

Chemical characteristics of summer precipitation at Point Barrow, Arctic Alaska^{*}

Hou Shugui (侯书贵) and Qin Dahe (秦大河)

Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences, Lanzhou 730000, China

Zhang Qingsong (张青松)

Institute of Geography, Chinese Academy of Sciences, Beijing 100101, China

Received February 17, 1997

Abstract Precipitation samples collected at Point Barrow, Alaska in the August and September of 1994 was analyzed for pH, conductivity and all major ions. A mean pH value of 5.53 was gained, and the samples' conductivity showed no linear correlation with its acidity, which did not agree to the similar work results on the Qinghai-Tibet Plateau. Cl^- and Na^+ were found to originate mainly with seasalt. The concentrations of SO_4^{2-} varied from event to event. But the exSO_4^{2-} concentrations remained small, which indicated less anthropogenic effect on the environment at the site.

Key words Point Barrow, precipitation, composition.

1 Introduction

The understanding of the acid precipitation phenomena and of the impact of human activities on the global environment requires information on the precipitation chemistry in remote areas. Such work has been undertaken in the Global Precipitation Chemistry Project (Galloway *et al.*, 1982), as well as in snowpack studies in the Arctic and Antarctic regions (Barrie and Vet 1984; Neftel *et al.* 1985; Qin *et al.* 1992). However, reports on chemical characteristics of directly collected Arctic precipitation are scarce (Dayan *et al.* 1985).

Based on the agreement between Chinese Academy of Sciences (CAS) and the government of North Slope of Borough, Alaska, 3-week field work was carried out at Point Barrow, Alaska during August 16, 1994 to September 7, 1994. Point Barrow (71°19'N, 156°40'W) is located on the northern coast of Alaska and is the most northern U.S. /WMO baseline station. The meteorology of the region is typical for the North Slope of Borough, an Arctic marine climate with relatively small amount of

^{*} This project was funded by Chinese Academy of Sciences and Wildlife Department of North Slope of Borough, Alaska.

precipitation (120 mm annual average), which falls mainly between July and October. The sampling site (NARL) is a small settlement about 5 km away from the main town, several hundreds meters from the Chukchi Sea (see Fig. 1). A total of 23 precipitation samples were collected.

Following Junge (1977), the concentrations of trace substances in precipitation are, in general, proportional to the atmospheric concentrations under clean air conditions. In a source-free area such as the Arctic region, a constant mixing ratio of aerosols in the lower troposphere can be assumed. So it is reasonable to evaluate the atmospheric environment condition from the precipitation chemical characteristics.

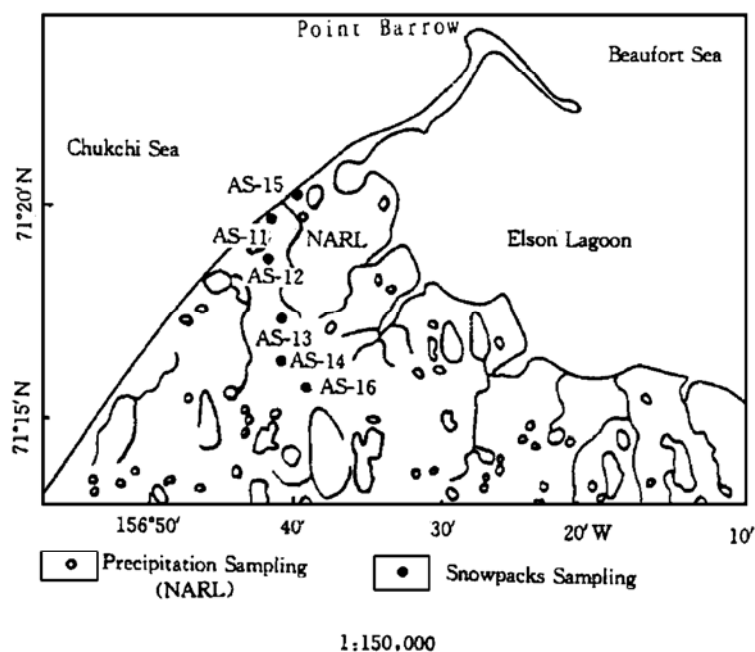


Fig. 1. Map of Barrow, Alaska and sampling sites.

2 Methods

Precipitation samples were collected with a sample bulk-type collector on event basis. The collector was cleaned directly before sampling and exposed only during precipitation. In this way, the amount of dry deposition in the samples was minimized. Immediately after a sample was collected, the pH and conductivity were measured on selected samples. To prevent the changes in composition of the samples by micro-biological activity, all the samples were held frozen in the refrigerator and air-mailed to the Laboratory of Ice Core and Cold Regions Environment in China, where they were also kept frozen until analysis was performed (Ridder *et al.* 1985).

Samples were melted under room temperature condition (about 20°C) and then analyzed for pH and conductivity. The cations were determined by model PE-2380 Atomic Absorption Spectrophotometer and the anions were determined by Dionex-100 ion-chromatography. Details of the analytical procedures are given by Galloway *et al.* (1982) and Dionex (1981).

3 Results and discussion

3.1 pH

The pH values presented in this paper are 5.53 and 5.70 for rain and snow precipitation samples, respectively, which are relatively higher than those reported in the Arctic region. GMCC (Geophysical Monitoring for Climate Change) recorded that the pH values of winter snowpacks at Point Barrow, ranged from 4.56 to 5.14 with a mean value of less than 5.0 (GMCC 1975, 1976). We speculated that the low pH values of winter snowpacks were caused by the strong Arctic Haze during winter. But it's not the same case in summer half year. Galloway *et al.* (1982) speculated that the natural mean pH of precipitation for the Point Barrow region was >5.0 , so their speculation was identified by our work. This is also partly supported by the work of Barrie *et al.* (1981) who reported that the estimated current pH of snow at Mould Bay in the Arctic was 5.2~5.5 and by Miller (see Galloway *et al.*, 1982) who stated that the pH of fresh snow at Point Barrow is about 5.

The reference level commonly used to compare acid precipitation to natural precipitation is pH of 5.6 — the pH that results from the equilibration of atmospheric CO_2 with precipitation. However, the pH 5.6 provides a useful reference level only in those areas that have no other acidic or basic precursors. In this paper both of the mean pH values for rain and snow precipitation samples are around the reference level. Galloway *et al.* (1982) speculated that the lower limits of the natural mean pH of precipitation in marine and continental areas were $\text{pH} \geq 5$. So could we say that Point Barrow represented one of those rare all-natural areas in the summer-half year.

3.2 Conductivity

The conductivity values showed large variations ranging from 4.9 to 170 $\mu\text{S}/\text{cm}$. They can be divided into two groups according to their conductivities. Samples in group 1 were more conductive, with values around 100 $\mu\text{S}/\text{cm}$ or more. Their Cl^- and Na^+ concentrations were much higher than the else samples, which suggested that these precipitation samples were mainly influenced by sea spray. Conductivity of precipitation samples in group 2 was extremely low (around 10 $\mu\text{S}/\text{cm}$) and some even approached the conductivity of de-ionized water in equilibrium with atmospheric CO_2 (1.0 $\mu\text{S}/\text{cm}$). These low values are consistent with those reported (Galloway *et al.* 1982; Barrie *et al.* 1985).

As shown in Fig. 2, the precipitation samples with higher conductivity values usually had higher $\delta^{18}\text{O}$ values, to the contrary, the lower conductivities always corresponded the lower $\delta^{18}\text{O}$ values, and the main ions concentrations (except Cl^-) showed a similar change trend with $\delta^{18}\text{O}$ as the conductivity did, which indicated that the vapour source was the controlling factor on the precipitation chemical characteristics.

Barrie *et al.* (1985) studied the relationship between conductivity and acidity of a melted ice layer in the Canadian High Arctic and a strong positive relationship between them was obtained. In the paper no relationship was found (Fig. 3). Because major ionic constituents of Arctic aerosols are acidic sulphates, the result in this paper is reasonable.

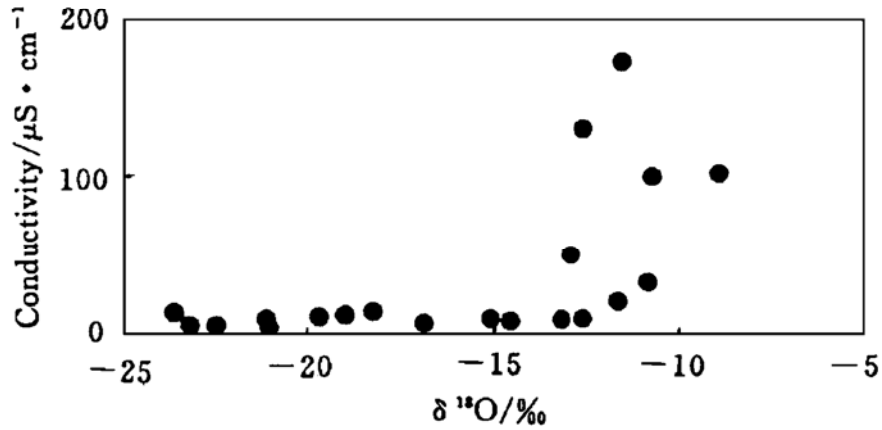


Fig. 2. The relationship between conductivity and $\delta^{18}\text{O}$ values in precipitation samples collected at Point Barrow, Alaska.

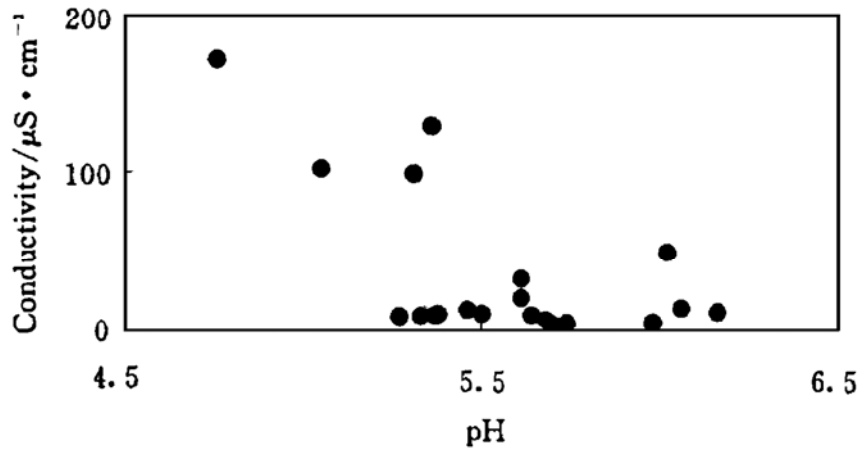


Fig. 3. The relationship between conductivity and pH values in precipitation samples collected at Point Barrow, Alaska.

3.3 Chemical composition

In Table 1 the analytical results are listed in unit of $\mu\text{mol/l}$. Results beyond the measuring range of machines are shown as " # ".

AS-3 and the AS-11~AS-16 samples are snowpack samples of the same snow event (see Fig. 1). The sampling spots of AS-11, AS-12 and AS-15 were very near the coast lines, and especially, AS-15 was the last one to be collected. We noticed in the field that much gray or dark particles were deposited on the snow surface. The

ion concentration results of these three samples were also atypically high, so they were excluded from the calculation.

The SO_4^{2-} concentrations in precipitation were characterized by large differences with a range from 1.13 to 43.11 $\mu\text{mol/l}$. Dayan *et al.* (1985) found that the SO_4^{2-} concentrations in precipitation varied from month to month. However, we noticed that the SO_4^{2-} concentrations even varied from event to event, which meant that SO_4^{2-} were much sensitive to environmental changes. Contrary to the SO_4^{2-} concentrations, the concentrations of NO_3^- were low and relatively constant.

Table 1. The pH, conductivity values, chemical concentrations and exSO_4^{2-} concentrations of precipitation samples collected at Point Barrow, Alaska in 1994

No.	Date	pH	Conduc- tivity / $\mu\text{S} \cdot \text{cm}^{-1}$	$\delta^{18}\text{O}$ /‰	Main ion concentrations/ $\mu\text{mol} \cdot \text{L}^{-1}$							exSO_4^{2-}	
					Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}	(Na ⁺) (Cl ⁻)	
AR-1	Aug. 17	5.70	4.9	-21.02	10.66	1.32	1.30	9.61	0	6.43	3.87	0.14	0.20
AR-2	Aug. 17	5.74	6.2	-23.13	19.72	1.03	1.13	16.79	2.56	0	4.28	0	0
AR-3	Aug. 17	5.68	7.9	-16.88	31.59	0	1.85	24.71	0	0	5.60	0	0
AR-4	Aug. 18	5.64	10.9	-15.08	56.41	0	3.12	45.11	2.91	7.04	9.87	0	0
AR-5	Aug. 18	6.02	50.9	-12.92	89.27	1.16	16.54	262.42	13.35	9.98	63.20	0	7.29
AR-6	Aug. 20	5.61	34.0	-10.84	87.04	0	10.71	169.94	10.46	8.78	42.05	0	1.69
AR-7	Aug. 20	5.37	10.6	-13.17	25.89	0	4.84	26.62	5.12	7.04	10.20	1.62	2.16
AR-8	Aug. 21	5.05	102	-8.95	87.92	4.97	43.11	343.19	43.41	14.67	115.61	1.58	4.00
AR-9	Aug. 23	5.33	10.2	-21.10	26.57	0	2.48	27.19	5.12	5.29	8.15	0	0
AR-10	Sep. 1	5.27	9.7	-14.55	7.42	0	2.48	15.66	6.47	7.63	8.15	0.58	1.71
AR-11	Sep. 3	5.38	11.1	-12.59	20.51	0	2.91	22.53	5.65	5.29	6.91	0.19	0.79
AR-12	Sep. 5	5.61	21.9	-11.65	86.00	1.23	7.36	102.83	4.76	5.89	19.26	0	0
AS-1	Aug. 22	5.36	129	-12.59	#	#	#	535.36	44.36	31.19	163.42	//	//
AS-2	Aug. 24	5.50	11.8	-19.68	25.24	0	2.63	22.88	4.94	5.89	7.24	0	0.02
AS-3	Aug. 26	5.46	14.3	-23.56	76.27	0	3.74	57.37	4.37	7.04	12.59	0	0
AS-4	Sep. 4	5.31	99.7	-10.73	#	#	#	317.88	27.45	17.61	122.11	//	//
AS-5	Sep. 7	4.76	170	-11.54	#	#	#	894.12	45.77	29.94	205.14	//	//
AS-11	Aug. 26	6.15	89.8	-23.13	#	#	#	518.62	15.78	12.33	110.84	//	//
AS-12	Aug. 26	6.26	98.1	-19.81	#	#	#	468.42	16.45	15.87	132.40	//	//
AS-13	Aug. 26	5.98	6.4	-22.43	32.13	0.71	1.86	27.62	0.64	6.44	6.17	0	0
AS-14	Aug. 26	6.16	13.0	-18.99	82.73	0	3.70	69.20	1.79	5.89	14.07	0	0
AS-16	Aug. 26	6.06	15.2	-18.24	84.34	0	4.69	83.08	3.48	5.89	16.46	0	0

Notes: AR and AS stand for rain and snow precipitation samples, respectively. “#” means that the corresponding chemical concentrations exceed the upper measuring limit, and “//” means that the corresponding values are not available.

The mean concentrations of Cl^- were 45.75 $\mu\text{mol/l}$ and 60.14 $\mu\text{mol/l}$ for rain and snow precipitation samples, respectively, which were consistent with other's work at Alaska (Dayan *et al.*, 1985). If assumed that all Cl^- originated with seasalt and that no fractionation occurred, in most case the Cl^- data indicates that the exSO_4^{2-} values are low (Table 1). If we took the Na^+ concentrations as reference values, the same result was attained for exSO_4^{2-} . Almost all the exSO_4^{2-} concentrations were lower than the reported results by Dayan *et al.* (1985). The other two samples with high exSO_4^{2-} was believed to be contaminated to a certain degree. However, we noticed that the exSO_4^{2-} values agreed with the results of Greenland (Busenberg and Langway 1979), which measured $(1.1 \pm 0.1) \mu\text{mol/l}$ of exSO_4^{2-} in pre-industrial ice and $(2.5 \pm 0.6) \mu\text{mol/l}$ exSO_4^{2-} in ice deposited in 1974~1975. So we had reasons to be-

lieve that much of the SO_4^{2-} in our precipitation samples originated with seasalt. This means that the precipitation chemistry at Point Barrow showed little anthropogenic effect during the field work period. This result is also consistent with Barrie's work (1986) who found that the addition of pollution from mid-latitudes to the Arctic was at a minimum and the exSO_4^{2-} was extremely low.

As mentioned above, The relationship between main ion concentrations and $\delta^{18}\text{O}$ (Fig. 4) gave the same change trend as observed in Fig. 2, which also reflected the vapour source effect on the precipitation chemical characteristics.

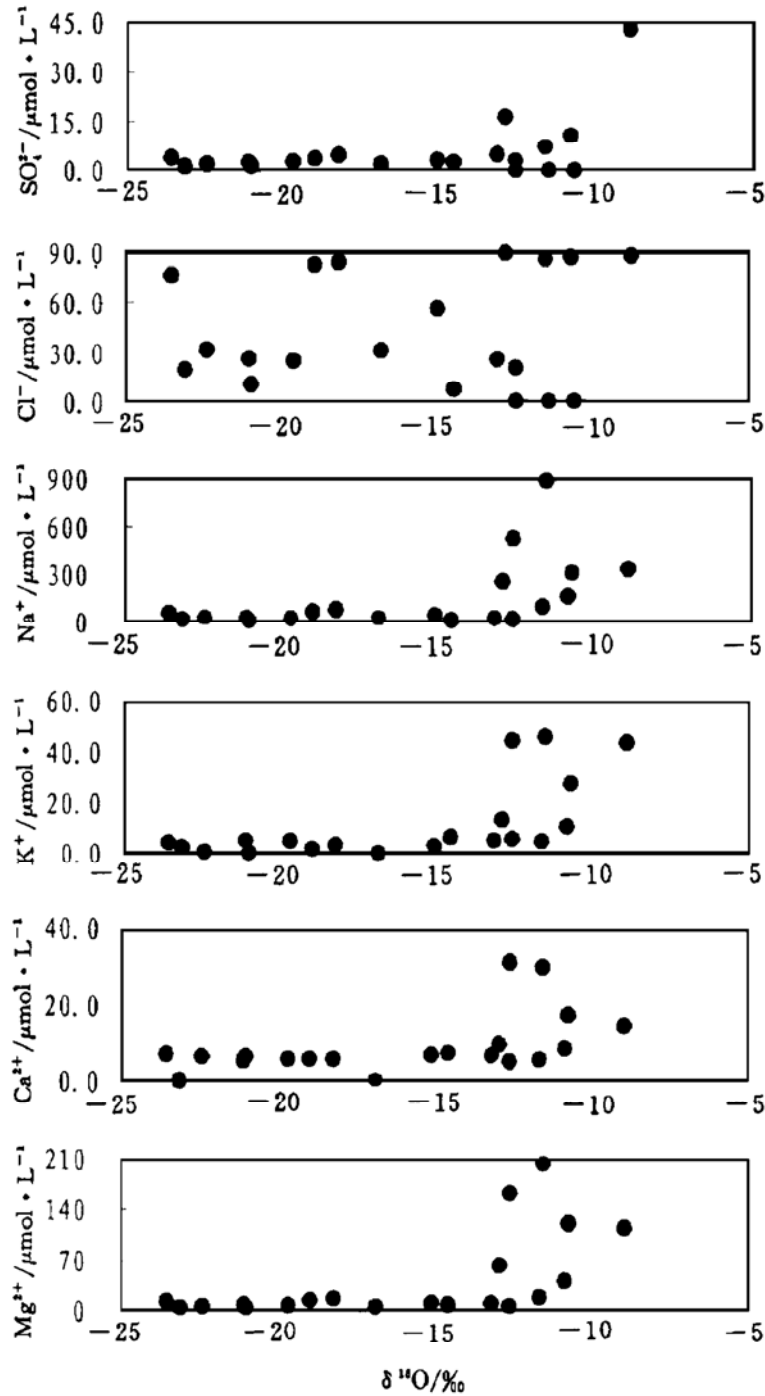


Fig. 4. The relationship between main ion concentrations and $\delta^{18}\text{O}$ values in precipitation samples collected at Point Barrow, Alaska.

4 Conclusion

The pH values of the summer precipitation at Point Barrow were higher than that of the winter precipitations, which agreed with Barrie's work in Mould Bay. Conductivity showed no linear correlation with pH values. Assuming that Cl^- or Na^+ originated with seasalt, almost all the SO_4^{2-} were associated with a seasalt origin. The concentrations of NO_3^- were low and relatively constant.

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