I. 15. Development of a Mini Step Sampler for Air-Pollution Monitoring


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Introduction

Atmospheric aerosol is small particulate matter caused by sandy dusts, smoke from factories, exhaust gas of cars and their deformed particles by photo chemical reactions in the atmosphere\textsuperscript{1-3}). Elemental concentrations in atmospheric aerosol reflect air pollution and its generating process. Therefore, elemental analysis of atmospheric aerosols is useful for aerosol source determination. Combination of aerosol collection on thin filter and PIXE analysis is one of the effective methods for elemental analysis of atmospheric aerosols\textsuperscript{1}). In previous study, we performed successive collection of aerosol samples with meteorological data and analyzed them by PIXE. The concentrations of Mn, Fe, Zn and Pb elements depended strongly on the direction of wind and their distributions for wind directions reflected to the position of aerosol sources. This result suggests that the aerosol source location can be determined by measuring the elemental concentrations of aerosols and wind directions at several positions with short sampling period\textsuperscript{4}). For this purpose, it is important to develop a compact sampler with low manufacturing and running costs for simultaneous sampling at several positions. The compact sampler is also useful for in-door sampling such as subway and houses. In this study, we developed mini step samplers and applied them to room aerosol monitoring.
Development of Mini Step Samplers

Sampler with smaller suction nozzle diameter is desirable for continuous sampling over extended periods and for the running cost. However, it causes problems as non-uniformity, choke of filter and high detection limit. Atmosphere is sucked through Nuclepore filter\(^5\) of 1.0 µm pore size in diameter, and aerosols are collected on the surface of this filter. Since the sizes of collected aerosol depend on face velocity as well as pore size\(^6\), these parameters must be determined when the sampler is designed. The suction nozzle of the step sampler (Green blue Co. LTD), which we used in previous studies, is 4 mm in diameter\(^7\). In order to get a more compact sampler, we tested the samplers of 2 mm-suction nozzle and 4 mm-suction nozzle. Test sampler is composed of filter holder, mass flow meter, fine control valve, vacuum pump and shelter. The suction nozzle of the filter holder can be easily changed. Aerosols were collected with the same face velocity of 80 m/min. The 50 % cutoff diameter of the sampler was less than 0.2 µm\(^8\) which is sufficient for anthropogenic aerosol collection. Sampling was performed at the same time using the two samplers for 3 hours at the campus of Tohoku University.

The samples were analyzed by the submilli-PIXE camera at Tohoku University\(^9\) Proton beams of 0.5 × 0.5 mm\(^2\) were uniformly scanned vertically and horizontally over the area of 5 mm × 7 mm. These samples contained Fe and Ca which are originating mainly in the soil. Elemental concentration ratios at the same time sampling using the same suction nozzle diameters of 4 mm are shown in Fig. 1. Figure 2 shows the results for the sampling using 4 mm- and 2 mm-suction nozzles. Elemental concentration ratios for both cases were consistent within ± 20 % except for few cases. Typical elemental distributions of Fe for suction nozzle diameters of 4 mm and 2 mm are shown in Fig. 3. While sample uniformity does not show meaningful changes among each other, it shows large deviation around 40%. In this case, a beam with uniform intensity across its cross sectional areas is required in the quantitative analysis. It is easier to get uniform beam over the small area. Therefore, sampling with small suction nozzle does not affect aerosol collections and is preferable for quantitative analysis.

Then we developed mini step samplers of 2 mm-suction nozzle diameter. The mini step sampler, shown in Fig. 4, is composed of a sampling unit, mass flow meter, fine control valve, vacuum pump, programmable control unit and shelter. A small reversible motor moves the suction nozzle. The programmable controller controls the movement of the suction nozzle one dimensionally and vacuum pump. The sampler collects more than 70
samples. The weight of the sampler is about 6 kg. The compact sampler allows easy setting.

**Application for in-door Monitoring**

We applied the mini step samplers to room aerosol monitoring. Aerosol samples were collected at two rooms inside our laboratory and a hall outside, during the period 11(Fri.)-15(Tue.) January 2002. Sampling points are in the second floor and are shown in Fig. 5. In our laboratory, no shoes are allowed. We change shoes in at the entrance. Sampling point 2 (Lab2) is near the entrance. The laboratory has only one entrance. The sampling point 1 (Lab1) is far from the entrance and student area. Sampling point 3 (Hall) is the corner of a hall and is near the copy machine. The hall can be accessed by anyone who wants to use.

The collected samples were analyzed by the Vertical in-air PIXE (ViaPIXE) system at Tohoku University\textsuperscript{10,11}. Beam spot size was around 1.5 mm in diameter. It covered 60 % of the sample area, which is sufficient for quantitative analysis. Seven elements (Ca, Fe, Zn, Pb, Ti, Ni and Cu) were observed in these samples. The main elements were Ca, Fe and Zn. Their average, maximum and minimum values are written in Fig. 5. Time distribution of elemental concentration of Ca, Fe and Zn are shown in Figs. 6-8. Elemental concentrations increased periodically in the daytime and decreased at night. The correlation between the elemental concentrations of Ca and Fe was very strong in the hall. The concentrations in weekday were several times higher than in holiday, especially at the hall and the Lab2. Since elements of Ca and Fe are components of soil dust, time distribution of elemental concentration is caused by up flung soil with human movement. Elemental concentrations of the hall were always higher than the Lab1 and Lab2. Concentrations at the Lab1 were almost the same as those of Lab 2 in holiday. In our laboratory, we change shoes at the entrance of the room. This is the reason why the elemental concentrations were lower than that of the hall.

The mini step sampler is very useful for in-door sampling and will be a powerful tool for air-pollution monitoring.

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References

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Fig. 1. Elemental concentration ratios for simultaneous sampling using the samplers of suction nozzle diameters of 4 mm.

Fig. 2. Elemental concentration ratios for simultaneous sampling using the samplers of suction nozzle diameters of 4 mm and 2 mm.
Fig. 3. Elemental distributions of Fe using the sampler of 4 mm-suction nozzle (left) and that of 2 mm-suction nozzle (right).

Fig. 4. Multi-step sampler.

Fig. 5. Sampling Points and the average, maximum and minimum values for the main elements (Ca, Fe and Zn) at the sampling points.
Fig. 6. Time distribution of Elemental Concentrations (Ca).

Fig. 7. Time distribution of Elemental Concentrations (Fe).

Fig. 8. Time distribution of Elemental Concentrations (Zn).