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Effect of Sampler and Manikin Conductivity on the Sampling Efficiency of Manikin-Mounted Personal Samplers

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Experiments were performed that examined how the electrical conductivity of personal samplers and the manikin on which the samplers were mounted affected sampling efficiency. These experiments were done in a wind tunnel using a 7 μm Mass Median Aerodynamic Diameter (MMAD) aerosol with conductive Institute of Occupational Medicine (IOM) samplers and conductive and nonconductive 37 mm cassettes mounted on a life-sized manikin, which was conductive or nonconductive. The charge on the aerosol was neutralized for some experiments. Nonconductive samplers gave lower sampling efficiency than conductive samplers for both the conductive manikin and nonconductive manikin, and the nonconductive manikin gave lower sampling efficiencies with both conductive and nonconductive samplers. These effects were smaller at reduced levels of charge on the aerosol. It is important to consider the conductivity of the manikin when designing experiments to determine the sampling efficiency of personal samplers mounted on a manikin.

INTRODUCTION

A recent study examining the sampling efficiency of commonly used personal samplers for inhalable dust (Kenny et al. 1997) found low and poorly reproducible sampling efficiencies at the smallest particle size studied ($<$10 μm aerodynamic diameter). In an effort to explain some of these results, the present study examined electrostatic effects on the sampling efficiency of manikin mounted samplers.

Several studies in the past have examined the influence of sampler conductivity on sampling efficiency (Turner and Cohen 1984; Puskar et al. 1991; Baron and Deye 1990; Johnston et al. 1987). These studies concluded that conductive samplers gave

higher efficiency when aerosols are charged. In the present study, the effect of both manikin and sampler conductivity was examined to study the relative size of each parameter on sampling efficiency.

MATERIALS AND METHODS

The experiments were performed in a wind tunnel having a 183 cm wide by 122 cm high cross section that was described previously (Smith et al. 1999) at a wind speed of 0.5 m/s with the manikin facing the wind. Descriptions of the placement of the manikin and reference samplers, the generation system, the aerosol charge neutralization system, and a 7 μm MMAD aerosol have been given previously (Smith et al. 1999). The manikin was painted with graphite paint (Energy Beam Sciences, Agawan, MA) to make it conductive, and the surface of the manikin was made nonconductive by covering it with a tight-fitting polyethylene plastic film. Six personal samplers were mounted on the front of the manikin at one time. These experiments used IOM samplers (Mark and Vincent 1986) (Part No. 225-70: SKC, Inc., Eighty Four, PA) with stainless steel filter assemblies (Part No. 225-75: SKC, Inc., Eighty Four, PA) and conductive (Part No. A-003750-3AC: Omega Specialty Instruments Co., Chelmsford, MA) and nonconductive (Part No. 225-3: SKC Inc., Eighty Four, PA) 37 mm closed-face cassettes. The IOM samplers pointed out from the body, while the 37 mm cassettes pointed down, the same orientations that these samplers have in field applications. For experiments involving the IOM samplers, all 6 samplers on the manikin were conductive; the experiments with the 37 mm cassettes used 3 conductive and 3 nonconductive cassettes mounted alternately on the manikin.

Filters from isokinetic reference samplers and manikin mounted personal samplers were weighed before and after exposure to the aerosol to the nearest 2 μg with an analytical balance (model AT20 Mettler Toledo Inc., Hightstown, NJ). The sampling efficiency was calculated as the ratio of the concentration

measured by the manikin mounted samplers to the isokinetic reference concentration.

For each of the experiments involving IOM samplers, the results from all 6 samplers were averaged. For the experiments using the 37 mm cassettes, results from conductive and nonconductive samplers were treated separately (3 of each kind of cassette were used in the experiments). Data from experiments conducted under the same conditions were pooled to obtain an overall mean and standard deviation and t tests were used to examine the significance of differences of mean values obtained under different conditions.

RESULTS AND DISCUSSION

Three sets of experiments were conducted. The first 2 sets were performed before an effective technique for assessing and neutralizing the charge was developed. The first set of experiments was done with IOM samplers, which were available only as conductive samplers. A second and third set of experiments were performed using 37 mm cassettes since these were available both as conducting and nonconducting samplers. In the last set of experiments, the charge was neutralized.

The set of experiments with the IOM samplers (Table 1) showed the clear influence of the nonconductive manikin on sampling efficiency. The sampling efficiency for the nonconducting manikin was significantly different from that of the conducting manikin. A t test performed on the data gave $t = 28.1$ and $p < .0001$ for 34 degrees of freedom. However, the results with the nonconductive manikin were reproducible (better than 5% coefficient of variation(CV)), even if they were lower than those obtained with the conductive manikin.

The same conclusion concerning the nonconductive manikin can be made for the 37 mm cassettes (Table 2), along with the additional conclusion that the nonconductive samplers always gave lower results than the conductive samplers. The p values calculated indicated differences were significant at the 99% confidence level. The combined effect of the nonconducting manikin and nonconducting samplers was to give even lower efficiency than either effect alone. Again, the results from the nonconducting manikin and the nonconducting samplers were reproducible (better than 5% CV for all experiments, except for the experiment done with the conductive manikin having nonconductive

Table 1
Experiments with IOM samplers; 6 samplers were mounted on the manikin; the manikin was painted with graphite paint (conductive) or covered with plastic (nonconductive); the aerosol charge was not neutralized

Manikin	Efficiency	Pooled SD
Conductive	0.82	0.02
Nonconductive	0.67	0.01

Pooled SD = pooled standard deviation.

Table 2
Experiments with 37 mm cassettes; 6 samplers were mounted on the manikin (3 conductive and 3 nonconductive mounted alternately on the manikin); the manikin was conductive (Cond) and nonconductive (Non), and cassettes were made of conductive (Cond) and nonconductive (Non) plastic

Manikin	Cassette	Efficiency	Pooled SD	Significance
Aerosol charge not neutralized				
Cond	Cond	0.79	0.02	
Cond	Non	0.69	0.04	$t = 5.09$, $n = 10$, $p = .0004$
Non	Cond	0.63	0.02	$t = 13.4$, $n = 10$, $p < .0001$
Non	Non	0.57	0.03	$t = 14.6$, $n = 10$, $p < .0001$
Aerosol charge was neutralized				
Cond	Cond	0.82	0.01	
Cond	Non	0.76	0.0	$t = 12$, $n = 4$, $p = .0002$
Non	Cond	0.74	0.02	$t = 7.1$, $n = 4$, $p = .002$
Non	Non	0.70	0.02	$t = 11.2$, $n = 4$, $p = .0004$

Pooled SD = pooled standard deviation.
Cond = conductive manikin or cassette.
Non = nonconductive manikin or cassette.
Significance = statistical significance of difference between experimental condition studied and experiment with conductive samplers and conductive manikin. p was calculated based on the calculated t and n degrees of freedom.

cassettes, where CV was 5.8%) even when they were lower than those having the conducting samplers and conducting manikin.

For the third set of experiments (Table 2) in which the charge was neutralized, the same conclusions can be reached. The efficiency was always lower with the nonconducting manikin and nonconducting samplers, and the combination of nonconducting samplers and a nonconducting manikin gave lower efficiencies than either effect alone. Again, better than 5% CV was obtained for all conditions studied. Experiments in Table 2 where the charge was neutralized showed higher efficiencies than the experiments done under the same conditions where the charge was not neutralized (also shown in Table 2). It appears that the charged aerosol results in lower efficiency, especially in combination with the nonconductive manikin and nonconductive samplers.

CONCLUSIONS

Both sampler and manikin conductivity affected the sampling efficiency of manikin mounted personal samplers. It is important to consider the conductivity of the manikin and the charge on the test aerosol, in addition to the conductivity of the samplers, when

designing experiments to determine the sampling efficiency of personal samplers mounted on a manikin.

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