IONS COMPOSITION IN A SMALL RIVER BASIN IN THE ROYAL RANGE OF THE ANDES

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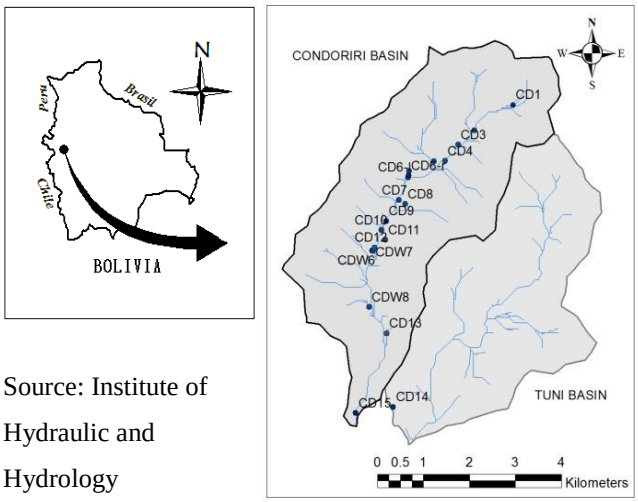
1. INTRODUCTION

Many researches have focused on the study of water quality in rivers worldwide. Water quality in a river basin is influenced by various factors related to the hydro chemical processes. In general, chemical water composition is determined by the presence of inorganic ions, organic dissolved substances and dissolved gases.

In the present study, field measurements were conducted in Condoriri River basin on major ions composition and physicochemical parameters. Thus, the water quality in the river basin is an important parameter that needs to be assessed. Knowledge of this study can provide information on the chemical composition in a high altitude river in the Andes.

2. MATERIALS AND METHODS

Condoriri River basin is located 36 kilometers north - west from La Paz city, Bolivia between 4400 m and 5300 m over sea level in the Royal Range of the Andes. The river flows downhill towards Tuni Lake and provides drinking water to La Paz and El Alto, the two major cities in Bolivia. The study area is showed in Fig. 1.



Source: Institute of Hydraulic and Hydrology

Figure 1: *Condoriri River basin, location of field measurement area*

The field work was conducted to analyze water quality in the streams and the lakes of the Condoriri River basin. 20 sampling points were taken through the whole basin in a dry season (July, 2012). The measurements began from the highest point near the glacier to the end of the river basin near the Tuni Lake. Water samples were taken from each monitoring point in the stream to analyze major ions. The chemical composition and the physicochemical parameters are listed in Table 1.

Total dissolved solids (TDS) were estimated and parameters in situ like dissolved oxygen (DO), temperature and pH were measured using a water quality analyzer. For ions analysis water samples were filtered in situ on collection through membrane filters of 0.45 μm pore size. A 50 ml aliquot was stored in a plastic bottle.

Ions were determined by ion chromatography using a DX-120 Dionex analyzer for the analysis of water samples at Tohoku University.

Table 1: *Chemical composition of surface water within the Condoriri River basin*

Sample ID	pH	T (◦C)	DO (mg/l)	TDS (mg/l)	SO_4^{2-} (mg/l)	NO_3^- (mg/l)	Cl^- (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)
CD1	8.3	0.20	7.74	158.00	89.07	0.11	0.34	47.55	4.27	1.21	0.57
CD2*	7.9	7.20	7.25	148.00	51.92	0.14	0.20	35.30	3.83	2.39	0.65
CD3	8.2	9.20	7.05	129.00	8.31	0.01	0.11	3.48	<0.01	0.45	0.24
CD4	8.1	7.60	6.89	106.00	2.14	0.04	0.12	9.63	<0.01	0.85	0.24
CD5i	8.4	9.40	7.21	95.00	20.43	<0.01	0.18	17.72	1.71	1.39	0.42
CD5o	8.2	9.40	7.00	90.00	17.66	<0.01	0.15	18.23	1.87	1.43	0.44
CD6*	7.9	5.90	5.72	128.00	24.84	0.17	0.16	22.30	2.99	1.72	0.48
CD6l	8.1	6.00	6.39	120.00	50.43	0.15	0.50	26.06	3.32	1.93	0.59
CD7*	8.1	7.70	6.87	128.00	22.32	0.11	0.14	25.43	3.37	1.91	0.51
CD8	8.3	1.30	7.86	142.00	36.81	0.17	0.35	36.93	5.82	1.69	0.28
CD9	8.1	7.40	7.04	117.00	8.16	0.13	0.05	3.91	<0.01	0.53	0.23
CD10	7.7	8.50	7.29	88.00	4.94	0.07	0.04	2.66	<0.01	0.45	0.21
CD11*	7.8	6.30	7.47	126.00	6.19	0.08	0.04	4.16	<0.01	0.55	0.24
CD12*	8.0	4.90	7.26	132.00	18.55	0.09	0.14	17.87	2.03	1.44	0.40
CDW6	7.7	5.10	6.14	73.00	9.77	0.50	6.20	16.87	4.78	2.24	0.36
CDW7	7.7	5.40	7.40	127.00	8.50	0.09	0.08	14.04	1.38	1.17	0.34
CDW8	7.8	5.00	6.26	119.00	5.72	0.08	0.25	15.83	1.85	1.39	0.41
CD13	7.8	5.00	6.99	122.00	51.29	0.08	1.14	34.23	5.34	2.83	0.67
CD14	7.6	2.70	7.25	121.00	52.42	0.08	0.69	34.27	5.27	2.72	0.65
CD15	7.9	3.60	6.91	123.00	48.66	<0.01	14.09	30.36	8.40	4.14	0.77

3. RESULTS AND DISCUSSIONS

Physicochemical parameters

All the water samples were slightly alkaline with pH values from 7.6 to 8.4 and with a mean value of 8.0. The average value of pH was a little low compared with the

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rivers located upstream of Atacama-Chile with a pH average value of 8.2. The water temperatures ranged from 0.2 to 9.4 °C with a mean value of 5.89 °C. The average value of dissolved oxygen was 7.00 mg/l higher compared with the streams of Cordillera Blanca in Peru with a dissolved oxygen average value of 5.08 mg/l. The total dissolved solids varied from 73 to 158 mg/l with a mean value of 119.6 mg/l which was higher compared with 34.2 mg/l in the Orinoco River.

Major ion chemistry

Calcium had values ranging from 2.66 to 47.55 mg/l with a mean value of 20.84 mg/l, which is higher than 6.4 mg/l in Chillan River in Chile and 2.59 mg/l in rivers in the Amazon basin. Magnesium had values ranging from 0.01 to 8.4 mg/l with a mean value of 2.81 mg/l similar to the Andean rivers, a little higher compared with 1.2 mg/l in Cumbaza River in Peru. Potassium had values ranging from 0.21 to 0.77 mg/l with a mean value of 0.44 mg/l lower compared with Andean and Amazon rivers. Sulfate had values ranging from 2.14 to 89.07 mg/l with a mean value of 26.91 mg/l higher compared with Amazon upstream rivers. The concentration of cations and ions ranked in the order of $Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$ and $SO_4^{2-}>Cl^{-}>NO_3^{-}$ respectively.

Table 2: *Ions ratio*

Ions ratio	
SO_4^{2-}/Cl^{-} (*)	41.0
SO_4^{2-}/NO_3^{-} (*)	188.1
Ca^{2+}/Mg^{2+} (*)	4.7
Ca^{2+}/Na^{+} (*)	7.4
Ca^{2+}/K^{+} (*)	44.4
Na^{+}/Cl^{-}(*)	11.7
$Ca^{2+}+Mg^{2+}/Na^{+}+K^{+}$ (**)	3.7
(*) = molar ratio; (**)= equivalent ratio	

Sources of major ions

If halite dissolution is responsible for the sodium, the Na^{+}/Cl^{-} molar ratio is approximately one (Meybeck, 1987), whereas a ratio of $Na^{+}/Cl^{-} > 1$ is interpreted as Na^{+} and K^{+} released from silicate weathering. The Na^{+}/Cl^{-} molar ratio was 11.7 suggesting the origin of Na^{+} and K^{+} from silicate weathering processes.

The $(Ca^{2+}+Mg^{2+})/(Na^{+}+K^{+})$ ratio was used to evaluate the relative contribution of rocks. If in the area there is a predominance of carbonates weathering the ratio >1 in our case the $(Ca^{2+}+Mg^{2+})/(Na^{+}+K^{+})$ ratio was 3.7>1 indicating carbonate weathering as primary contributor for the major ions. The plot of $(Ca^{2+} + Mg^{2+})$ versus SO_4^{2-} showed the weathering of carbonates (Figure 2).

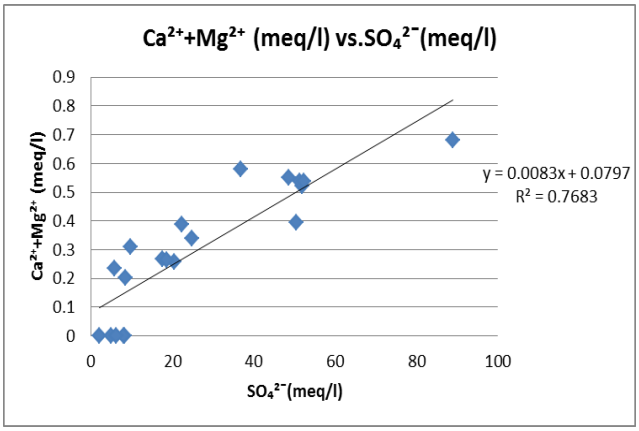

Figure 2: *$(Ca^{2+} + Mg^{2+})$ versus SO_4^{2-}*

4. CONCLUSIONS

The water chemistry of Condoriri River basin is mostly composed by SO_4^{2-} (26.91 mg/l) and Ca^{2+} (20.84 mg/l). Major ion concentrations have big variations through the whole basin and the ion composition has a strong influence in total dissolved solutes (TDS) values. Despite the concentration of ions depend of many factors chemical weathering remains the main resource of dissolved substances. According to the results, Na^{+} released from silicate weathering with Na^{+}/Cl^{-} molar ratio = 11.7 > 1 (Xiao, et al., 2012) and $(Ca^{2+}+Mg^{2+})/(Na^{+}+K^{+})$ ratio = 3.7 > 2.2 represents carbonate rocks as the main sources of dissolved loads.

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