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Hydrogeochemical characteristics in the Gozha Lake area of the West Kunlun Mountains

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Abstract

Glacial melt and river water in the Gozha Lake area was all bicarbonate type, fresh and soft, while lake water was mid–mineralized, sodiumchloride–type hard water. The concentration, total alkalinity, hardness, Na^+–content and pH values of water are in the following order:

Lake water >> River water > Glacial melt water.

The contents of main ions (in mmol/l) in river water are functions of concentration X (in mg/l).

Total alkalinity $= 0.0137\ X^{0.946}$

$Cl^- = 0.0977 \exp(0.00518\ X)$;

$SO_4^{2-} = 0.112 \exp(0.00459\ X)$;

Total hardness $= 2.24 \exp(-53.2/X)$

$Ca^{2+} = 2.47 - 0.0106\ X + 0.0000163\ X^2$;

$Mg^{2+} = 2.81 \exp(-292/X)$;

$K^+ = -0.0613 + 0.000580\ X - 0.000000910 \exp(0.0261\ X)$;

$Na^+ = -1.37 + 0.0113\ X$.

For total alkalinity and hardness glacial melt water is included, and X ranges from 24.2 to 460 mg/l; for Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+, and Na^+, the X ranges from 126 to 460 mg/l.

The concentration, total alkalinity, total hardness, Na^+ content and other quantities measured in water in the hydrological sections reveal daily and seasonal variations, opposite to those of the discharge.

1. Introduction

The main purpose of this paper is to provide basic information on the hydrogeochemical characteristics in the Gozha Lake area of the West Kunlun Mountains and describe some regular features of its variation in time and space.

The Gozha Lake area is located at 35°04' – 35°12' N, 81°03' – 81°07'E, with a high elevation and cold, arid to semi–arid climate. The Chongce Ice Cap and Gozha Glacier with a total area of 49.85 km² are at over 5,700 m a.s.l.; in this area, the ice and snow melt water runoff flows 18 km into the Gozha Lake. The Sino–Japanese Joint Scientific Expedition set sampling sites at points B, P, S, TS and GF (Fig. 1).

2. Hydrogeochemical characteristics of glacial ice and melt water

Point B (Fig. 1) was a sampling point for glacial ice and melt water on the ice surface. This kind of water is characterized by low total concentration, 29.7 mg/l in average. The total hardness is 0.349 mmol/l in average, so it is fresh soft water. The mean pH value is 7.06. The dominant anion is HCO_3^-, and the dominant cation is Ca^{2+}. In other words, the ice and melt water of glaciers belong to the bicarbonate type (Table 1). From Table 1, one can see that the concentration, total alkalinity and hardness of the melt water are slightly higher than in glacial ice. This is because the melting process of ice begins from the saline film in the surface of ice crystals, and dust,

Table 1. Chemical composition of glacial melt water, river water and lake water in Gozha Lake area.

No. of sample	Sampling Point	Sampling Time	Altitude (m.a.s.l)	Water Type	Concentration (mg/L)	ion content in 1 L	ion Content CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	K^+	Na^+	Total Hardness (mmol/L)	Total Alkalinity (mmol/L)	PH	Hydrogeochemical Type
BS1	B	Aug.1, 1987	5700	Glacial Melt Water	24.18	mg		16.76	0.59	0.78	4.81	0.59	0.30	0.35	0.2882	0.2746	7.010	HCO_3-Ca
						mmol		0.2746	0.0167	0.0162	0.2400	0.0482	0.0076	0.0151				
						mmol%		89.3	5.4	5.3	77.2	15.5	2.4	4.9				
BES1	B	Aug.1, 1987	5700	Glacial Melt Water	35.22	mg		24.22	1.05	1.09	7.63	0.32	0.21	0.65	0.4094	0.3969	7.112	HCO_3-Ca
						mmol		0.2969	0.0297	0.0226	0.3833	0.0261	0.0053	0.0283				
						mmol%		88.4	6.6	5.0	86.5	5.9	1.2	6.4				
P1	P	June. 29, 1987	5300	River Water	151.0	mg		94.1	7.7	10.7	27.9	4.6	0.7	5.3	1.773	1.542	7.687	HCO_3-Ca
						mmol		1.542	0.218	0.223	1.394	0.379	0.019	0.230				
						mmol%		79.8	11.0	11.2	68.9	18.8	0.9	11.4				
P9	P	Aug. 10, 1987	5300	River Water	158.8	mg		98.5	8.4	12.6	24.7	5.4	1.0	8.2	1.678	1.615	7.549	HCO_3-Ca
						mmol		1.615	0.236	0.262	1.235	0.443	0.025	0.356				
						mmol%		76.4	11.2	12.4	60.0	21.5	1.2	17.3				
S1	S	June. 29, 1987	5300	River Water	343.1	mg	6.6	200.1	19.9	24.4	13.4	14.3	5.2	59.2	1.845	3.499	8.445	HCO_3-Na,Mg
						mmol	0.219	3.280	0.561	0.508	0.668	1.177	0.133	2.577				
						mmol%	4.8	71.8	12.3	11.1	14.7	25.8	2.9	56.6				
S7	S	July. 31, 1987	5300	River Water	194.6	mg		125.6	8.5	11.3	17.2	8.4	2.4	21.2	1.556	2.058	8.267	HCO_3-Na,Ca, Mg
						mmol		2.058	0.240	0.236	0.861	0.695	0.062	0.942				
						mmol%		81.2	9.5	9.3	33.9	27.3	2.4	36.4				
S9	S	Aug. 1 10, 1987	5300	River Water	249.6	mg	5.0	148.4	12.4	17.8	17.6	11.1	3.5	33.8	1.794	2.598	8.435	HCO_3-Na,Mg,Ca
						mmol	0.166	2.432	0.351	0.370	0.877	0.917	0.089	1.472				
						mmol%	5.0	73.3	10.6	11.1	26.1	27.3	2.7	43.9				
TS 2-9	TS	June. 29, 1987	5210	River Water	363.2	mg	10.9	202.3	23.2	26.6	16.2	14.4	4.8	64.8	1.998	3.679	8.375	HCO_3-Na
						mmol	0.364	3.315	0.654	0.553	0.810	1.188	0.123	2.818				
						mmol%	7.5	67.8	13.4	11.3	16.4	24.0	2.5	57.1				
TS4	TS	July. 6, 1987	5210	River Water	268.3	mg	5.6	154.2	16.5	20.2	20.1	9.7	3.1	38.9	1.806	2.714	8.327	HCO_3-Na,Ca
						mmol	0.186	2.528	0.466	0.420	1.004	0.802	0.080	1.691				
						mmol%	5.2	70.2	12.9	11.7	28.1	22.4	2.2	47.3				
TS5	TS	July. 10, 1987	5210	River Water	269.1	mg	10.4	145.8	17.0	22.7	19.5	11.4	3.3	39.0	1.907	2.734	8.496	HCO_3-Na,Ca ,Mg
						mmol	0.345	2.389	0.479	0.473	0.972	0.935	0.085	1.696				
						mmol%	9.4	64.8	13.0	12.8	26.4	25.3	2.3	46.0				
TS6	TS	July. 14, 1987	5210	River Water	220.8	mg		141.7	9.5	13.9	25.7	3.0	2.4	19.6	1.947	2.323	7.888	HCO_3-Ca,Na
						mmol		2.323	0.267	0.290	1.284	0.663	0.060	0.852				
						mmol%		80.6	9.3	10.1	44.9	23.2	2.1	29.8				
TS15	TS	Aug. 10, 1987	5210	River Water	215.0	mg		134.8	10.7	15.6	19.9	9.1	2.5	22.4	1.747	2.210	7.874	HCO_3-Ca,Na,Mg
						mmol		2.210	0.301	0.324	0.994	0.753	0.065	0.973				
						mmol%		78.0	10.6	11.4	35.7	27.1	2.3	34.9				
GF8	GF	Aug. 16, 1987	5080	Lake Water	367.0	mg	155.4	606.5	1391.8	236.3	6.2	117.4	80.2	1075.9	9.97	15.12	8.993	Cl-Na
						mmol	5.18	9.94	39.26	4.92	0.31	9.66	2.05	46.80				
						mmol%	3.7	16.8	66.2	8.3	0.5	16.4	3.5	79.6				

which contains some soluble salts, is deposited from the atmosphere on the ice surface.

3. Geochemistry of the river water

Samples from Points P, S and TS show that the river water has the following features:

(1) In early summer (June), the concentration, total alkalinity and Na^+—content of the water will increase with decrease of altitude; in July and August, water concentration at Point TS will be lower than that at Point S, and higher than that at point P.

(2) At the same altitude, the concentration, total alkalinity and Na^+—content at Point S was higher than that at Point P (Table 1).

These can be explained as follows. In June, the river is supplied mainly by melting snow, which dissolved some salts on the ground or snow surface, and is concentrated by evaporation on its way. As the water flows, more salts are dissolved and more water is evaporated; therefore, the concentration of salts in river water increases with lower altitude.

In July and August, however, the rivers are supplied mainly by melt water from the glacier. Since Point TS obtained more water from the glacier through the main stream of River Tianshuihe, the water at this point would be diluted in some extent, and its concentration would be lower than that at point S.

As the drainage area above point S is a wide valley and that of point P has no obvious river bed, the water at point S must be more be more concentrated than that at point P, although they are at the same altitude.

The water at points S, P and TS is fresh, soft and weakly alkaline with average salt concentrations of 154 mg/l, 250 mg/l and 238 mg/l, average hardnesses of 1.72 mmol/l, 1.71 mmol/l and 1.77 mmol/l, and average pH values of 7.71, 8.34 and 8.19, respectively.

Among anions, HCO_3^- is always dominant for points P, S and TS. Among cations, Ca^{2+} is dominant for point P, while for point S, Na^+ and Mg^{2+} are dominant when the concentration is relatively high; the Mg^{2+}—content will decrease and the Ca^{2+}—content will increase when the concentration of salt in water at point S becomes lower. At point TS, Na^+ will be dominant when the salt concentration is higher; as the concentration becomes lower, Ca^{2+}— and Mg^{2+}—content will increase. In order words, as the concentration becomes higher, the type of water at point S will change from HCO_3 – Na. Ca. Mg type to HCO_3–Na.Mg.Ca type, then to the HCO_3–Na.Mg type; and for point TS, the hydrochemical type will change from HCO_3–Ca. Na. or HCO_3–Ca. Na. Mg to HCO_3–Na.Ca.Mg or HCO_3–Na.Ca, then to HCO_3–Na (Table 1).

Based on regression analysis by using chemical analysis data, the relationship between the contents of individual ions and the total concentration X can be found as follows.

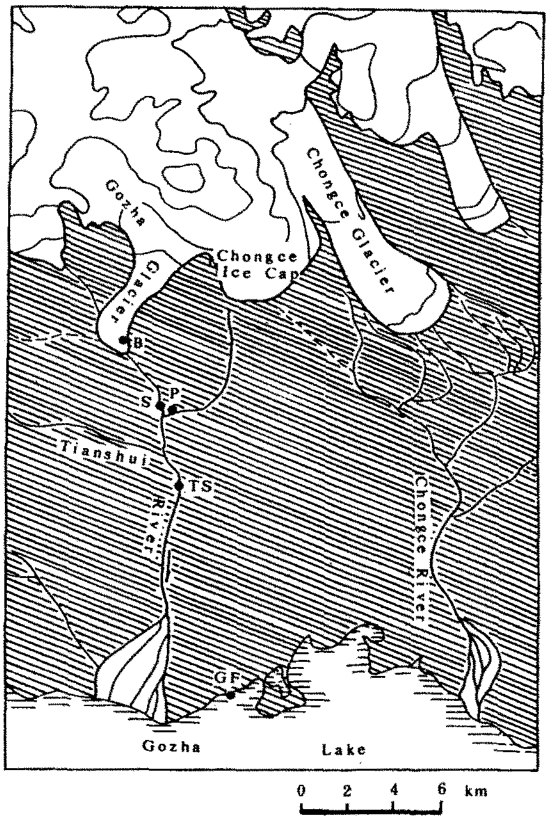

Fig. 1. Water sampling points on Chongce Ice Cap and the surrounding region.

$$\text{Total alkalinity} = 0.0137\ X^{0.946} \quad (1)$$

$$Cl^- = 0.0977\ \exp\ (0.00518\ X) \quad (2)$$

$$SO_4^{2-} = 0.112\ \exp\ (0.00459\ X) \quad (3)$$

$$\text{Total hardness} = 2.24\ \exp\ (-53.2/X) \quad (4)$$

$$Ca^{2+} = 2.47 - 0.0106\ X - 0.0000163\ X^2 \quad (5)$$

$$Mg^{2+} = 2.81\ \exp\ (-292/X) \quad (6)$$

$$K^+ = -0.0613 + 0.000580X - 0.000000910\ \exp\ (0.0261X) \quad (7)$$

$$Na^+ = -1.37 + 0.0113\ X \quad (8)$$

The correlation coefficients R and standard deviations of the above equations are shown in Table 2. The above equations are also shown in Fig. 2.

At the hydrological point TS, the daily temperature variation caused corresponding fluctuations in

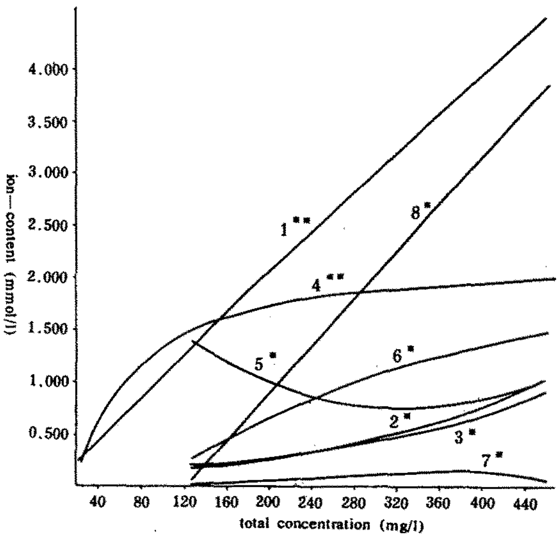

Fig. 2. Relationship between individual ion and total concentration X.
1. Total alkalinity; 2. Cl^-; 3. SO_4^{2-}; 4. Total hardness; 5. Ca^{2+}; 6. Mg^{2+}; 7. K^+; 8. Na^+.(*;73 samples of river water are applied to statistics: **;73 samples of river water and 2 samples of glacial melt water are applied to statistics.)

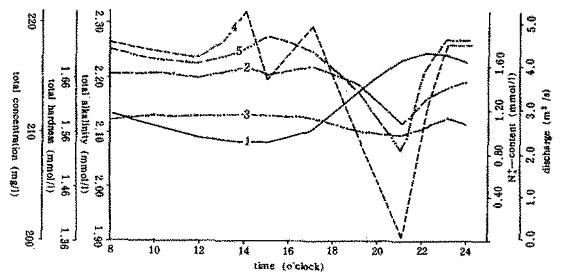

Fig. 3. Daily variation in (1) Discharge; (2) Hardness; (3) Na^+–content; (4) Concentration; (5) Alkalinity at point TS.

Table 3. Mean value of total concentration, alkalinity, hardness, Na^+—content and pH value of glacial melt water, river water and lake water in the Gozha Lake area.

Sampling Point	Type of water	Altitude (m.a.s.l.)	Total Mineralization(mg/L)	Total Akalinity (mmol/L)	Total Hardness (mmol/L)	Na^+ -content (mmol/L)	PH
B	Glacial Melt Water	5,700	29.69	0.3358	0.3488	0.0217	7.061
P	River Water	5,300	153	1.578	1.720	0.284	7.712
S	River Water	5,300	250.2	2.578	1.705	1.520	8.336
TS	River Water	5,210	238.4	2.424	1.766	1.329	8.186
GF	Lake Water	5,080	3,651	15.01	9.987	46.79	8.996

Table 2. Coefficient R and standard deviation of equations 1 to 8.

No. of equation	R	σ
1	0.999	0.061
2	0.982	0.043
3	0.964	0.041
4	−0.956	0.150
5	0.790	0.114
6	−0.982	0.062
7	0.932	0.012
8	0.996	0.088

the quantity of melt water, and opposite fluctuations in total concentration, alkalinity, hardness and Na^+—content (Fig. 3).

The seasonal variations in the total concentration, hardness, alkalinity and Na^+—content are similar to the daily variation. The peak value occurred at the beginning of the thawing season; in summer when the discharge reached the maximum value, they all decreased to the minimum values (Fig. 4).

4. Chemical characteristics of lake water.

Point GF (Fig. 1) is a sampling point of lake water. From the end of June to end of August, the average concentration of lake water is 365 mg/l, the average total hardness is 9.99 mmol/l, and the pH value varies from 8.90 to 9.03 with an average of 9.00. The dominant anion is Cl^- and the dominant cation Na^+. That is to say, the lake water belongs to medium—mineralized alkaline, Cl—Na type in hydrogeochemistry.

The total concentration, alkalinity, hardness, pH value and the Na^+—content of water in this area are in the following order, as shown in Table 3.

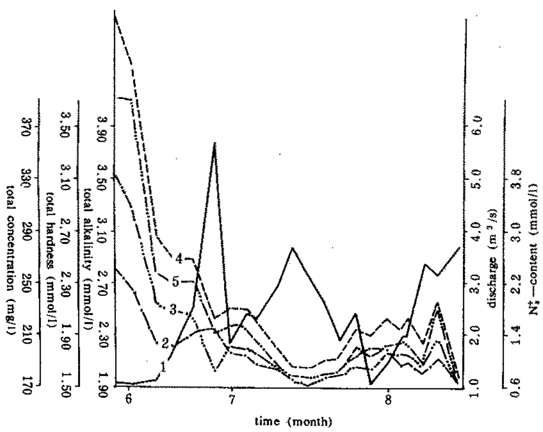

Fig. 4. Seasonal variation of (1) Discharge; (2) Total hardness; (3) Na^+—content; (4) Concentration; (5) Total alkalinity.

Lake water >> River water > Glacial melt water

Total concentration increases with lower altitude. This is because solute salts in rock and soil are dissolved and transported to the lake, and lake water is concentrated by evaporation.

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