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A survey of SO_2, NO_2 and NH_3 concentrations in atmosphere at high latitudes and in Arctic

Chen Letian (陈乐恬) and Tong Yuqin (佟玉芹)

Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

Fang Jingyun (方精云)

Department of Urban and Environmental Science, Peking University, Beijing 100871, China.

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Abstract Simple passive diffusive samplers were used for the determination of SO_2, NO_2 and NH_3 in atmosphere from three stations at high latitudes and in Arctic area. The concentrations of SO_2, NO_2 and NH_3 were found to be below 1.0, 0.3 and 2.0 $\mu g/m^3$ respectively. These values were obtained with sampling periods of 5 - 10 d. These preliminary data suggest that SO_2, NO_2 concentrations should be lower 2 order of magnitude than those of Beijing area, and an order of magnitude than those of other areas with less pollution in China.

Key words Arctic, passive sampling, environmental survey.

1 Introduction

A scientific investigation on Arctic for the first time was carried out by China Arctic Scientific Expedition (CASE) between April and May 1995. To study the background values of surrounding atmosphere in Arctic, the air samples of three sites were collected by using passive sampling methods. The chemical analysis for SO_2, NO_2 and NH_3 in atmosphere was made. At the same time the atmospheric samples were collected in Beijing by the same methods and same chemical analysis was made. This paper is to lay stress on studying the concentration distribution of these trace gases as a part of research on environmental background value in Arctic, and is to compare them with those found in other areas. So it is expected to make a preliminary understanding for air quality in Arctic.

2 Procedures

2.1 Sampling set-up

Ely (Minnesota, USA), Churchill (Manitoba province, Canada) and Resolute located in the northwest part of Canada were selected as sampling sites for collecting air samples. The team has stayed at these places for a period of time. It was possible

to collect the air samples. The samplers should be put up in wind-shadow area, far away from residential quarter and 3 – 5 m above the ground. The temperature was recorded three times a day (8:00 Am, 12:00 and 6:00 Pm) for calibrating the day-average temperature, start and stop date, landscape and vegetation should also be recorded.

2.2 Sample collection and analytical methods

The sampling methods for trace gases in atmosphere can be broadly divided into passive and active (pump-driven)types. In active sampling, a pump is used to draw a known volume of air through an adsorbent. That is impossible to do in Arctic. The major advantage of the passive sampler is that it is unnecessary to use elaborate sampling equipment. Neither pump nor power supplies are required. The technique is both simpler and less expensive than active sampling with a pump. Passive samplers are used to measure time-average concentrations of gases and generally depend on mass transport of the gas by diffusion or permeation mechanisms (diffusion device was used in this work). It has more environmental implication in evaluating ambient air quality.

The details of principle and description about the sampler have been given (Ferm 1991; Chen *et al.* 1992). The concentration C is obtained from following: $C = \frac{XK}{tD}$, where X is the gases amount trapped on the filter (μg); t is the sampling time (s); D is the diffusion coefficient of the sampled gas in air; $D_{SO_2} = 1.32 \times 10^{-5}$ m^{2}s^{-1}(20 ℃); $D_{NO_2} = 1.68 \times 10^{-5}$ m^{2}s^{-1}(25 ℃); $D_{NH_3} = 2.54 \times 10^{-5}$ m^{2}s^{-1}(25 ℃). It is necessary to calibrate D by using the average temperature. K is the constant related to the size and shape of the passive samplers 37.72 m^{-1}.

Table 1 gives the impregnated reagents, extraction solutions and analytical methods for trace gases.

Table 1. The condition of experiment

Gas	Impregnant reagent	Extraction solution	Analytical method
SO_2	4% K_2CO_3	0.03% H_2O_2	Ion chromatographic determination of SO_4^{2-} after oxidation of SO_2 by H_2O_2
NO_2	25% triethanolamine (TEA) in acetone	De-ionized water	Spectrophtometric determination of NO_2^- using N-1-naphthylethylendiamine dihydrochloride
NH_3	2% H_3PO_4	De-ionized water	Spectrophotometric determination of NO_2^- after oxidation of NH_3 by hypobromite

3 Results and discussion

Table 2 shows the concentrations of SO_2, NO_2 and NH_3 in Ely, Churchill, Resolute and at Zhongguancun, Beijing.

(1) Normally two samplers were used for collection of trace gases at non-background areas. The concentrations of trace gases were calculated after subtracting the blanks of sampler. The gases amounts trapped on the filter frequently were the same order of magnitude with blanks values of sampler, owing to the extremely low con-

centrations of trace gases at high latitudes and in Arctic. Additionally, the blanks of samplers could not keep a constant because of passable contamination during preparing, storage and transport process. The results of the experiments show that the blanks of SO_2, NO_2 and NH_3 samplers are below 10, 2 and 30 nmol respectively. Six passive samplers were normally supplied for use in each station for each gases with the three remaining samplers being stored unopened and used as the blanks in the analysis for trace gases in Arctic areas. Sometimes one or two samplers were lost or contaminated so 4 – 6 data were given in Table 2. The concentrations of trace gases were calculated, after subtracting the blanks of samplers. Table 3 shows the blank values of samplers at each station.

Table 2. Average concentrations of SO_2, NO_2 and NH_3 in atmosphere

Sampling station	Location		Duration	Average temp. /C		Gas concen. /($\mu g \cdot m^{-3}$)			Landscape near sampling station
	Longitude	Latitude				SO_2	NO_2	NH_3	
Ely (Minnesota, USA)	91°48′W	47°58′N	1995-04-13 | 1995-04-19	2.8		1.60	-	-	Temperate deciduous and broad leaf forest zone
						-	-	0.21	
						1.60	0.04	-	
						0.34	-	0.15	
							0.12		
					A.V.	0.89	0.03	0.09	
Churchill (Manitoba, Canada)	94°04′W	58°46′N	1995-04-05 | 1995-04-10	−17.2		1.18	0.64	1.94	near Hudson Bay coast
						1.63	0.06	2.52	
						-	0.64	2.00	
						-	-	2.00	
							0.06	1.24	
							0.40	1.98	
					A.V.	0.70	0.30	1.95	
Resolute (Northwest in Canada)	97°W	74°43′N	1995-04-24 | 1995-05-04	−18.1		0.78	0.17	0.09	An airport is 2.5 km distant from the Resolute Bay in shore
						0.78	0.03	2.34	
						0.56	-	0.09	
						-	-	1.69	
					A.V.	0.53	0.05	0.83	
Zhongguancun (Beijing, China)	116°E	40°N	1995-04-26 | 1995-05-03	16.0		33.33	27.78	18.54	Residential quarter
						32.29	28.16	17.53	
							29.67	18.79	
					A.V.	32.81	28.54	18.28	

Note: "-" means that the value measured is below blank value and it takes zero in the calculation of the average value; A.V.: Average value; Gas concen.: Gas concentration; Average temp.: Average temperature.

Table 3. Blank of samplers (nmol)

Station	SO_2	NO_2	NH_3	Station	SO_2	NO_2	NH_3
	10	1.7	17		6.5	2.0	28
Ely	8	2.1	19	Resolute	7.5	1.9	27
	9	1.9	18		6.9	1.8	29
Average value	9	1.9	18	Average value	7.0	1.9	28
	7.1	1.6	20				
Churchill	6.8	1.8	21	Beijing	11	1.9	29
	6.9	1.7	19		9	2.1	28
Average value	6.9	1.7	20	Average value	10	2.0	28

(2) With regard to the concentration values of three trace gases at three stations in Arctic, the concentration of NO_2 was the lowest, the concentration of SO_2 was

slightly higher but still in the background levels (Heikes *et al.* 1987). They were lower 1 – 2 order of magnitude than those of Beijing area during same period and lower an order of magnitude than those of other areas with less pollution in China. For example, the concentration of SO_2 was 8.0 $\mu g/m^3$ at Xiaolongmen forest ecological station (belonging to Chinese Academy of Sciences) located at the bound of Beijing and Hebei Province in July 1991(Chen *et al.* 1992). The concentration of NO_2 was 4 – 6 $\mu g/m^3$ at Lin'an, Zhejiang Province in Feb. 1994(Chen and Tong 1995). Although the concentration of NH_3 was also lower 1 – 2 order of magnitude than those of Beijing area but the higher concentration of NH_3 was found in Churchill. It was almost the same level with those of southern provinces in China (Pang and Tong 1985).

(3) An analysis of the concentration distribution of these trace gases were given in the following, Ely, Churchill and Resolute are located from south to north in turn. The population and industry have been decreasing from Ely to Resolute. According to the transportation rule of particulate, the concentrations of air pollutants should decrease from south to north at high latitudes. From Table 2 the smallest concentration 0.53 $\mu g/m^3$ and the highest concentration 0.89 $\mu g/m^3$ for SO_2 were found in Resolute and in Ely respectively. The medium value of SO_2 0.7 $\mu g/m^3$ was found in Churchill as might be expected. There was no trend toward such a change of NO_2 and NH_3 levers. The highest value for NO_2 and NH_3 were found in Churchill. The reason for this was not well known, but the landscape of near sampling stations could give the partial description. Churchill is located in the transition area between Taiga forest and Arctic frozen plain. Both vegetation and soil have strong biological active. Churchill is also one of the biggest harbor in Northern America. These may increase concentration value. Ely is located in the south surrounding by forests, which may adsorb some nitrogenous compounds and decrease the concentration. The further researh on concentration distribution of these trace gases will still be needed.

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