators for use against gases and vapors which are even smaller than nanoparticles. Respirators are commonly used against gases and vapors in industrial applications. Therefore, these same fit test methods are applicable for respirators used during exposure to engineered nanoparticles.

For those who would like to perform fit testing using nanoparticles, particulate respirators may also be fit tested using the TSI Portacount® Pro+. It measures ambient nanoparticles inside and outside of a probed respirator to determine respirator fit.

DISCUSION

Future versions of AS/NZS 1715 may include comments regarding ultrafine particles. At this time, it may be prudent to select a P2 or P3 filter according to the selection logic for thermally generated particles. However, exposure reduction is estimated using the respirator protection factor, not just filtration efficiency. Simply put, worker exposure equals the outside concentration divided by the protection factor. A list of protection factors according to respirator type is given in AS/NZS 1715. However, this assumes that the respirators are used in conjunction with a complete respiratory protection program that complies with all requirements listed in AS/NZS 1715. This includes, but is not limited to training on proper use and limitations, maintenance, fitting the respirator, wearing the respirator during all times of exposure, etc.

CONCLUSION

More work needs to be done regarding toxicology and exposure limits for engineered nanoparticles. A hierarchy of control measures may be used to help limit exposure. Particulate respirators may be used to help reduce exposure to engineered nanoparticles, but do not eliminate exposure or risk of illness. Respirators must be used within the context of a proper respiratory protection program.