METHODOLOGICAL STUDIES FOR QUANTIFYING AEROSOL EXPOSURE TO ORGANIC RESPIRABLE-SIZED FIBER-SHAPED PARTICULATES (RFP) IN THE WORKPLACE: RESULTS OF A ROUND ROBIN AND COWL WASHING STUDY

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Abstract

Methodological studies were conducted as part of our ongoing effort to develop standardized methods for quantifying respirable organic fiber exposure in the workplace. The first study was designed to evaluate the influence of electrostatic potential of respirable organic fibers (also known as RFP) on the quantification of aerosolized RFP samples. Counts derived from highly electrostatic RFP such as p-Aramid are postulated to result in an underestimate of the actual respirable fiber count. Accordingly, studies were performed to compare the RFP counts from the filters directly exposed to p-Aramid or cellulose RFP with other filters directly exposed and supplemented with any RFP that may have deposited on the supporting cowl. The results demonstrated no significant differences between the two sets of samples for either the highly electrostatic p-Aramid RFP or the low electrostatic cellulose RFP samples.

The objective of the second study was to compare the results of aerosolized organic RFP counts from three different laboratories and from four different individual counters, using light microscopy methods. Atmospheres of p-Aramid RFP were generated in an inhalation chamber. Fifteen methylcellulose filters were exposed to a p-Aramid aerosol for 5 minutes at estimated concentrations of 20 - 30 f/cc. Subsequently, filters were prepared for PCOM (phase contrast optical microscopy) counting by standard techniques. The prepared slides containing a portion of the fiber-exposed filters were first counted at DuPont Haskell Lab., and then the same slides were sent to the Denkendorf Institute and finally to the IOM. For quantification of fibers, the NIOSH 7400 method was used at DuPont Haskell Lab., while a WHO/EURO MMF fiber counting method was utilized in the European laboratories.

The results demonstrated that Laboratory A had consistently lower counts when compared to Laboratory B (mean values for the 15 filters = 18.4 ± 4.3 f/cc vs. 27.7 ± 4.3 f/cc). Laboratory C, with 2 different counters, was frequently intermediate between the counts of Laboratory A and B (24.2 ± 1.1 f/cc and 22.1 ± 2.2 f/cc). The differences in fiber counts may be related to variation in counters, or to the slight differences in counting rules between the US and European methods. With a few exceptions, the intra-laboratory variability between counts was rather low, while the inter-laboratory variability among counts was higher. Studies are ongoing to better understand the expected variability for organic RFP counts when comparing the results from one laboratory to another.

Introduction

Two separate studies were undertaken, in part, to assess current or develop new methods for counting aerosolized organic RFP. In the first study, we assessed the influence of the electrostatic properties of organic RFPs on the numbers of aerosolized respirable fibers which deposit directly on the sampling filters. As background, most PCOM fiber counting methods have been developed for quantifying aerosolized <u>asbestos fiber</u> samples. Since most forms of asbestos are known to have low electrostatic properties, it is assumed that few fibers would deposit on the surrounding cowl but instead would deposit directly upon the sample filter. The cowl apparatus is essentially the holding device for the sample filter and is the structure supporting the filter. In contrast to asbestos fibers, organic RFP have physicochemical properties very different from asbestos. These properties include nonuniform (often curly) fibrous shapes and greater electrostatic charges. Thus, a greater percentage of organic RFPs with high electrostatic properties relative to those with lower electrostatic properties (i.e., similar to asbestos in this regard) are postulated to adhere to the cowl during aerosol sampling procedures. As a result of this adherence, a count of the sample filters (in the absence of washing the cowl) would therefore yield an underestimate of the actual RFP count, in contrast to the counts obtained by rinsing the cowl onto a separate filter and combining the results of the two filters. To test the "electrostatic" hypothesis, studies were implemented comparing the RFP counts from the originally exposed filters with those samples wherein the cowl was washed onto another filter and the combined counts (i.e. the original exposed filters vs. original exposed filters + filters containing the contents from the washed cowl) were compared.

The second study was associated with round robin RFP counting comparisons. In this study we tested the reproducibility of organic respirable fiber counts (i.e., p-Aramid RFP) among 3 different laboratories (1 North American laboratory and 2 European laboratories) and 4

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different people using light microscopy fiber counting methods. For each sample, all counters used the same slide.

Methods

Cowl-Washing Study

This study investigated the influence of electrostatic effects of aerosolized organic RFPs on aerosol sampling and fiber counts. Two different organic fiber aerosols were generated for this study. P-Aramid RFP was considered to be highly electrostatic. Cellulose RFP was considered to have low electrostatic properties. Aerosols of p-Aramid and cellulose RFP were generated according to the procedures described below (1) and the atmospheres were sampled. Following aerosol exposures, 15 exposed filters (designated as filters A) were removed, processed, and according to standard fiber counting techniques (NIOSH 7400 counting methods). In addition, 15 different filters (designated as filters B) were collected and the attached cowls were rinsed onto 15 additional methyl cellulose filters (designated filters C) using deionized water, thus washing any adherent fibers from the cowl. RFP counts were made from all 45 filters. Counts from individual filters derived from B and C were combined and compared with the counts from filter A, to answer the question, are the counts from B+C > A?

Round Robin Counting Studies

The purpose of this study was to compare the results of aerosolized organic RFP counts from three different laboratories and from four different counters, using light microscopy methods. Atmospheres of p-Aramid RFP were generated in an inhalation chamber. Fifteen methylcellulose filters were exposed to a p-Aramid aerosol for 5 minutes at estimated concentrations of 20-30 f/cc. The filters were processed for RFP counting, and prepared slides containing a portion of the RFP-exposed filters were first counted at DuPont Haskell Laboratory, and then the same slides were sent to the Denkendorf Institute in Stuttgart, Germany, and finally sent to the Institute of Occupational Medicine in Edinburgh, Scotland. For respirable fiber quantification, the NIOSH 7400 method (2) was used at Haskell Lab, while a WHO/EURO MMF method (3) was used in the European laboratories.

Inhalation Exposures

Briefly, atmospheres of p-Aramid and cellulose RFP were generated using a K-tron bin feeder (K-tron Co., Glassboro, NJ) equipped with twin screws. Baffles were inserted into the generation apparatus to increase the respirability of the samples. The respirable fiber samples were metered into a microjet apparatus (Micro-jet, Fluid Energy Co., Hatfield, PA) where high-pressure air transferred the test material through a series of glass and metal cyclones into the sampling chamber. Preliminary studies were conducted to validate the consistency of the exposure (i.e., reduced variability within the chamber). The target concentrations for the p-Aramid RFP atmospheres were 40 f/cc and the target aerosol concentrations for the cellulose RFP atmospheres were 25 f/cc.

Results

Cowl Washing Study

Filters A vs. filters B + filters C. No significant differences were observed between counts on filters exposed directly to the aerosol (filters A) compared to filters exposed directly + additional filters containing the washed material from the cowl (filters B and C combined) (see Table 1). For p-Aramid RFP exposures, the mean values for the directly sampled filters was 41.4 f/cc vs. 39.5 f/cc for the combined filters (i.e., directly sampled filter + filtrate from the cowl washing). For cellulose RFP exposures, the mean values for the directly sampled filters was 23.2 f/cc vs. 24.7 f/cc for the combined filters (i.e., directly sampled filter + filtrate from the cowl washing). These results suggest that the electrostatic potential of the p-Aramid or cellulose RFP had little effect on the fiber counts.

Round Robin Results

Laboratory A had consistently lower counts when compared to Laboratory B (mean values for the 15 filters = 18.4 $\pm$ 4.3 f/cc vs. 27.7 $\pm$ 4.3 f/cc. Laboratory C, with 2 different counters, was intermediate between the lower and higher counts (i.e., 24.2 $\pm$ 1 f/cc and 22.1 $\pm$ 2.2 f/cc) of Laboratories A and B, respectively. The raw data from the individual ports is presented in Table 2.

Conclusions

The results of our cowl washing study indicate that the electrostatic nature of the p-Aramid or cellulose RFPs apparently do not affect the fiber counts. Thus, the sample filters can be processed and counted directly without any additional cowl washing. It should be noted that, under the conditions of these studies, RFP aerosols were generated and filters were exposed in an inhalation chamber, similar to the procedures we would utilize for conducting inhalation toxicity studies. The aerosol sampling conducted in a plant setting may be different, although the electrostatic RFP sampling dynamics should be similar to the conditions used in our study.

Some differences were observed among laboratories in our round robin RFP counting study. The differences in respirable fiber counts may be related to the variability among counters, or to the slight differences in counting rules between the US and European methods. The counting rules for these two techniques are similar but not identical (2-3). The intra-laboratory variability between counts was lower than the inter-laboratory variability in RFP counts. Inter-laboratory variability in asbestos fiber counting has been reported by several investigators (4-6). Ogden and colleagues have noted that common problems are often associated with low-density slides and has suggested that reference slides become available (4). This suggestion could be a difficult task to implement for organic RFPs, given the numerous variety of organic fiber-types (e.g. nylon, polyester, acrylic, p-aramid, cellulose, etc.) concomitant with the observation that the organic RFP geometry generally depends upon the process method and the commercial application. In addition, different counting rules are likely to be responsible, in part, for the variability in inter-laboratory RFP counts (5). To our knowledge, this study represents the first published attempt to compare organic RFP counts among different laboratories. Studies are ongoing to better understand the inter-laboratory variability involved in organic RFP counts.

Acknowledgments

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Table 1. Comparisons of RFP counts on p-Aramid and cellulose-exposed filters vs. filters + contributions of washed cowls (n = 15).

	RFP counts (f/cc)	
	Control	**Cowl Washing**
p-Aramid	41.4 ± 3.7	39.5 ± 5.7
Cellulose	23.2 ± 2.7	24.7 ±1.5

Table 2. Round Robin RFP Counting Data – p-Aramid RFP experiment.

	Port Number															
	1	**3**	**6**	**8**	**9**	**11**	**13**	**14**	**16**	**19**	**21**	**23**	**25**	**28**	**30**	
Lab 1 (= f/cc)	(28.0)	(24.9)	(22.8)	(17.7)	(18.5)	(14.4)	(12.3)	(15.0)	(17.8)	(20.6)	(13.5)	(19.6)	(16.6)	(16.5)	(17.2)	n= 15 x= 18.35 + 4.3
Lab 2	(32.8)	(29.0)	(33.9)	(30.5)	(31.8)	(32.6)	(26.7)	(30.8)	(25.2)	(27.4)	(25.7)	(24.4)	(22.9)	(20.8)	(21.2)	n= 15 x= 27.7 + 4.3
Lab 3a	(26.9)	(24.1)	(22.8)	(23.3)	(24.1)	(23.5)	(25.6)	(25.1)	(23.4)	(22.5)	(24.0)	(24.4)	(24.2)	(23.6)	(24.7)	n= 15 x= 24.15 + 1.1
Lab 3b	(21.9)	(21.7)	(26.7)	(22.5)	(25.5)	(17.6)	(21.3)	(20.7)	(22.6)	(23.6)	(19.0)	(21.7)	(22.6)	(20.9)	(22.7)	n= 15 x= 22.0 + 2.2