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## **Investigation on Air Pollution in Vietnam - Concentration of Water-soluble Ions in Suspended Particulate Matters -**

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### **Introduction**

The Socialist Republic of Vietnam is one of the countries making especially remarkable industrialization in the Southeast Asian. The numbers of motorcycles are increasing rapidly in the cities, and as a result it is apprehensive for the influence of exhaust gas from motorcycles to the human health. The investigation on ambient air pollution in Hanoi City and Ho Chi Minh City has been carried out for the past 3 years (2000-2002 years). In this report, we described the results of concentrations of water-soluble anions and cations contained in the suspended particulate matters (SPM) in 2 cities of Vietnam and Osaka City in Japan during the period of 2002.

### **Keywords**

Dry Deposit, High-Volume air sampler, SPM and PM10, Water-soluble ions, Hanoi, Ho Chi Minh, Osaka City

### **Methods**

**Sample collection:** SPM was collected on a quartz fiber filter paper (ADVANTIC QR-100, 203 x 254mm) by using Hi-Volume air sampler at flow rate of 1m<sup>3</sup>/min for 24 hours. Using the apparatus for particle size separation attached on the air sampler also collected the SPM sample (PM10), of which the particle size is less than 10µm.

**Sampling period:** Sampling was carried out during the period of January in Ho Chi Minh City, September in Hanoi City, and May in Osaka in the year of 2002.

**Sampling site:** Samples were collected on the ground of Hydro-Meteorological Service of Vietnam (HMSV) in Hanoi City, at roadside of Department of Science and Technology (DOSTE) and on the roof of Institute for Tropical Technology and Environmental Protection (ITTEP) in Ho Chi Minh City, and on the roof of Environmental Pollution Control Center (EPCC) in Osaka City.

**Pretreatment for determination of water-soluble ions:** The filter paper, which collected samples, was clipped out in the circle of 25mm diameter, and the piece of filter was put in the plastic container of 100ml volume. A thirty ml of purified water was added in it, then extracted by using ultrasonic vibration for about 10 minutes. The extract was filtered with MF<sup>TM</sup>-Membrane filter (0.45 µm HA, Millipore), and then submitted to the ion chromatographic analysis.

**The target ions:** The five kinds of cations: sodium ion (Na<sup>+</sup>), potassium ion (K<sup>+</sup>), ammonium ion (NH<sub>4</sub><sup>+</sup>), calcium ion (Ca<sup>2+</sup>), and magnesium ion (Mg<sup>2+</sup>). The three kinds of anions: chloride ion (Cl<sup>-</sup>), nitrate ion (NO<sub>3</sub><sup>-</sup>), and sulfate ion (SO<sub>4</sub><sup>2-</sup>)

### **Results and Discussion**

#### **SPM, PM10, and the total concentration of water-soluble ions**

The concentration of SPM and the total concentration of water-soluble ions measured in the

three cities were shown in Table 1. As for the SPM and PM10 concentration in Hanoi City, the PM10 concentration was about half of the SPM concentration. From the comparison of the PM10 concentration in Vietnam Cities, the PM10 concentrations were in the same concentration level though the concentration level of the roadside was a little higher than that of residential area. These results suggested that the SPM concentrations were in same level in both cities of Vietnam. Accordingly, the SPM concentrations of Vietnam Cities were higher about 6-7 times than that of Osaka City.

Table 1 Concentration( $\mu\text{g}/\text{m}^3$ ) of SPM (PM10), and Water-soluble Ions in SPM  
unit :  $\mu\text{g}/\text{m}^3$

Sampling Location	Particulate Matter	City	Water-soluble Ions ( $\mu\text{g}/\text{m}^3$ )	SPM ( $\mu\text{g}/\text{m}^3$ )	Ratio of ions to SPM	n
EPCC (Ambient)	SPM	Osaka	11 (80)	35	0.30	7
			8 (46)*	32	0.24	6
ITTEP (Ambient)	PM10	Ho Chi Mihn	19 (27)	103	0.18	7
DOSTI(Roadside)	PM10	Ho Chi Mihn	22 (22)	128	0.17	7
HMSV(Ambient)	PM10	Hanoi	13 (37)	104	0.13	4
HMSV(Ambient)	SPM	Hanoi	15 (12)	229	0.07	3

\* One of data was excluded because of photochemical smog accident.

EPCC : Environmental Pollution Control Centaer

DOSTI: Department of Science, Technology and Environment

ITTEP : Institute for Tropical Technology and Environmental Protection

HMSV : Hydro-Meteorological Service of Vietnam

SPM : Suspended Particulate Matters

PM 10 : Particulate Matter(size less than 10 $\mu\text{m}$ )

As for the total ion concentration of SPM and PM10 in Hanoi City, the ratio of total ion concentration of SPM to that of PM10 was about 1.2. By contraries, the ratio of SPM concentration to PM10 concentration was 2.2. These results indicated that the most of water-soluble ions were contained in the PM10 sample, that is, the fine particles (the size, less than 10  $\mu\text{m}$ ) mainly contributed to the ion concentrations.

The mean of total ion concentration of Osaka City was 10.7  $\mu\text{g}/\text{m}^3$ . Except for one of the seven data, where the hourly concentration of oxidant exceeded more than 110ppb, the mean value was 7.7  $\mu\text{g}/\text{m}^3$ . The means of the total ion concentration were increasing in order of Osaka, Hanoi, Ho Chi Minh City, and the means in Vietnam Cities were higher about 2-3 times than that in Osaka City. On the contrary, the ratios of the total ion concentration to the SPM concentration were decreasing in the same order of Osaka, Hanoi, and Ho Chi Minh City.

### Ion balance

The relationship between the total equivalent concentrations (eq/L) of cation (x) and of the anion (y) was plotted in Fig. 1. The relation between the total cation and anion was estimated to be  $y=0.82x$  except for the abnormal three data, thus the concentration of anion was less by 20% than that of cation. It has been reported<sup>1)</sup> that the relations of the two were closely 1.00 ( $y=1.0x$ ), and they were kept equivalently in balance.

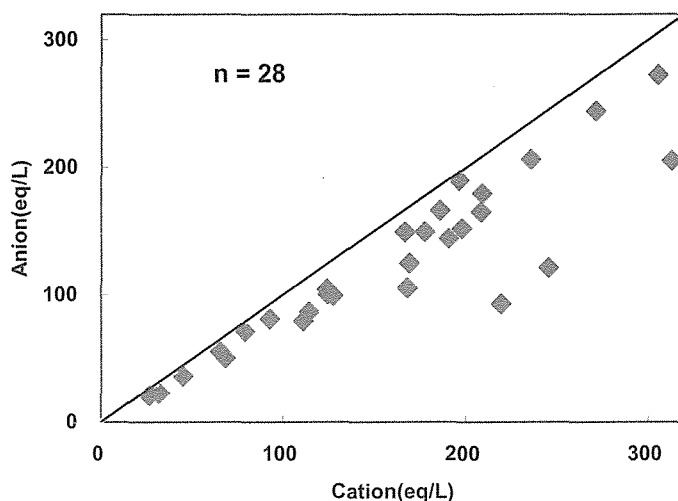


Fig. 1 Correlation between total equivalent Concentration (eq/L) of Anions and that of Cations

### The ion concentrations<sup>2)</sup>

The ion concentrations (nmol/m<sup>3</sup>) measured in the three cities were shown in Table 2. For comparison, the annual means, maximum, and minimum of ion concentrations in SPM were cited from the 3<sup>rd</sup> Investigation on Acid Deposition of Japan enforced in 2000.

Table 2 Comparison of the Mean Concentrations (nmol/m<sup>3</sup>) of Water-soluble Ions among Sampling Sites

Ions	Unit : nmol/m <sup>3</sup>							
	Osaka	Ho Chi Mihn		Hanoi		Cities in Japan*		
	EPCC SPM	ITTEP PM10	DOSTE PM10	HMSV PM10	HMSV SPM	mean	max	min
Na <sup>+</sup>	19.9	77.3	103.8	9.9	15.8	39.6	101.9	8.1
NH <sub>4</sub> <sup>+</sup>	96.6	99.2	59.6	92.2	40.6	93.5	164.7	20.7
K <sup>+</sup>	1.6	21.9	17.4	14.9	19.8	6.3	16.0	1.8
Ca <sub>2</sub> <sup>+</sup>	20.7	52.0	76.2	45.9	123.8	12.1	28.0	2.4
Mg <sub>2</sub> <sup>+</sup>	4.0	11.0	15.0	3.9	7.3	5.6	15.0	1.2
Cl <sup>-</sup>	5.6	37.1	75.7	2.2	17.9	28.6	83.6	4.8
NO <sub>3</sub> <sup>-</sup>	33.8	39.4	48.6	9.8	28.9	37.0	96.9	6.6
SO <sub>4</sub> <sup>2-</sup>	54.1	87.6	86.5	87.2	62.1	50.4	93.9	15.0

\*The survey was conducted in ficical 2000 year, and the values were estimated from the Report on the 3rd Investigation on Acid Deposition of Japan published in 2001

As most of cities in Japan were located in the coastal area, the SPM sample in the city often influenced from the sea salt particles, thus the concentrations of Na<sup>+</sup>, Mg<sup>2+</sup>, and Cl<sup>-</sup> ion were

comparatively high.

Though the sampling site of EPCC was located in Osaka City at the distance of 20km from the coast area, the ion concentration of  $\text{Na}^+$ ,  $\text{Mg}^{2+}$ , and  $\text{Cl}^-$  were not so high, that is, this sampling site was hardly influenced by the sea salt from the sea. On the other hand, the ion concentrations of  $\text{Na}^+$ ,  $\text{Mg}^{2+}$ , and  $\text{Cl}^-$  were very high in Ho Chi Minh City. Their concentrations were in the same levels of the annual maximum concentrations observed in Japan cities. Ho Chi Minh City is located in Mekong delta area, faced to the Pacific Ocean. However, the sampling sites are at the distance of 50km from the coastal area. These sites were hardly influenced by the sea salt from the Ocean. The ground water (well water) in the city is used mainly for the drinking water and watering of the plants. It has been reported that the well water in some part of city area tastes saltish. From the above consideration, the high concentrations of these three ions could be originated from sea salts contained in a soil.

The concentrations of  $\text{Ca}^{2+}$  and  $\text{K}^+$  among the cations were relatively high in Vietnam cities. These results were coincident with the analytical results of metal components in  $\text{SPM}^{2)}$ . The origins of the  $\text{Ca}^{2+}$  were suggested to be the sea salt and the soil. The  $\text{ssCa}^{2+}$  is a concentration of  $\text{Ca}^{2+}$  caused by the sea salt, and estimated by the averaged ratio of the  $\text{Ca}^{2+}$  to  $\text{Na}^+$  in the sea salts, on assumption that all of  $\text{Na}^+$  is caused by the sea salts. The  $\text{ssCa}^{2+}$  was very low and negligible, thus it seems the origin of the  $\text{Ca}^{2+}$  to be the soil. The origins of the  $\text{K}^+$  were supposed to be the sea salt, the soil, and the natural sources such as a plant (pollen and seed). The  $\text{ssK}^+$  estimated by same process as the  $\text{ssCa}^{2+}$  was very low and negligible. Considering the thick growth of the many kinds of plants in the tropics, it seems the origin of the  $\text{K}^+$  to be the natural sources.

It has been reported that the concentration of  $\text{NH}_4^+$  of the city area (the annual maximum value  $165\text{nmol/m}^3$ , the annual mean value  $94\text{nmol/m}^3$ ) was higher than that of the rural area in Japan, and the concentration of  $\text{NH}_4^+$  could depend on population. The concentration levels of the  $\text{NH}_4^+$  of the Vietnam cities were similar to those of Japan cities.

The  $\text{NO}_3^-$  is one of the reaction products of the primary pollutant such as  $\text{NO}$  and  $\text{NO}_2$  from emission sources. The concentration levels of the  $\text{NO}_3^-$  of the Vietnam cities were similar to those of Japan cities.

The origins of the  $\text{SO}_4^{2-}$  were divided into two categories: the natural sources such as the sea salt and soil, and the artificial sources such as reaction products of the primary pollutant ( $\text{SO}_x$ ) from the emission sources. The  $\text{ssSO}_4^{2-}$  was very low and negligible, thus the  $\text{SO}_4^{2-}$  were mainly originated from the reaction products of primary pollutants in the fuel combustion process. The concentration of the  $\text{SO}_4^{2-}$  of Vietnam cities were higher than that of Japan cities.

### Correlation of ion components

The correlation coefficients between each ion component were shown in Table 3. All of the correlation coefficients between  $\text{Na}^+$  and each anion, and between  $\text{Mg}^{2+}$  and each anion were shown to be predominant ( $0.506\sim 0.959$ ). And all of the correlation coefficients between  $\text{SO}_4^{2-}$  and each cation were shown to be predominant ( $0.506\sim 0.737$ ). The  $\text{NH}_4^+$  and the  $\text{NO}_3^-$  were the exceptions. The correlation coefficients between these two were not shown to be predominant. These two ions were supposed to be originated from the different origins and showed their different behaviors in ambient air. As for the  $\text{NH}_4^+$  and the  $\text{NO}_3^-$  in ambient air, the  $\text{NH}_4^+$  and the  $\text{NO}_3^-$  were reacted to be  $\text{NH}_4\text{NO}_3$  as a particulate matter under the temperature of less than  $20^\circ\text{C}$ , and with increasing the temperature, the  $\text{NH}_4\text{NO}_3$  was decomposed to the original ions. In Vietnam of which the averaged temperature was more than  $30^\circ\text{C}$ , the  $\text{NH}_4^+$  and the  $\text{NO}_3^-$  could not exist as  $\text{NH}_4\text{NO}_3$ .

### Contents of the sea salt particles in SPM and PM10

From the consideration that the concentrations (eq/L) of the  $\text{Na}^+$  and the  $\text{Cl}^-$  were equivalent, and these ions were mainly originated from the salts (sodium chloride), the contribution of sea salts to

SPM and or PM10 samples were estimated on the assumption that all of the  $\text{Na}^+$  was caused from the sea salts. The total amount of ion from the sea salts was calculated by summation of the values obtained with multiplying the concentration of the  $\text{Na}^+$  in SPM and or PM10 sample by molar ratio: the molar ratio of each main component (Na, Cl, S, K, Ca, and Mg) to Na in the sea water. The contents of the sea salts varied depending on the sampling sites were estimated to be 10% in Hanoi City, 50% in Ho Chi Minh City, and 20% in Osaka City.

### Acknowledgement

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### Summary

During the period of 2002 year, the investigation on the water-soluble ions contained in SPM and PM10 was carried out in the three cities, Osaka, Hanoi, and Ho Chi Minh City by using the High Volume air sampler, and the results obtained were following:

1. The concentrations of SPM of Vietnam cities are estimated to be about 6-7 times higher than that of Osaka City, and the total ion concentrations of Vietnam cities is to be about 2-3 times higher than that of Osaka City.
2. The averaged ratio of the tonal equivalent concentration of anion to that of cation was 1.2, and the cation was in excess of 20% of anion over the ion balance.
3. The higher concentration of  $\text{Na}^+$ ,  $\text{Cl}^-$  and  $\text{Mg}^{2+}$  observed in Ho Chi Minh City were supposed to be originated from the sea salt in soil. The higher concentration of  $\text{Ca}^{2+}$  and  $\text{K}^+$  were observed in Vietnam cities, and the  $\text{Ca}^{2+}$  is supposed to be originated from the soil and  $\text{K}^+$  from the natural sources such as plants. The concentration level of  $\text{NH}_4^+$  was similar in the cities of the both countries.
4. The concentration level of  $\text{NO}_3^-$  was similar in the cities of the both countries. The main origin of the  $\text{SO}_4^{2-}$  was supposed to be the artificial sources on the combustion process.
5. From the correlation coefficients between the  $\text{NH}_4^+$  and the  $\text{NO}_3^-$ , they were supposed to be originated from the deferent sources and behave in the different manner in ambient air.
6. The contribution of the sea salts to SPM and or PM10 estimated were 20% in Osaka City, 50% in Ho Chi Minh City, 10% in Hanoi City, respectively.

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