Development of a Small Inhalation System for Rodent Exposure to Fine and Ultrafine Titanium Dioxide Aerosols

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INTRODUCTION

There has been great attention paid to the potential health effects of fine and ultrafine particles in the working environment. It is not only because of the increased application and use of fine/ultrafine powders in industry, but also due to the concern regarding the association between increased risk of morbidity and mortality and particulate air pollution on $PM_{2.5}$ and PM_{10} (Samet et al. 2000). Although the data imply that PM can affect tissues and organs outside the respiratory tract, as evidenced by the occurrence of cardiovascular dysfunction (Goldberg et al. 2000), the biological mechanisms which evoke systematic effects remain to be defined. In this collaborative research between NIOSH and WVU, we try to understand the mechanisms by identifying significant effects of pulmonary PM exposure on the systemic microcirculation (Nurkiewicz et al. 2004). As an initial step in this effort, a small-scale inhalation system was developed to expose rats to fine/ultrafine TiO_2 aerosols.

METHODS

An inhalation system, containing an aerosol generator, an animal chamber, and several monitoring devices, was developed (Figure 1). It was designed based on the criteria of simplicity, ability to disperse fine/ultrafine TiO_2 aerosols, and ease of maintenance.

Since the biological procedures are labor-intensive and, thus, only one rat can be examined per day, a 19-l metabolism chamber that contains a dual-component cage was modified for use as the whole-body exposure chamber.

TiO_2 powder (P25) obtained from DeGussa (Parsippany, NJ) was used. Although the average primary size is reported as 21 nm by the manufacturer, the primary particles tend to form aggregates as a result of van der Waals force. To reduce the size of the aggregates, the TiO_2 powders were carefully prepared for generation by sieving (to remove the big aggregates), drying (to avoid aggregate formation due to high humidity), and storage (to prevent aggregate attraction through contact charges). A TSI fluidized-bed aerosol generator (Marple et al. 1978) was used in this study because it was able to disperse powders during the preliminary trials.

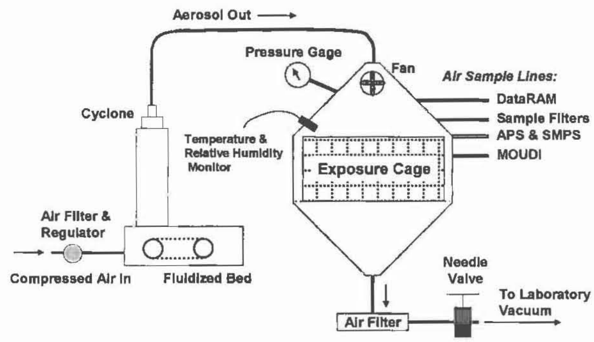

Figure 1. The schematic diagram of a small-scale inhalation exposure system.

A variety of aerosol instruments were used to characterize the aerosol: a Data RAM (MIE, Bedford, MA) for monitoring the mass concentration in real time, a combined APS/SMPS device (TSI, St. Paul, MN) for sizing both coarse and fine fractions of the aerosol, a MOUDI (MSP, Minneapolis, MN) for measuring mass-based aerodynamic size distribution, and two air filters to provide gravimetric measurements. Some samples were examined for particle morphology using electron microscopy. In addition, temperature, relative humidity, and pressure in the chamber were monitored throughout the exposure.

RESULTS AND DISCUSSION

Preliminary results indicated that the exposure system can produce a TiO_2 aerosol having a stable concentration for more than 4 hrs (maximum exposure duration). Mass concentrations up to 15 mg/m^3 could be achieved with a count mode size of approximately 120-170 nm, similar to those reported by Bermudez et al. (2004). Figure 2 shows the electron micrographs of the particles. The presence of nano-size particles in the TEM electron micrograph demonstrates that the fluidized-bed provided sufficient shear force to break up the matrix of loosely attracted aggregates and the cyclone in the generator performed well in removing coarse particles prior to aerosol output.

(a)

(b)

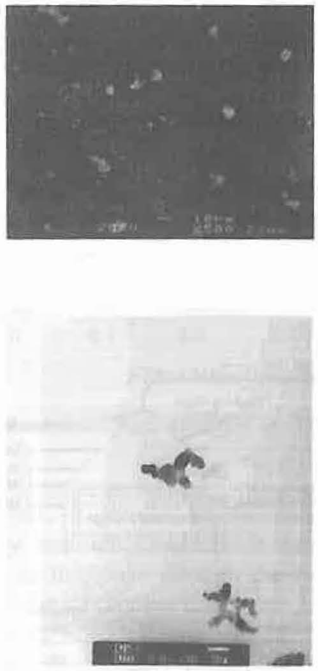

Figure 2. Electron micrographs of TiO_2 particles.
(a) SEM, (b) TEM

Results showed that the mass concentration of the TiO_2 aerosol can be maintained relatively stable solely by varying the conveyor chain speed with both the bed and purge flow rates fixed. As an example, at an 8-lpm bed flow and a 4-lpm purge flow, mass concentrations of 6 - 12 mg/m^3 can be achieved by adjusting the chain speed setting between 20 and 45. It was noted that undispersed powders from the bed should be routinely removed from the bed to ensure a low concentration (e.g., 6 mg/m^3). Generally, a lower concentration tends to have a smaller mean size.

Although it was reported that reaching a stable concentration requires at least an hour (Marple et al. 1978), we were able to achieve a stable concentration in the inhalation chamber within 20 min by gradually adjusting the chain speeds based on the real-time Data RAM profile.

Keywords: *inhalation exposure, fine and ultrafine aerosols, titanium dioxide*

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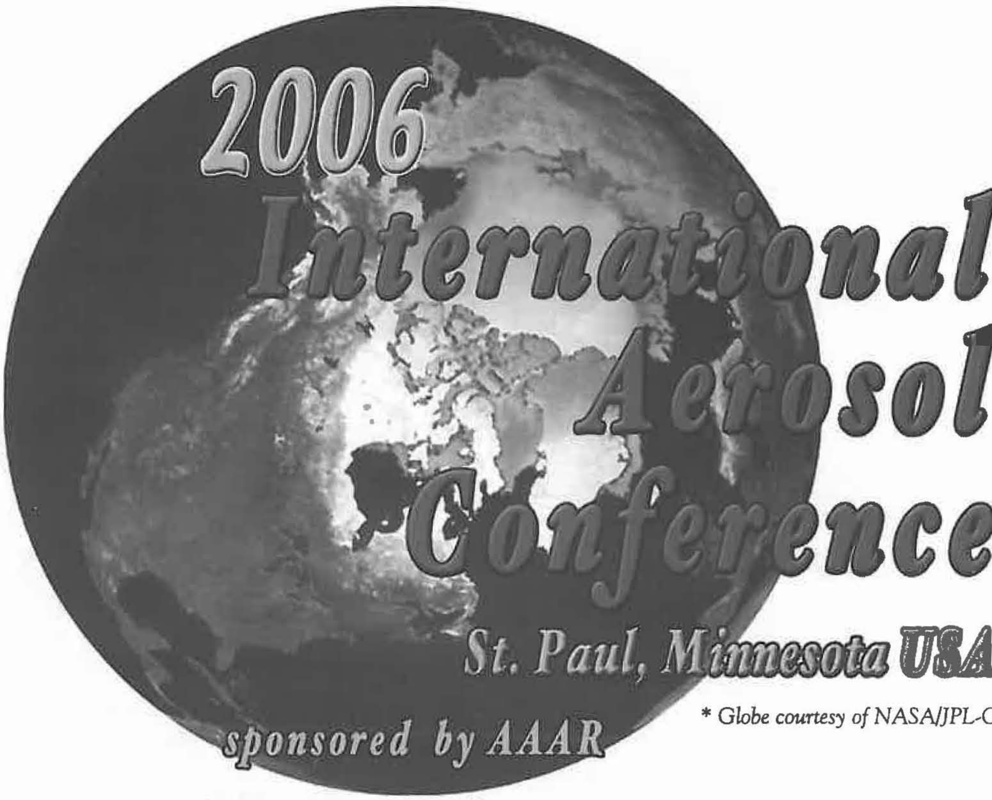

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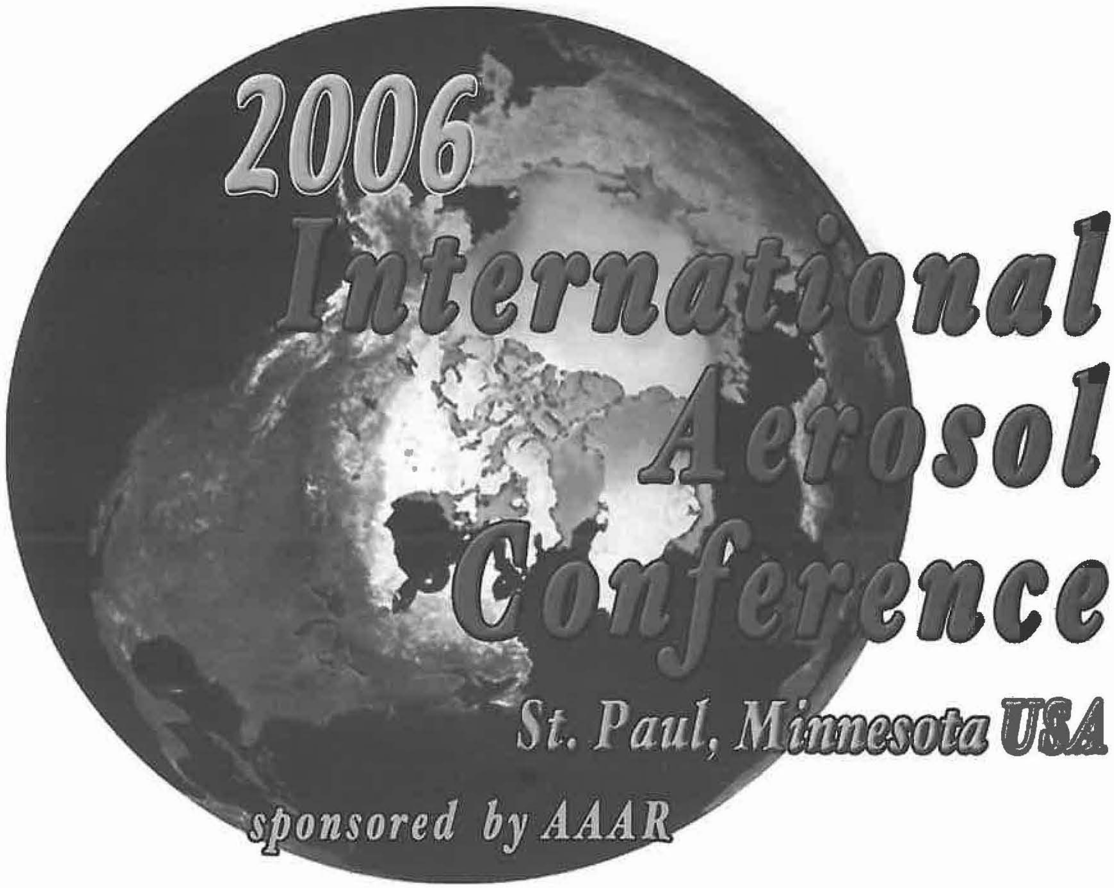

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