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CHEMICAL CHARACTERISTICS OF FOUR KINDS OF WATER IN THE RONGBUK GLACIER BASIN, MOUNT QOMOLANGMA①

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ABSTRACT: The chemistry of water samples collected in May of 1997 from snow, lakes, rivers, and spring on the north side of Mt. Qomolangma is reported. The pH value is between 7.35–8.52, the order of which is: lake water> river water> snow. All the samples are alkalinity. The pH values of the surface snow samples are relatively higher than the other China's glacial regions. The conductivity of the samples is low, varying between 34.8–194 μs/cm. The conductivity values and total concentrations of the samples on the same glacier usually increase with decreasing altitude, but ones of the surface snow samples are converse for topographical causes. The anions are determined, the SO_4^{2-} concentration is the highest in river and lake samples; in the surface snow samples, the Cl^- concentration is the highest. Among the cations of all the samples, the Ca^{2+} concentration is the highest. The relationships between SO_4^{2-}, Mg^{2+}, F^-, Ca^{2+}, conductivity and the total concentrations show the increasing trend. On the other side, the conductivity, F^-, Ca^{2+}, the total concentration, SO_4^{2-} and Mg^{2+} of the river water samples all increase with decreasing altitude.

KEY WORDS: chemical characteristics, Rongbuk Glacier, Mt. Qomolangma

During the three Mt. Qomolangma Expeditions of 1959–1960, 1966–1968 and 1975, Chinese scientists had obtained many data of glaciers in the district of Mt. Qomolangma (Wang *et al.*, 1980; Xie *et al.*, 1975; Zhang *et al.*, 1975). In May 1997, Prof. Qin Dahe and Prof. Paul A. Mayewski organized another Mt. Qomolangma Glacial Expedition. The authors collected 32 samples from snow, lakes, rivers, and spring on the north side of Mt. Qomolangma (Fig. 1). Following the previous works, we analyze and discuss chemical characteristics of these water samples.

1 METHODS

Each of the surface snow samples were collected with a pair of once-used plastic gloves and put into a once-used plastic bag. Water samples were collected from rivers, lakes and spring with plastic bottles. Using water sample washing 3 times, then the author collected water samples. To prevent the changes in composition of the samples, all the samples were held frozen in the refrigerator and transported to the Laboratory of Ice Core and Cold Regions Environment, LIGG, CAS, where they were also kept frozen until analysis was performed.

Samples were melted under room temperature (about 20℃) 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-300 ion-chromatography. Details of the analytical procedures are given by Huang Cuilan (1994).

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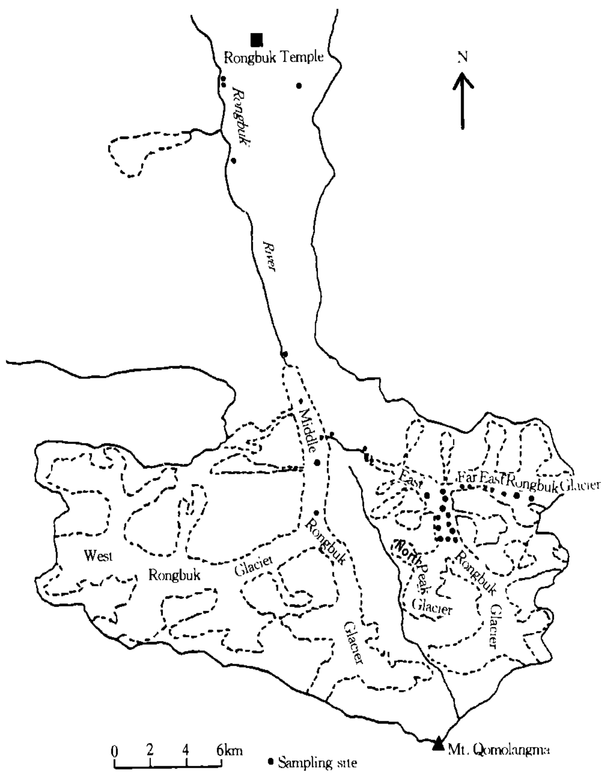

Fig. 1 Map of the Rongbuk Glacier, Mt. Qomolangma and sampling sites

2 RESULTS AND DISCUSSION

2.1 pH

The pH value of samples is between 7.35–8.52, thus the samples are alkalinity. The mean pH value of the surface snow samples is 7.53, which is relatively higher than those reported in other Chinese glacial region. It is clear that the acidic pollution of humanity activity did not affect the region. So it can be one of the districts that stand for atmospheric basic conditions. The mean pH values in this paper are 7.98 and 8.14 for river and lake water samples, respectively. The order of pH values is: lake water> river water> snow. The pH value of spring sample is 8.14, which is a reference of underground water.

2.2 Conductivity

The conductivity values of the surface snow samples are lower than other samples, with a mean value of 46.1 μS/cm. The conductivity values of river and lake water samples varied from 65.3–194 μS/cm, the mean ones of them are 106.9 μS/cm and 108.97 μS/cm, respectively. As regards the samples on the same glacier, the conductivity values of them increase with decreasing altitude.

The lakes were sited on the middle moraine of the East Rongbuk Glacier and the Middle Rongbuk Glacier. There was a thin till layer on the glacier. The till is heavy color, so it can absorb much calorific capacity, which melts much larger glacial water into nearby lakes than the evapotranspiration from the lakes. So the conductivity values of the lake water samples are slightly higher than that of glacier ice. However, the MR–3 sample was collected in the lake which was not supplied for water except the precipitation (about 300 mm/a (Xie *et al.*, 1975)). So all kinds of values of the MR–3 sample are very higher than the other ones. The conductivity value of spring sample is 184 μS/cm, which is a reference of underground water.

2.3 Chemical Composition

2.3.1 Total concentration

Zhang (1975) had ever collected glacier ice, river water, lake water and spring water samples. Among the anions of all kinds of samples, the concentration of HCO_3^- is the highest, which occupies 39.92%–66.92% of total anions' concentrations.

The total concentrations of surface snow samples vary from 6.538 to 15.460 mg/L, and they decrease with decreasing altitude, which is opposite to the others' conclusions (Pu *et al.*, 1988; Li *et al.*, 1993; Yao *et al.*, 1993; Huang *et al.*, 1995; Sheng *et al.*, 1996; Reynolds *et al.*, 1995). The surface snow samples were collected from the Pass of the Far East Rongbuk Glacier (about 6300 m a.s.l.). The air current coming from southern can easily across the Pass and affect the precipitation on the northern slope of Mount Qomolangma. This is the cause of the conclusion.

Table 1 The chemical compositions of water samples collected in May of 1997 from snow, lakes, rivers, and spring on the north side of Mount Everest

No.	Date	Altitude (m)	Types of samples	pH	Conductivity (μS/cm)	Main ion concentrations (mg/L)								
						K^+	Na^+	Ca^{2+}	Mg^{2+}	F^-	Cl^-	NO_3^-	SO_4^{2-}	Total concentrations
FE-2	May 18	6250	Snow	7.43	62.9	2.826	4.130	2.588	0.233	0.268	4.350	0.424	0.641	15.460
FE-3	May 18	6200	Snow	7.69	40.6	0.734	1.183	3.944	0.132	0.087	0.992	0.253	0.223	7.549
FE-4	May 18	6150	Snow	7.46	34.8	0.483	0.803	3.243	0.157	0.091	0.676	0.593	0.493	6.538
FE-5	May 18	6100	River	7.73	87.1	0.719	0.498	8.983	1.579	0.073	0.426	0.957	3.761	16.996
FE-6	May 18	6020	River	8.42	93.4	2.448	0.248	10.971	1.402	0.070	0.153	0.600	2.414	18.306
FE-7	May 18	5920	River	8.41	104	6.613	0.511	11.604	1.724	0.123	0.102	0.417	1.844	22.939
FE-8	May 18	5890	Lake	8.00	170	2.979	3.584	13.547	5.485	0.317	0.305	0.262	25.448	51.926
ER-1	May 20	6060	Lake	7.98	103	6.58	3.391	10.926	0.717	0.084	2.945	0.419	3.087	28.149
ER-2	May 20	6030	Lake	7.92	76.9	0.944	0.530	8.374	0.687	0.187	0.350	0.534	2.668	14.273
ER-3	May 20	5990	River	7.76	92.4	0.959	0.408	10.7	0.831	0.101	0.189	0.503	2.024	15.715
ER-4	May 20	5935	River	8.08	105					0.157	2.816	0.055	4.678	
ER-5	May 20	5935	Lake	7.64	78.7	0.783	0.496	9.141	0.475	0.228	0.306	0.333	4.693	16.454
ER-6	May 20	5905	River	8.23	74.7	0.584	0.229	9.412	0.403	0.085	0.148	0.272	0.916	12.049
ER-7	May 20	5900	Lake	8.49	74.1	0.644	1.423	8.26	0.534	0.100	1.184	0.179	0.875	13.199
ER-8	May 20	5820	River	7.60	79.5	1.341	3.156	9.028	0.437	0.192	2.270	0.149	1.844	18.417
ER-9	May 27	5520	Lake	8.42	131	3.525	3.228	11.152	1.93	0.400	0.620	0.190	20.581	41.625
ER-10	May 27	5510	River	7.66	108	0.963	0.329	11.852	1.396	0.105	0.042	0.258	6.759	21.704
ER-11	May 27	5460	River	8.06	130	2.051	1.575	12.508	1.903	0.293	0.162	0.174	11.764	30.431
ER-12	May 28	5270	River	8.05	135	1.667	1.506	13.163	1.977	0.355	0.066	0.191	14.475	33.399
ERN-1	May 20	6015	River	7.35	84	0.978	2.508	8.711	0.429	0.110	2.126	0.438	3.217	18.517
ERN-2	May 20	5930	River	8.18	74.3	0.959	3.052	7.085	0.435	0.122	2.398	0.271	3.039	17.361
ERN-3	May 20	5880	River	8.23	72.3	0.742	2.859	6.904	0.465	0.137	2.422	0.195	3.008	16.733
ERN-4	May 20	5815	River	7.78	73.8	3.881	0.268	9.141	0.467	0.118	0.081	0.191	0.775	14.922
MR-1	May 28	5350	Lake	8.52	65.3	0.629	0.440	7.536	0.673	0.069	0.303	0.154	0.617	10.421
MR-2	May 28	5300	Lake	7.93	68.8	0.622	0.287	8.079	0.471	0.086	0.191	0.120	0.936	10.791
MR-3	May 28	5215	Lake	8.35	194	2.894	1.325	19.106	4.892	0.733	0.182	0.103	46.591	75.826
SW-1	May 11	4930	River	7.84	192	1.875	3.085	18.654	2.286	0.309	1.039	0.753	5.851	33.852
SW-2	May 11	4970	River	7.84	152	1.319	1.040	14.474	1.312	0.228	0.163	0	2.114	20.650
RIVER-1	May 11	5120	River	8.38	141	2.754	3.640	12.824	2.169	0.428	1.097	0.164	17.957	41.034
RIVER-2	May 11	4930	River	8.02	163	3.119	3.921	14.135	2.94	0.392	1.950	0.282	18.419	45.158
SPRING	May 11	4960	Spring	8.14	184	3.083	4.487	11.988	5.652	0.462	3.397	0.723	19.157	48.949

Notes: FE and ER stand for the samples collected from the Far East Rongbuk Glacier and the East Rongbuk Glacier, respectively; ERN and MR stand for the samples collected from the Northern Peak Glacier and the Middle Rongbuk Glacier, respectively; RIVER stands for the samples collected from the Rongbu River; SPRING stands for the sample collected from spring.

The total concentrations of river water samples range from 12.049 to 45.158 mg/L, the mean is 23.423 mg/L. They can be divided into two groups according to their variations with altitude. Samples in the Northern Peak Glacier are in group 1, their total concentrations decrease with decreasing altitude, for the dilution of lower concentration lake water is bigger than the dissolve of river water. Total concentrations of samples in other glacier increase with decreasing altitude, for the opponent cause. These samples are in group 2.

The total concentration of the lake samples vary between 10.421 to 75.826 mg/L, the mean is 29.116 mg/L. They increase with decreasing altitude. The total concentration of spring sample is 48.949 mg/L, which is a reference of underground water.

2.3.2 Main ions composition

Zhang *et al*. (1975) concluded that the HCO_3^- was the highest anion. In this paper, we think so.

For the anions determined, the SO_4^{2-} concentrations is highest in river and lake samples, the mean is 7.971 mg/L. But in the surface snow samples, the Cl^- concentration is highest, the mean is 2.006 mg/L.

Among the cations of all the samples, the Ca^{2+} concentration is highest. The mean Ca^{2+} concentrations of surface snow, lake and river samples are 3.258 mg/L, 10.322 mg/L and 11.328 mg/L, respectively. Based on the milligram equivalent concentrations of the samples, the order of the cation and anion concentrations of the samples is:

For the surface snow samples: $Ca^{2+} > Na^+ > K^+ (Mg^{2+})$, $HCO_3^- > Cl^- > SO_4^{2-}, NO_3^-, F^-$; for the lake samples: $Ca^{2+} >> Mg^{2+} > K^+ (Na^+)$, $HCO_3^- > SO_4^{2-} >> Cl^- > F^- (NO_3^-)$; for the river water samples: $Ca^{2+} >> Mg^{2+} > Na^+ > K^+$, $HCO_3^- > SO_4^{2-} >> Cl^- > F^- (NO_3^-)$.

2.3.3 *Relationships*

Based on correlation coefficients between the main ions and the total concentrations of the samples, the relationships between SO_4^{2-}, Mg^{2+}, F^-, Ca^{2+}, conductivity and the total concentrations (Fig. 2) gave the increasingly trend. On the other side, the conductivity, F^-, Ca^{2+}, total concentration, SO_4^{2-} and Mg^{2+} of river water samples all increase with decreasing altitude (Fig. 3).

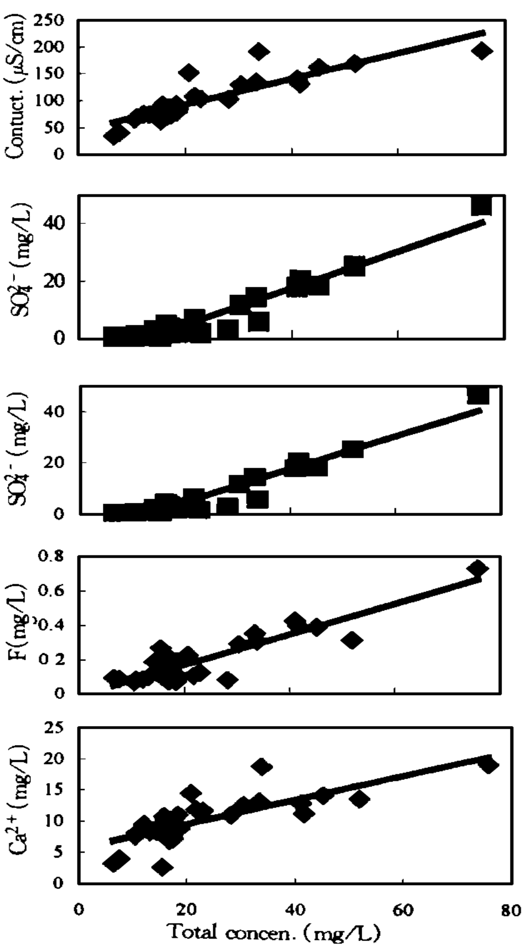

Fig. 2 The relationship between main ion concentrations, pH values and total concentrations

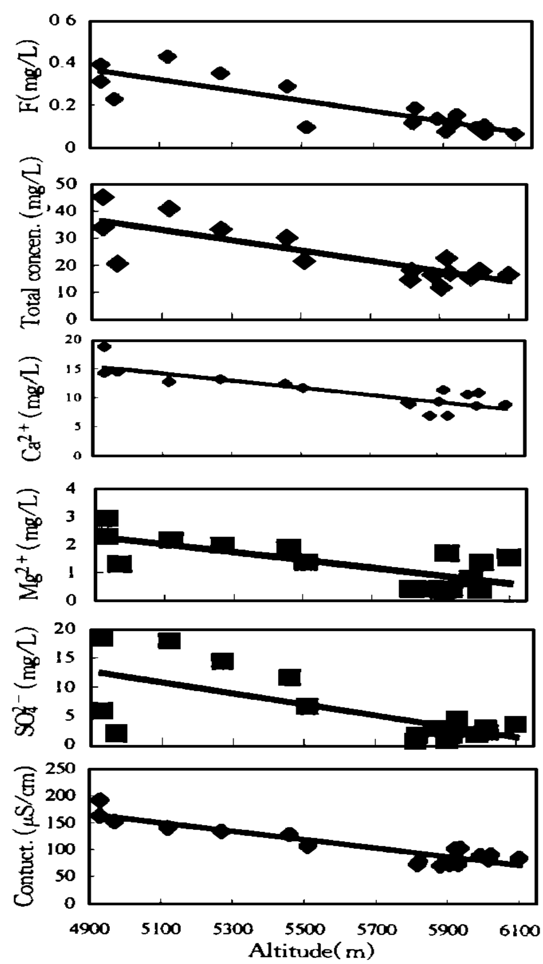

Fig. 3 The relationship between the main ion concentrations of the river water samples and altitude

3 CONCLUSIONS

All the samples are alkalinity. The pH values of the surface snow samples are relatively higher than the other Chinese glacial regions. The conductivity values and total concentrations of the samples on the same glacier usually increase with decreasing altitude.

For the anions determined, the SO_4^{2-} concentration is the highest in river and lake samples; in the surface snow samples, the Cl^- concentration is the highest. Among the cations of all the samples, the Ca^{2+} concentration is the highest.

The relationships between SO_4^{2-}, Mg^{2+}, F^-, Ca^{2+}, conductivity and the total concentrations gave the increasingly trend. On the other side, the conductivity, F^-, Ca^{2+}, the total concentration, SO_4^{2-} and Mg^{2+} of the river water samples all increase with decreasing altitude.

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