Characterization of a Vortex Shaking Method for Producing Airborne Glass Fibers for Toxicology Studies

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Introduction

Current fiber measurement techniques arose primarily due to health concerns over asbestos exposure. Fiber toxicity appears to be mostly a function of fiber concentration, dimensions (diameter and length) and durability in the lungs. A fiber length classifier (FLC) was used to identify the toxicity of fiber length for an in vitro study (Zeidler-Erdely et al., 2006), but an important technological barrier to toxicological testing is the inability to generate large quantities of fibers in narrow length-classified size ranges (NIOSH Asbestos Roadmap 2011). To improve the performance of the FLC for toxicology studies, it is necessary to generate well-dispersed (or less agglomerated) airborne fibers at high concentrations to the inlet of the FLC. A vortex shaking method has been used to aerosolize fibrous particles such as carbon nanofibers and carbon nanotubes in previous studies because it is simple and easy to use (Ku et al., 2006; Maynard et al, 2007).

In this study we investigated characteristics of a vortex-tube shaking method for different initial batch amounts of glass fibers. The effect of pre-shaking and concentration decay with time were investigated and the potential for continuous feeding the vortex shaking generator was tested.

Methods

Glass fiber powder (GW1), supplied by the Japan Fibrous Material Research Association (JFMRA) (Kohyama et al., 1997), was used as a surrogate of asbestos to generate airborne glass fibers by a vortex shaking method (Ku et al., 2006). The experimental setup is shown in Fig. 1. Size distributions of the airborne glass fibers from a vortex shaker were measured by an Aerodynamic Particle Sizer (3321, TSI Inc.), and the airborne fibers were collected on a mixed cellulose ester filter (SKC Inc) in a 25 mm conductive cassette to measure length distribution of the fibers by a phase contrast microscope (PCM) with 40X and 10X objective magnifications. APS measurement and filter sampling were made at an aerosol flow rate of 1.5 lpm, and naturally charged level of the fibers was measured using an aerosol electrometer (3068B, TSI Inc.).

Measurements and Control Parameters

Control parameters: initial batch amounts of glass fibers, pre-shaking effect, charging effect, vortex strength and humidity.

Number concentrations of generated glass fibers were investigated at different conditions:

- Initial batch amount: 0.1, 0.2, 0.5, 0.8 and 1.0 g
- Pre-shaking: no pre-shaking, 30 min pre-shaking
- Humidity: dry air and 90 % relative humid air
- Charging: naturally charged by vortex shaker and neutralized.
- Vortex strength: varied from low to high strength

Measurement: decay of number concentration with time was measured continuously by APS for two to three hours. Charge level of fibers generated by vortex shaker was measured using an aerosol electrometer (3068B, TSI Inc.)

Results and Conclusion

Figure 2 shows number size distribution of glass fibers generated by vortex shaker as a function of time for batch amount of 0.2 g. Aerodynamically larger fibers (> 2 μm) decay faster than smaller ones. Fibers from a larger initial batch (not shown here) show one mode initially and then two modes over time while fibers from a smaller batch (0.2 g) show one mode for most of time.

Figure 3 shows number size distribution of glass fibers generated by vortex shaker as a function of time for batch amount of 0.2 g after 30 min pre-shaking. Initial concentrations with pre-shaking are higher than those for no pre-shaking case, and larger particles are generated for relatively long period.

Figure 4 shows total fiber number concentration of glass fibers generated by vortex shaker as a function of time for various batch amounts of fiber powder. The higher the initial batch material is, the higher the total number concentration is, and the longer the initial plateau concentration is. While the duration and initial plateau concentration depends on the initial batch, the concentration decay is very similar to all batches.

The charge on airborne fibers affects the number concentrations as shown in Fig. 5. The number of naturally charged fibers was a little bit lower in the size ranging from 1.5 to 4 μm than that of neutralized fibers, and the former was similar to the latter outside this size range. It is suspected that the fibers in the size range of 1.5 to 4 μm might be thin and long fibers, which could be electrostatically deposited on the walls of tubing.

Raising the humidity from dry air to 90 % changed the size distributions of fibers by shifting the modal diameter to a smaller size, i.e., from 1.0 μm to about 0.8 μm. This may be possibly because high humidity can make agglomerated fibers more easily dispersed by a coating of water vapour on the surface of fibers.

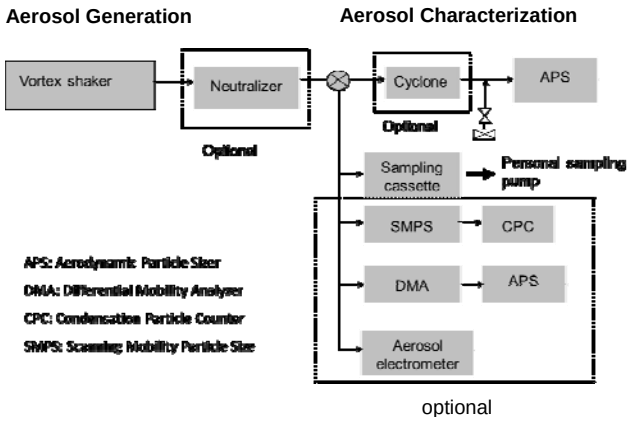

Figure 1. Experimental setup

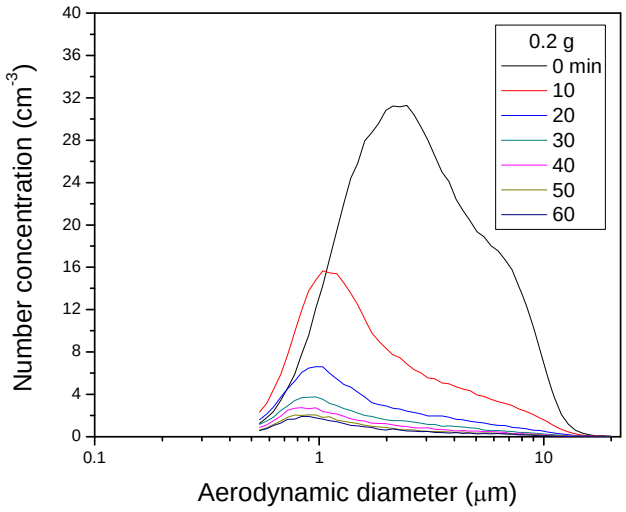

Figure 2. Number size distribution of glass fibers generated by vortex shaker as a function of time for batch amount of 0.2 g.

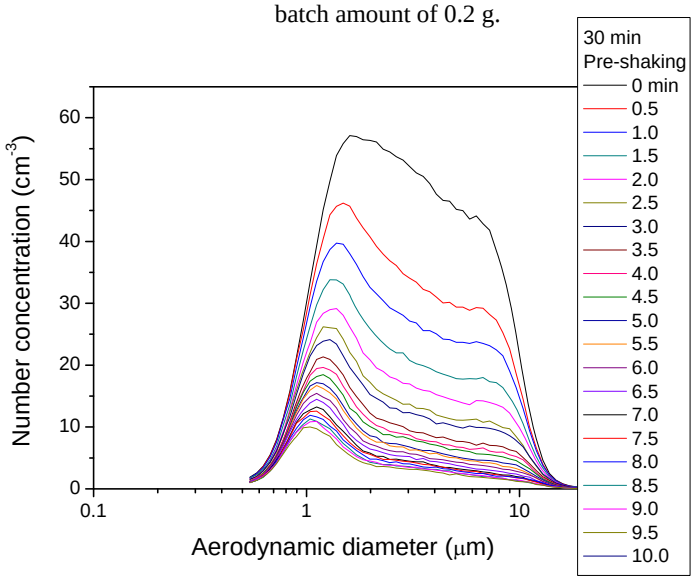

Figure 3. Number size distribution of glass fibers generated by vortex shaker as a function of time for batch amount of 0.2 g after 30 min pre-shaking.

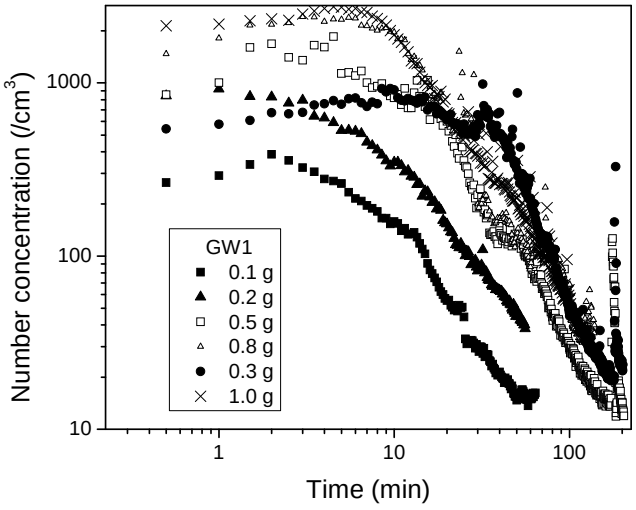

Figure 4. Total fiber number concentration of glass fibers generated by vortex shaker as a function of time for various initial batch.

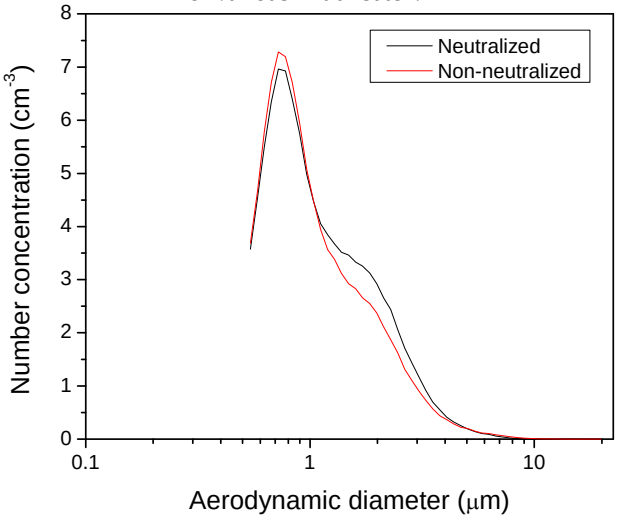

Figure 5. Number size distribution of neutralized fibers and naturally charged fibers.

Acknowledgments

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