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PA25) 저용량 PM2.5 도입부 개발 및 성능평가

Design and Performance Evaluation of Low-Volume PM2.5 Inlet

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1. INTRODUCTION

Most particles capable of reaching the thoracic region of humans are in the size range below 10 ㎛ in diameter. Particles with a diameter smaller than 2.5 ㎛ are deposited in large amounts in the alveolar region during mouth inhalation. The hazard caused by fine particles depends on their chemical composition and the site within the human respiratory system where they are deposited (Hinds, 1982). Therefore, the concentration of air borne fine particles is an important parameter for the evaluation of the degree of hazard in an atmospheric environment.

There are several commercially available PM2.5 inlets for the sampling of particles. Their flow rates, however, are too high to use the semi-continuous device which can analyze the chemical composition of the particles. The flow rates of commercial cyclones (e.g. URG cyclone) and particle cup impactor (Kim et al., 2002) are 16.7 and 25 l/min, respectively. In the present study, a low volume PM2.5 inlet for analyzing the chemical composition was designed, fabricated and evaluated.

2. DESIGN AND EXPERIMENT

'Figure 1' is a schematic diagram of the inlet, designed for a PM2.5 sampler. In this study, the PM2.5 inlet design is based on a particle cup impactor configuration. Major advantages of the cup impactor are its freedom from particle bounce-off and the problem of overload.

The value of 0.24 was used for the Stk_{50}. Although the nozzle diameter, 2.6 mm, was determined from the Stk_{50}, the nozzle-to-cup distance of the instrument could easily be varied. The cup diameter was 7 mm, which was large enough to collect particles. Thus the ratio of cup diameter to nozzle diameter was about 2.7. The intake angle of an acceleration nozzle is very important to effect particle focusing and reduce coarse particle loss. Intake angle of all the acceleration nozzles was 45°.

Polystyrene latex (Solid particles, 1.05 g/㎤), oleic acid (Liquid particles, 0.887 g/㎤) and ammonium sulfate (Solid particles, 1.77 g/㎤) particles were used to evaluate the performance of the PM2.5 inlet. The size of monodisperse particles was ranged from 0.8 to 5.0 ㎛ as the aerodynamic diameter. Generally, several drops of the particles were introduced in a mixture of filtered isopropyl alcohol (50%) and distilled water (50%). The atomizer (TSI Inc., Model 9302) provided the particles, which were then made to pass through a heating tube. Thus, any remaining isopropyl alcohol and distilled water were allowed to evaporate completely. After drying, the aerosol was introduced into a Kr-85 radioactive source to

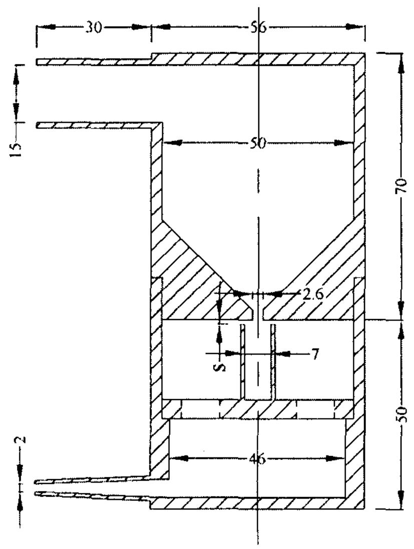

Fig. 1. Schematic of the PM2.5 inlet.

neutralize static charges. Before entering the PM2.5 inlet, the particles were diluted and mixed with air, which had been filtered through a HEPA cartridge-type filter (Gelman Science, Model 12144), in the mixing chamber.

Particle concentrations of both upstream and downstream of the PM2.5 inlet were measured using an Aerosizer (API Inc., Model Mach II). To reduce errors due to time variations in the upstream aerosol concentrations, repeat measurements were commenced at least 5 minutes after the introduction of the aerosol into the system. The sampling flow rate for the PM2.5 inlet was set at 5 l/min. However, the measurements in change with flow rates were conducted at flow rates of 3, 5, 8 and 10 l/min for each particle size.

3. RESULTS AND DISCUSSION

The penetration was found to be dependent on a smaller nozzle-to-cup distance (S). With a flow rate of 5 l/min, the smaller the S values, the smaller the cutoff diameter. When the S value was 1.1 mm, the cutoff diameter was smallest and .the penetration efficiency lowest. In addition, the cutoff diameter decreased as the flow rate increased. It is apparent that the collection efficiency increases linearly between the flow rates of 3 and 10 l/min, because the inertial force acting on the particles is greater at the higher flow rate.

'Figure 2' shows the penetration curve for the PM2.5 inlet at the sampling flow rate of 5 l/min, with an S value of 1.1 mm. The results show that for particles smaller than 2.5 ㎛ in diameter, the penetration rapidly increased as the particle size decreased, whereas the penetration of the particles with a diameter larger than 2.5 ㎛ decreased as the particle size increased. It is shown in Figure 2 that the designed PM2.5 inlet had a cutoff diameter of 2.55 ㎛, with an S value of 1.1 mm and a flow rate of 5 l/min. Thus, the cutoff diameter of the inlet was within the EPA specification of 2.5 ±0.2 ㎛. In addition, the inlet had the same penetration efficiency for the different aerosols (ammonium sulfate, oleic acid and polystyrene latex aerosols).

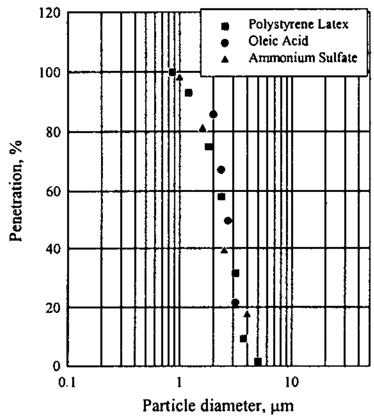

Fig. 2. Penetration for the PM2.5 inlet at the sampling flow rate of 5 l/min.

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