

Chemical Characteristics of Groundwater in the Anaconda River Plain Area

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Abstract

The python river plain area is influenced by the topography and geomorphology, which is conducive to the enrichment of groundwater and is a prosperous area for the development of industrial and agricultural production in Jiyuan. The collection of relevant samples was carried out in 03, 2018, on the basis of which the groundwater chemical characteristics of the python river plain area were analyzed by using mathematical statistics, Piper diagram, Gibbs diagram, and ion scale analysis. The results show that: (1) the main water chemistry types in the study area are Ca•Mg-HCO₃•SO₄ and Ca•Mg-HCO₃•Cl; (2) the groundwater in the study area is mainly controlled by rock weathering, and the main ions in the water body come from the dissolution of calcite and dolomite-dominated carbonate rocks; (3) sulfuric acid and carbonic acid jointly participate in the dissolution process of carbonate rocks.

Keywords

Python River Plain Area; Water chemistry characteristics.

1. INTRODUCTION

In recent decades, climate warming and drying, regional industrial and agricultural water use have affected groundwater quality. Identifying the spatial and temporal distribution patterns, formation effects and influencing factors of groundwater quality has always been the basic task of hydrogeochemistry, the main discipline of WRI research [1]. The chemical composition of groundwater is the product of long-term interaction between groundwater and the external environment. The study of the chemical composition of groundwater is not only of academic significance to the elucidation of the origin and formation of groundwater, but also of great value to the scientific and rational development of groundwater and the protection of groundwater resources.

The python river plain area, influenced by regional fault control and topography, is conducive to groundwater enrichment. Agricultural irrigation, production, living and ecological water in the area are derived from river water and groundwater, and people exploit water resources while affecting the water cycle conditions of groundwater, leading to changes in the fugitive water environment. It is important to understand the characteristics of groundwater chemistry and its formation role for the protection and sustainable development and utilization of groundwater resources.

2. STUDY AREA OVERVIEW

The Python River is one of the larger rivers in Jiyuan, and its main tributaries are the North Python River, the Zhulong River and the Free Flowing Museum. The python river flows in the middle of the Jiyuan basin and forms an alluvial flood plain by accumulating alluvial deposits

from its tributaries. The Python river plain area is north of the Python river, south of the Taihang Mountains, west of the Kong Mountains, and east of the Wangyang Mountains in the Jiyuan basin, and consists of the Python river floodplain fan, cone, and sedimentary plain.

The water-bearing rock group in the plain area of Python River is mainly loose rock pore water and carbonate rock karst water. Loose rock pore water mainly consists of: (1) Alluvial sand and gravel layer of the Quaternary Holocene, 40~80m thick (Q_4^{al+pl}); (2) Alluvial sand and gravel layer of the Quaternary Upper Pleistocene (Q_3^{al+pl}), 20~100m thick, distributed in Python River basin with multiple layers, the upstream constitutes alluvial fan and cone slope, and the downstream is buried under the Quaternary Holocene, which is alluvial plain and contains pore pressurized artesian water. Carbonate rock karst water is mainly: (1) Ordovician (O_2) limestone, brecciated limestone, dolomite, 90~263m thick; (2) Cambrian (ϵ) dolomite, calcareous shale with limestone, < 900m thick, distributed in the surrounding mountains.

3. SAMPLE COLLECTION AND TESTING

A total of 38 groups were sampled in the study area in March 2018, including surface water and groundwater, groundwater were from drinking wells and agricultural wells, and groundwater were mainly shallow groundwater including loose rock type pore water and carbonate rock type karst water. Surface water was obtained from rivers or reservoirs. When the water samples were collected in the field, pH and HCO_3^- were tested on site, where pH was measured using a Remagnet PSH-3B pH meter produced by Shanghai Precision Scientific Instruments and the instrument electrodes were calibrated with a standard buffer solution of pH 9.18 before measurement. The mass concentration of HCO_3^- was determined using a German MColorTest™ HCO_3^- test kit (accuracy range 0.1~10 mmol/L). The rest of the samples were taken in clean and dry sampling bottles, filtered through 0.45 μm acetate membrane at low pressure, and the samples for the determination of cations (K^+ , Na^+ , Ca^{2+} , Mg^{2+}) were immediately acidified to pH < 2 by adding HCO_3^- ; the samples for the determination of anions (Cl^- , SO_4^{2-}) were left untreated. The mass concentrations of SO_4^{2-} and Cl^- were determined by ion chromatography (DX-120), the mass concentrations of Ca^{2+} , Mg^{2+} , Na^+ and K^+ were determined by ICP emission spectrometry, and the TDS was determined by drying and weighing method.

4. RESULTS AND DISCUSSION

4.1. Water Chemistry Characterization

4.1.1 Water chemical composition characteristics

The pH of surface water ranged from 6.70 to 7.40, with an average value of 7.15; the pH of pore water ranged from 6.60 to 7.50, with an average value of 7.17; the pH of karst water ranged from 6.90 to 7.43, with an average value of 7.05, and was generally neutral or weakly alkaline. The pH value gradually increases along the direction of groundwater runoff. The TDS values of surface water ranged from 0.42 to 0.74 g/L, with the average value of 0.55 g/L, less than 1 g/L as fresh water; the TDS values of pore groundwater ranged from 0.33 to 0.84 g/L, with the average value of 0.54 g/L, less than 1 g/L as fresh water; the TDS values of karst groundwater ranged from 0.37 to 0.71 g/L, with the average value of 0.5 g/L, less than 1 g/L as fresh water.

The average ion concentration content of different water bodies in the study area is relatively close, the average cation content of surface water is $Ca^{2+} > Mg^{2+} > Na^+ > K^+$, the average anion content is $HCO_3^- > SO_4^{2-} > Cl^-$; the average cation content of pore groundwater is $Ca^{2+} > Mg^{2+} > Na^+ > K^+$, the average anion content is $HCO_3^- > SO_4^{2-} > Cl^-$; the average size of cations in karst groundwater is $Ca^{2+} > Mg^{2+} > Na^+ > K^+$, and the average size of anions is $HCO_3^- > SO_4^{2-} > Cl^-$. The relationships between the major anions and cations in surface water and shallow groundwater are similar, indicating that their recharge sources are related.

4.1.2 Water chemistry type

The results of the water chemistry analysis of surface water and groundwater can be seen in the Piper trilinear diagram (Figure 1), Ca^{2+} and are the dominant ions, followed by Mg^{2+} and . The main water chemistry type in the study area is $\text{Ca}\cdot\text{Mg}\text{-HCO}_3\cdot\text{SO}_4$, followed by $\text{Ca}\cdot\text{Mg}\text{-HCO}_3\cdot\text{Cl}$. The water chemistry type in the study area does not vary much along the Python River basin area, and $\text{Ca}\cdot\text{Mg}\text{-HCO}_3\cdot\text{SO}_4$ is predominant. In the southern part of the study area, the water chemistry varies greatly from $\text{Ca}\cdot\text{Mg}\text{-HCO}_3\cdot\text{Cl}$ to $\text{Ca}\cdot\text{Mg}\text{-HCO}_3\cdot\text{SO}_4$, with more anions and Cl compared to $\text{Ca}\cdot\text{Mg}\text{-HCO}_3\cdot\text{SO}_4$.

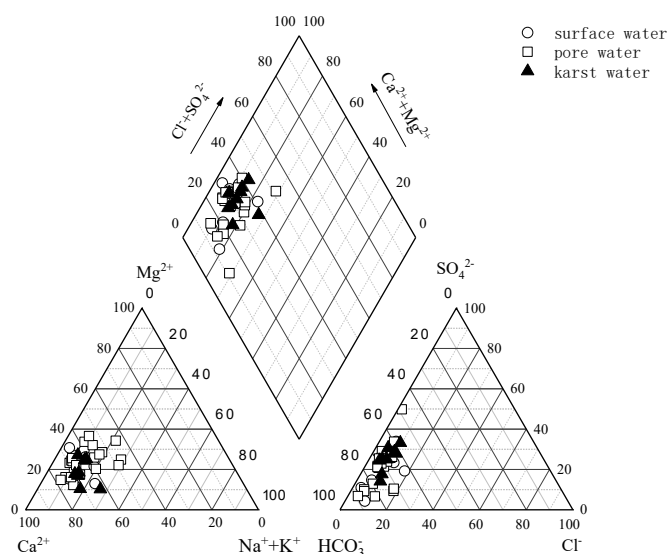


Figure 1. Piper trilinear map of water samples in the study area

4.2. Water Chemistry Components and Control Sources

4.2.1 Surface water and groundwater primary control factors

Gibbs diagram can visualize the influencing factors of surface water and groundwater water chemistry, and it classifies the origin mechanisms affecting water sample ions into evaporation-concentration, rock weathering and precipitation control, etc. In the Gibbs, the water samples with low ρ (TDS) but with high $\text{Na}^+(\text{Na}^+\text{+Ca}^{2+})$ or $\text{Cl}^-(\text{Cl}^+\text{+HCO}_3^-)$ ratios close to 1 are mainly distributed in the lower right corner of the plot, indicating that the chemical composition of these water samples is mainly controlled by atmospheric precipitation. The water samples with medium dissolved substance content and $\text{Na}^+(\text{Na}^+\text{+Ca}^{2+})$ or $\text{Cl}^-(\text{Cl}^+\text{+HCO}_3^-)$ ratios less than or close to 0.5 are mainly distributed in the left middle of the figure, and the chemical components of these water samples are mainly from rock weathering. of water sample points are mainly distributed in the upper right corner of the figure, indicating that the chemical composition of such water is mainly influenced by evaporation-concentration[2-3].

The Gibbs of the study area shows (Figure 2) that the dissolved substance content in surface water and groundwater is moderate, with $\text{Na}^+(\text{Na}^+\text{+Ca}^{2+})$ ratios ranging from 0.03 to 0.26, less than 0.5, and $\text{Cl}^-(\text{Cl}^+\text{+HCO}_3^-)$ ratios ranging from 0.03 to 0.22, less than 0.5, in surface water, and $\text{Na}^+(\text{Na}^+\text{+Ca}^{2+})$ ratios ranging from 0.06 to 0.37, less than 0.5, and $\text{Cl}^-(\text{Cl}^+\text{+HCO}_3^-)$ ratios in groundwater. The water sample site is located in the middle of the left side of the Gibbs diagram, indicating that the main ionic action of surface water and groundwater in the study area is rock weathering.

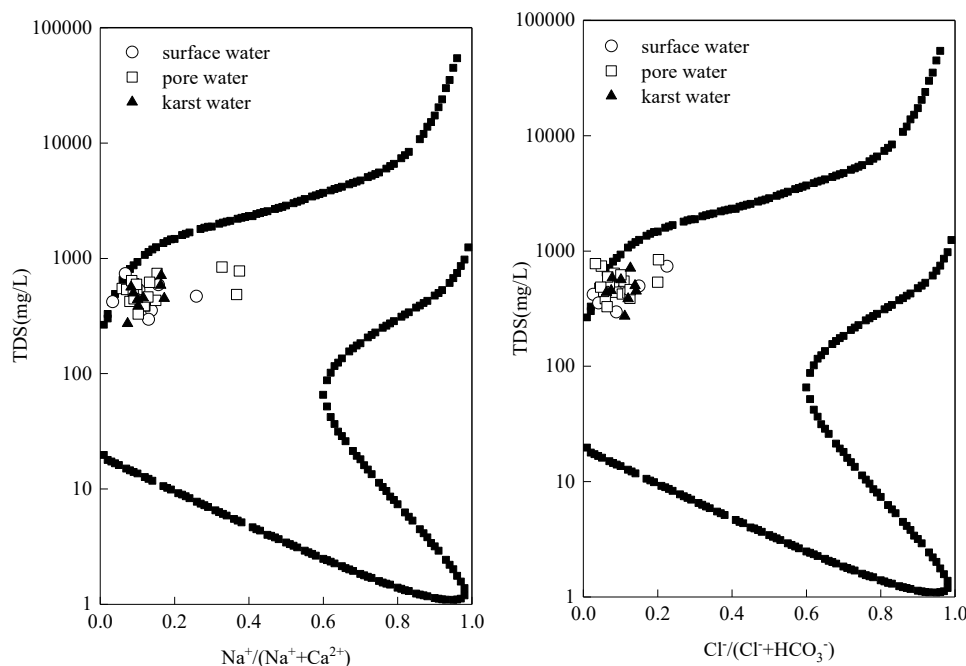


Figure 2. Gibbs diagram of surface water-groundwater in the study area

4.2.2 Ion ratio analysis

The ratio of the relative relationship of the content of major ions in groundwater can be used to study the formative role of water chemistry and the origin of major ions [4-5]. In order to further analyze the main ion sources and hydrochemical evolution of groundwater and surface water in the Python River Plain area, the hydrogeochemical processes of various ion ratios in water bodies were applied to analyze them [6].

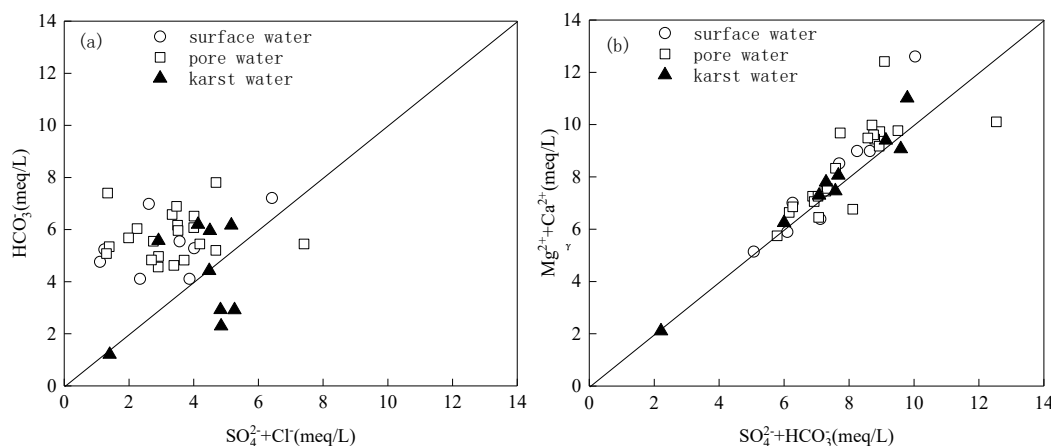


Figure 3. The relationship diagram of $SO_4^{2-} + Cl^-$ and HCO_3^- , $Ca^{2+} + Mg^{2+}$ and $SO_4^{2-} + HCO_3^-$

In the relationship of $SO_4^{2-} + Cl^-$ and HCO_3^- , the point is located on the upper side of the 1:1 linear line for carbonate rock dissolution, accompanied by evaporite on the lower side. The water sample is located above the 1:1 equivalent line (Figure 4), indicating that dissolution of carbonate rocks mainly occurs; the relationship between $(Ca^{2+} + Mg^{2+})$ and $(SO_4^{2-} + HCO_3^-)$ identifies the source of Ca^{2+} and Mg^{2+} with a ratio close to 1, indicating that Ca^{2+} and Mg^{2+} in the water body require carbonate and sulfate ions to chemically equilibrate and suggesting that sulfuric acid in surface water and groundwater may involved in the dissolution of carbonate minerals and/or the dissolution of sulfate evaporite minerals in the basin[7]. The water samples were distributed in a straight line and deviated below the 1:1 line with relatively low Ca^{2+} and

Mg^{2+} content, indicating that cation exchange may have occurred in addition to the dissolution of carbonate and sulfate rocks. This shows that the groundwater in the study area is dominated by dissolution of carbonate minerals and sulfate minerals, while the contribution of evaporite to groundwater and surface water components cannot be excluded.

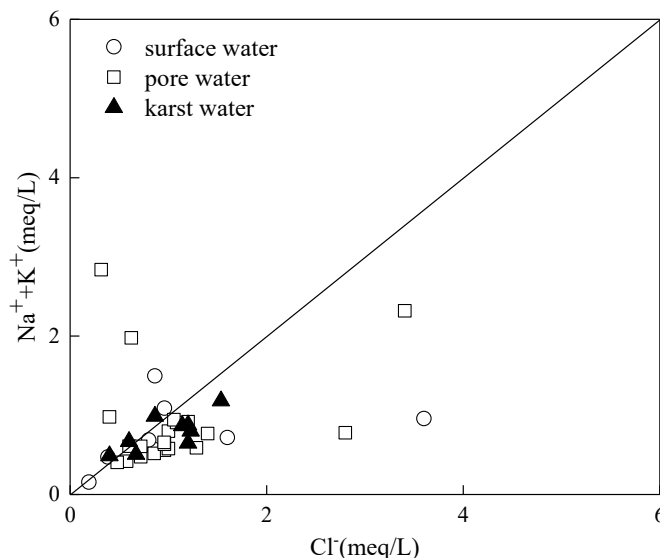


Figure 4. The relationship diagram of $Na^{+}+K^{+}$ and Cl^{-}

The $\gamma_{Na^{+}}/\gamma_{Cl^{-}}$ coefficient is known as the genesis coefficient of groundwater, an indication of the intensity of groundwater salinity leaching and accumulation [8]. The distribution of groundwater in the study area is on both sides of the 1:0.85 line, and most of the karst water and pore water $\gamma(Na^{+}+K^{+})/\gamma_{Cl^{-}}$ is less than 0.85, indicating that Na^{+} mainly originates from the weathering-solution filtration of salt-bearing rock layers; most of the surface water $\gamma(Na^{+}+K^{+})/\gamma_{Cl^{-}}$ is greater than 0.85, indicating the existence of mixing and cation exchange in the surface water. The $\gamma(Na^{+}+K^{+})/\gamma_{Cl^{-}}$ should be 1:1 when salt rock dissolution-filtration-weathering is dominant, while the $\gamma_{Cl^{-}}$ in groundwater and surface water is significantly higher than $\gamma(Na^{+}+K^{+})$, indicating that the sources of Na^{+} and Cl^{-} are mainly dissolution of evaporite, mixing and cation exchange.

Cation exchange is the adsorption of certain cations in groundwater by the surface of rock particles under certain conditions to replace the originally adsorbed cations, and the release of the originally adsorbed cations into the components of groundwater. Common cation exchange in groundwater includes Na-Ca and Mg-Na ion exchange. The equivalence of $(SO_4^{2-}+HCO_3^{-})-(Ca^{2+}+Mg^{2+})$ and $(Na^{+}+K^{+}-Cl^{-})$ can characterize the magnitude of the water sample affected by ion exchange.

The ratio of $(SO_4^{2-}+HCO_3^{-})-(Ca^{2+}+Mg^{2+})$ to $(Na^{+}+K^{+}-Cl^{-})$ in surface water and groundwater in the study area was around 1 (Figure 5), and the increase of HCO_3^{-} and SO_4^{2-} or the decrease of Ca^{2+} and Mg^{2+} with the increase of Na^{+} indicated that cation exchange occurred in surface water and groundwater in the study area.

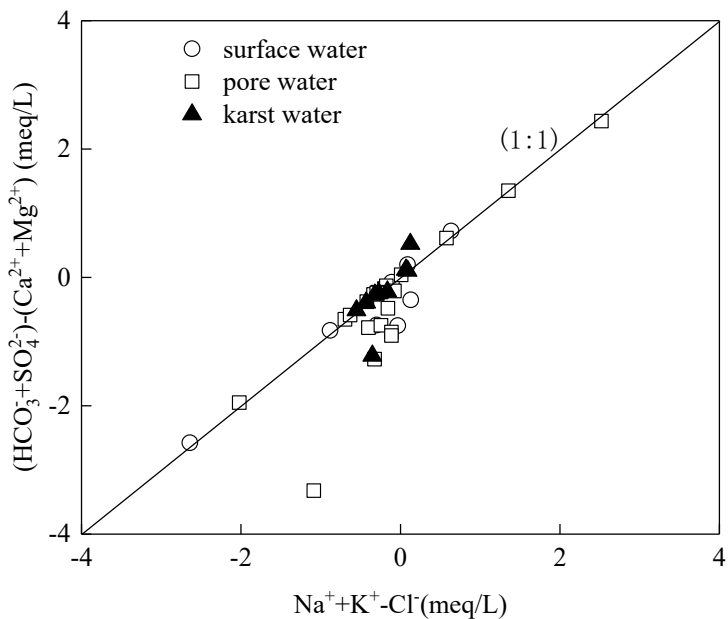


Figure 5. The relationship diagram of $(\text{HCO}_3^- + \text{SO}_4^{2-}) - (\text{Ca}^{2+} + \text{Mg}^{2+})$ and $(\text{Na}^+ + \text{K}^+ - \text{Cl}^-)$

4.2.3 Sulfuric acid is involved in the chemical weathering process of carbonate rocks

Considering the involvement of CO_3^{2-} and SO_4^{2-} in the dissolution process of carbonate rocks, when only carbonic acid is involved in the dissolution process of carbonate rocks, CO_3^{2-} mainly comes from the dissolution of CO_2 and the dissolution of carbonate rocks, $(\text{Ca}^{2+} + \text{Mg}^{2+}) / \text{HCO}_3^-$ is 1; when only sulfuric acid is involved in the dissolution process of carbonate rocks, SO_4^{2-} mainly comes from the dissolution of gypsum, the When only sulfuric acid is involved in the dissolution process of carbonate rock, SO_4^{2-} is mainly from the dissolution of gypsum, oxidation of sulfide as $\text{SO}_4^{2-} / \text{HCO}_3^-$ is 1, $(\text{Ca}^{2+} + \text{Mg}^{2+}) / \text{HCO}_3^-$ is 2; when carbonic acid and sulfuric acid are involved in the dissolution process of carbonate rock in the ratio of 1:1, $(\text{Ca}^{2+} + \text{Mg}^{2+}) / \text{HCO}_3^-$ is 1.5, $\text{SO}_4^{2-} / \text{HCO}_3^-$ is 0.5[9].

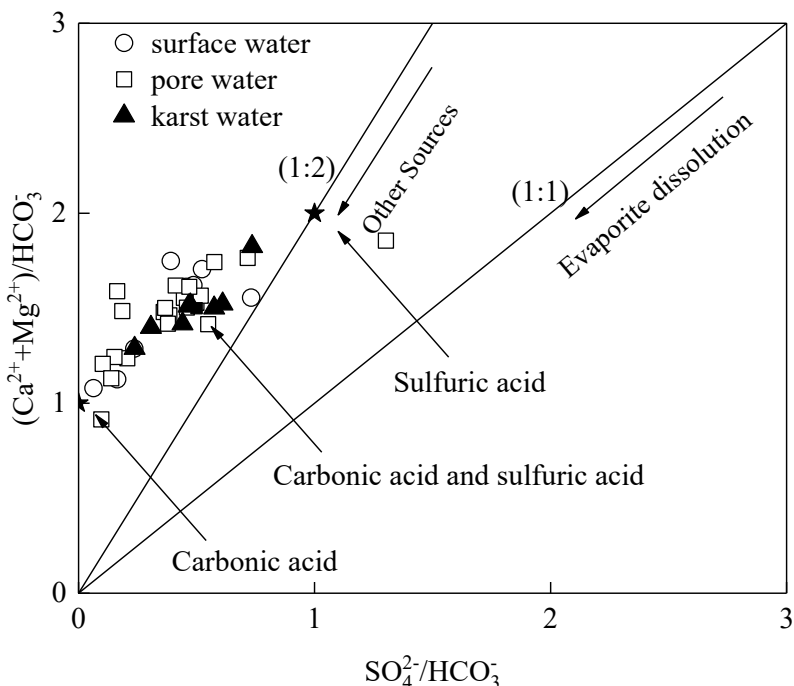


Figure 6. The relationship diagram of $(\text{Ca}^{2+} + \text{Mg}^{2+}) / \text{HCO}_3^-$ and $\text{SO}_4^{2-} / \text{HCO}_3^-$

The $\text{SO}_4^{2-}/\text{HCO}_3^-$ (equivalent ratio) of surface water in the study area ranged from 0.24 to 0.76, with a mean value of 0.52, mostly between 0.5 and 1, $(\text{Ca}^{2+} + \text{Mg}^{2+})/\text{HCO}_3^-$ (equivalent ratio) ranged from 1.29 to 1.75, with a mean value of 1.61, mostly between 1.5 and 2; the $\text{SO}_4^{2-}/\text{HCO}_3^-$ (equivalent ratio) of pore water ranged from 0.10 to 1.30, with a mean value of 0.39, mostly between 0.1 and 0.5, $(\text{Ca}^{2+} + \text{Mg}^{2+})/\text{HCO}_3^-$ (equivalent ratio) 0.10~1.30, mean 0.39, mostly between 0.1~0.5, $(\text{Ca}^{2+} + \text{Mg}^{2+})/\text{HCO}_3^-$ (equivalent ratio) range 0.91~1.86, mean 1.45, mostly between 1~1.5; karst water $\text{SO}_4^{2-}/\text{HCO}_3^-$ (equivalent ratio) range 0.23~0.74, mean 0.49, mostly between 0.4~1, $(\text{Ca}^{2+} + \text{Mg}^{2+})/\text{HCO}_3^-$ (equivalent ratio) range 1.19~1.82, mean 1.51, mostly between 1~1.5, indicating that sulfuric acid in surface water and groundwater is widely involved in chemical weathering of carbonate rocks.

5. CONCLUSION

(1) Among the major ionic compositions of the water samples in the study area, Ca^{2+} and HCO_3^- were the dominant ions, followed by Mg^{2+} and SO_4^{2-} . The dominant water chemistry type was $\text{Ca}\cdot\text{Mg}\text{-HCO}_3\cdot\text{SO}_4$, followed by $\text{Ca}\cdot\text{Mg}\text{-HCO}_3\cdot\text{Cl}$. There is little variation in water chemistry types along the Python River basin and more variation in water chemistry types in the southwestern part of the study area.

(2) The chemical components of surface water and groundwater in the study area are mainly controlled by rock weathering. Na^+ and Cl^- mainly originate from the dissolution of evaporite, Ca^{2+} , Mg^{2+} , HCO_3^- and SO_4^{2-} mainly from the dissolution of calcite and dolomite-based carbonate rocks, and cation exchange is an important process in the formation of the chemical components of groundwater in the study area.

(3) The hydrochemical components of surface water and groundwater in the study area are mainly dissolved in carbonate rocks, and sulfuric acid in surface water and groundwater is extensively involved in the weathering of carbonate rocks.

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