

BERYLLIUM PARTICLE SIZE AND NUMBER RISK FACTORS AND SAMPLING METHODS

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Surveillance efforts have established that particular processes conferred substantially increased risk of beryllium sensitization and disease. However, in one study, the highest risk process involving beryllium metal and alloys was found to have relatively lower historical gravimetric indices of exposure than many less risky processes (ref. B-1). This discrepancy between gravimetric exposure and health outcome suggested that mass measurements of total beryllium were likely a poor marker of biologic risk of granulomatous disease, which might be more closely associated with some other measure of exposure.

Because the particle number concentration in the area of the metal and alloys operation with the highest risk exceeded by at least two orders of magnitude the concentrations in other areas, particle number was considered as possibly a better metric (ref. B-2). Number concentration is strongly influenced by the smaller particle sizes. The mean particle size for the high risk area was less than 0.1 μm , a size range usually referred to as ultrafine. Exposure to ultrafine particulate has been associated with decreases in the clearance mechanism of the lung (ref. B-3). These particles could, therefore, be retained for longer periods and also be capable of penetrating the pulmonary epithelium thus making them available for retention in the interstitium. Ambient air studies have also indicated that particle number concentrations of ultrafine aerosols may be responsible for increased mortality in the general population. (ref. B-4 and B-5). The ultrafine (<0.1 μm) component of the aerosol must therefore be considered.

Little attention has also been paid to the role of lung deposition and the weighting given to various particle sizes. Even a study considering particle size (ref. B-6) has looked only at the effect of respirable penetration efficiency, which is not the same as deposited dose. Below 0.5 μm , deposition in the lung rises rapidly. As particle size changes, so too does the difference between a measure of the penetration and deposition. (ref. B-7). Total dust measurements weight the probability of deposition of all particle sizes equally and thereby conceal the actual dose. If the particle size distributions were constant, total dust might be as good a measure as any other. Variability in the size distribution can, thereby, change the dose without changing the exposure measured by a respirable sampler. That is, the total amount of submicrometer material can remain constant even though the size distribution changes, changing the actual dose. As an example, for a geometric mean of 0.4 μm and a geometric standard deviation of 2, only 20% is deposited. When the geometric mean decreases to 0.1 μm , the fraction deposited increases to almost 30%. The deposited mass or number of particles would increase in this example if the total or respirable concentrations remained steady.

Because of the possibility that current epidemiologic investigations may show an association between particle number concentration with an emphasis on the ultrafine component of the aerosol, information on the deposited number concentration may be useful. Recent, ongoing work has shown that three Nuclepore polycarbonate track-etched membrane filters with a pore

size of $3.0\ \mu\text{m}$ (called a *trilayer sampler*) can be used to overcome the problem of not knowing the fraction of the particles deposited. This trilayer sampler will allow an estimate to be made of the deposited submicrometer particulate without the necessity of determining particle size distribution (ref. B-8). The penetration characteristics of the three nuclepore filters, in series, approximately match those of the lung. To provide an optimum match with lung deposition it is necessary to scale the amount of particulate collected by the three layer membrane filter, when the sampler is operated at 0.7 liters per minute, by multiplying the amount detected by 60%. The sampler can be operated in the range of 0.7 to 2 liters per minute making it possible to obtain personal samples. When used with particle counters, such as those used for respirator fit testing, at the normal instrument flow rate of 0.7 liters per minute, the deposited particle number concentration can be obtained. The differential value (i.e., the total particle count minus what passes through the trilayer and is counted) is the value which when multiplied by 0.6 is the particles number concentration which would have deposited in the lung. The polycarbonate filters can be ashed as would the mixed cellulose ester filters normally used for beryllium analysis and analyzed for the beryllium content. Because the polycarbonate filters are weight stable they can also be analyzed gravimetrically before ashing to obtain a weight of total particulate. The fractional beryllium content can then be obtained after chemical analysis and that fraction attributed to the particle number concentration to obtain the beryllium number concentration.

Alternatively, the particle size distribution can be determined, although this is more difficult to do if the beryllium particle count size distribution is the ultimate goal. The beryllium mass distribution can be achieved in a relatively straightforward manner, using either a personal impactor to characterize the size distribution between $20\ \mu\text{m}$ and $0.5\ \mu\text{m}$ or a microorifice impactor to characterize the size distribution as low as $0.05\ \mu\text{m}$. The advantage of the personal impactor is the ability to obtain personal samples as well as determine the total or respirable beryllium mass fraction of the dust. The disadvantages are the relatively low sample volume obtained from the normal operational flow rate of two liters per minute and the relatively large lower cut point of $0.5\ \mu\text{m}$. The microorifice impactor has the advantage of covering most of the particle size range of interest. Its disadvantage is that its size makes it suitable to be only an area sampler. If polycarbonate grease-coated substrates are used for the sampling, both total mass and fractional beryllium content can be obtained for each of the size fractions. The fractional beryllium content can be applied to a particle number distribution obtained from an instrument such as an electrical mobility analyzer attached to a condensation particle counter. With the particle size distribution known for either the mass or number of particles it is possible to integrate that function with respect to the lung deposition curve recently published by the International Commission for Radiation Protection (ICRP) (ref. B-9).

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