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Trace-element ions in snow, ice and water from Antarctic and Arctic with reference of their water vapor chemistry

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Abstract The some trace elements in the Antarctic and Arctic snow, ice, water were studied using the methodology and theory of water vapor chemistry. The concentrations of ions Zn^{2+}, Cd^{2+}, Pb^{2+}, Cu^{2+}, Sn^{4+}, Bi^{3+} in Antarctic and Arctic snow a significant spatial similarity; they are also close to those defined elsewhere on the basic of studies of water vapor chemistry: on average Zn^{2+} 5.0 μg/L, Cd^{2+} 0.080 μg/L, Pb^{2+} 0.030 μg/L, Cu^{2+} 0.70 μg/L, Sn^{4+} 0.99 μg/L, Bi^{3+} 0.18 μg/L. Apparently, the ion concentration in the Antarctic and Arctic region represent natural baseline values and are controlled by natural water cycles.

Key words Antarctic and Arctic snow, trace element ions, water vapor chemistry.

1 Introduction

"Anti-adsorption physically coated mercury film electrode system" ASV method was proposed by Institute of Oceanology, Chinese Academy of Sciences, and was used to analyze the trace-element ions Zn^{2+}, Cd^{2+}, Pb^{2+}, Cu^{2+}, Sn^{4+}, Bi^{3+} in the natural waters of Qinghai-Tibetan Plateau, Yangtze River, East China Sea and the Pacific Ocean. The rules of homogeneous distribution and constant water-vapor transfer of trace-element ions Zn^{2+}, etc. in the natural water cycle were learned, and a new branch of sciences-water vapor chemistry was thus established. The reliability of "anti-adsorption physically coated mercury film electrode system" was proved after its ion speciation analysis agreed with biological toxicity experiment. The Antarctic and Arctic snow are mainly from seawater evaporation and, evidently, are less contaminated, which are used as the important samples to research and prove the rule "constant water-vapor transfer of trace-element ions"(Gu 1991b, 1994, 1996; Gu *et al.* 1991). In this paper, the some trace-element ions in the Antarctic snow and Arctic snow, ice and water were studied by application of the methodology and theory of water vapor chemistry.

2 Experimental

2.1 Sampling

Samples for the study of ions Zn^{2+}, Cd^{2+}, Pb^{2+}, Cu^{2+}, Sn^{4+}, Bi^{3+} in the Arctic snow,

ice and water were collected on 24 April – 5 May 1995 at 7 stations from 82°45′21″W, 88°01′20″N to 75°02′42″W, 89°48′26″N. The Antarctic snow samples were collected on 9 April 1996 at 3 stations from 58°57′56″W, 62°12′56″S to 58°57′57″W, 62°13′02″S, on the two sides of West Lake in the Great Wall Station. Samples were stored in polyethylene bottles below −20℃.

2.2 Analysis

Samples were analyzed in Qingdao laboratory using the method of anti-adsorption physically coated mercury film electrode system of ASV. No reagent is added for analysis of Zn^{2+}, Cd^{2+}, Pb^{2+}, Cu^{2+} in sea water, and 0.1 mol/L HCl is used for analysis of Sn^{4+} and Bi^{3+}. For the analysis of fresh and snow water, half the volume of sea water with known metal concentrations is added (Gu 1991a; Gu *et al.* 1991).

3 Results and discussion

The determined concentrations of Zn^{2+}, Cd^{2+}, Pb^{2+}, Cu^{2+}, Sn^{4+}, Bi^{3+} ions in Antarctic snow and Arctic snow, ice and water are listed in Table1, 2 and 3.

Table 1. Concentrations of Zn^{2+}, Cd^{2+}, Pb^{2+}, Cu^{2+}, Sn^{4+}, Bi^{3+} in the Arctic snow, ice and water

Station	Depth/m	Sample	Ion/($\mu g \cdot L^{-1}$)						
			Zn^{2+}	Cd^{2+}	Pb^{2+}	Cu^{2+}	Sn^{4+}	Bi^{3+}	S
NP02	0	Water	3.4	0.047	0.021	0.62	0.78	0.17	12.4
	50	Water	6.5	0.044	0.032	0.58	0.87	0.14	14.2
	150	Water	5.6	0.042	0.023	0.59	0.78	0.14	9.6
	250	Water	4.9	0.059	0.028	0.62	0.78	0.15	12.5
	300	Water	4.9	0.053	0.027	0.58	0.78	0.15	12.6
NP04	0	Water	4.6	0.043	0.022	0.55	0.85	0.14	12.5
	50	Water			0.028	0.66	0.74	0.14	13.0
	150	Water	4.4	0.058	0.025	0.58	0.74	0.15	11.1
	300	Water		0.058	0.025	0.62	0.79	0.14	14.2
NP06	0	Water	4.5	0.063	0.027	0.57	0.74	0.16	10.5
	50	Water	4.7	0.063	0.028	0.59	0.79	0.13	24.2
	150	Water	4.7	0.056	0.028	0.56	0.74	0.13	17.6
	300	Water	4.3	0.056	0.026	0.56	0.74	0.13	11.0
NP09	0	Water	5.1	0.053	0.028	0.62	0.81	0.14	16.5
	50	Water	4.5	0.048	0.028	0.59	0.75	0.14	20.0
	150	Water	4.8	0.048	0.026	0.57	0.75	0.14	21.6
	300	Water		0.056	0.028	0.57	0.75	0.13	21.5
NP01	0	Ice			0.022		0.76	0.12	
	0	Snow		0.083	0.018		0.76	0.14	
NP04	0	Ice	4.5	0.083	0.019	0.68	0.82	0.17	
	0	Snow	4.8	0.059	0.020	0.60	0.76	0.12	
NP13	0	Ice	4.1	0.047	0.018	0.53	0.76	0.12	
Arctic Pole	0	Snow	4.5	0.057	0.018	0.64	0.71	0.12	
Resolute	0	Snow	4.0	0.047	0.020	0.75	0.75	0.13	

Table 2. Average concentrations of free ions in the Arctic

Sample	Depth/m	Ion/($\mu g \cdot L^{-1}$)					
		Zn^{2+}	Cd^{2+}	Pb^{2+}	Cu^{2+}	Sn^{4+}	Bi^{3+}
Water	0	4.4	0.051	0.025	0.59	0.79	0.15
	50	5.2	0.052	0.029	0.60	0.78	0.14
	150	4.9	0.051	0.025	0.58	0.75	0.14
	250	4.9	0.059	0.028	0.62	0.78	0.14
	300	4.6	0.056	0.027	0.58	0.76	0.14
Ice	0	4.3	0.065	0.020	0.61	0.78	0.13
Snow	0	4.4	0.062	0.019	0.66	0.74	0.13

Table 3. Concentrations of Zn^{2+}, Cd^{2+}, Pb^{2+}, Cu^{2+}, Sn^{4+}, Bi^{3+} in the Antarctic snow

Station		Ion/($\mu g \cdot L^{-1}$)					
		Zn^{2+}	Cd^{2+}	Pb^{2+}	Cu^{2+}	Sn^{4+}	Bi^{3+}
A1	(1)*	4.5	0.065	0.019	0.61	0.84	0.16
	(2)*	4.5	0.056	0.019	0.66	0.73	0.17
A2	(1)	4.3	0.056	0.023	0.61	0.84	0.15
	(2)	4.5	0.056	0.019	0.61	0.78	0.16
B7	(1)	4.4	0.062	0.025	0.61	0.78	0.13
	(2)	4.2	0.062	0.019	0.65	0.91	0.14
B8	(1)	4.2	0.062	0.019	0.64	0.91	0.13
	(2)	4.2	0.062	0.019	0.61	0.78	0.13
B10	(1)	4.5	0.063	0.021	0.65	0.80	0.12
	(2)	4.2	0.062	0.024	0.65	0.80	0.14
C11	(1)	4.4	0.063	0.021	0.58	0.74	0.14
	(2)	4.2	0.063	0.021	0.58	0.74	0.12

* : duplicate

The ion concentration and ion average ($\mu g/L$, snow water) in Antarctic snow are: Zn^{2+} 4.2 – 4.5, 4.3; Cd^{2+} 0.056 – 0.065, 0.061; Pb^{2+} 0.019 – 0.025, 0.021; Cu^{2+} 0.58 – 0.65, 0.62; Sn^{4+} 0.73 – 0.91, 0.80; Bi^{3+} 0.12 – 0.17, 0.14, respectively.

The ion concentration and ion average ($\mu g/L$, sow water) in Arctic snow are: Zn^{2+} 4.0 – 4.8, 4.4; Cd^{2+} 0.047 – 0.083, 0.062; Pb^{2+} 0.018 – 0.020, 0.019; Cu^{2+} 0.60 – 0.75, 0.66; Sn^{4+} 0.71 – 0.76, 0.74; Bi^{3+} 0.12 – 0.14, 0.13, respectively.

The ion average concentrations ($\mu g/L$) in Arctic water (seawater under ice layer and diluted with snow water) are: Zn^{2+} 4.8, Cd^{2+} 0.054, Pb^{2+} 0.027, Cu^{2+} 0.59, Sn^{4+} 0.77, Bi^{3+} 0.14.

The ion average concentrations ($\mu g/L$, ice water) in Arctic ice are: Zn^{2+} 4.3, Cd^{2+} 0.065, Pb^{2+} 0.020, Cu^{2+} 0.61, Sn^{4+} 0.78, Bi^{3+} 0.13.

The results from Table 1 – 3 show that the ion concentrations of Zn^{2+}, Cd^{2+}, Pb^{2+}, Cu^{2+}, Sn^{4+}, Bi^{3+} in Antarctic snow and Arctic snow, ice, water are very close, and also similar with the ion average in water vapor chemistry: Zn^{2+} 5.0 $\mu g/L$, Cd^{2+} 0.80 $\mu g/L$, Pb^{2+} 0.030 $\mu g/L$, Cu^{2+} 0.70 $\mu g/L$, Sn^{4+} 0.99 $\mu g/L$, Bi^{3+} 0.18 $\mu g/L$.

Clearly, the trace-element ions Zn^{2+}, etc. in Antarctic and Arctic are in natural baseline concentration and in natural water cycle, which shows that the rules of water vapor chemistry are of worldwide significance.

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