Pol. J. Environ. Stud. Vol. 31, No. 6 (2022), 5611-5620
DOI: *10.15244/pjoes/152988* ONLINE PUBLICATION DATE: 2022-10-17

Original Research

Hydrochemical Characteristics and Water Quality Evaluation of Surface Water in Chating Mining Area, Xuancheng, Anhui, China

Mengyuan Chen, Songbao Feng*

School of Resources and Civil Engineering Suzhou University, Suzhou, Anhui, China, 234000

Received: 2 June 2022
Accepted: 25 August 2022

Abstract

In order to reveal the hydrochemical characteristics and influencing factors of surface water in Chating mining area, find out the source of ions and clarify the water quality, 33 surface water samples were collected. The hydrochemical types, material sources and influencing factors of surface water in the study area were analyzed by means of mathematical statistical analysis, hydrochemical graphical method and spatial interpolation. Comprehensive water quality index (WQI) and irrigation water quality assessment were used to evaluate the surface water quality in the study area. The results show that the surface water in the study area was freshwater, weakly alkaline, and its water chemical type was mainly Ca-HCO_3. The water chemical composition is mainly controlled by rock weathering, with little influence from human activities and cation exchange. The chemical composition comes from silicate weathering, carbonate dissolution and sulfate dissolution. The results of WQI drinking evaluation showed that the surface water quality was excellent and reached the drinking standard under certain conditions. Irrigation water quality evaluation results showed that surface water samples could be directly used as irrigation water, and rational utilization will not cause soil salinization.

Keywords: Chating mining area, water chemical characteristics, ion source, influence factor, water quality evaluation

Introduction

As an indispensable part of geochemical cycle, surface water is the medium of material and energy cycle between land and sea, as well as an important source of water for human life, agriculture, animal husbandry and fishery [1-2]. Water interacts with the surrounding environment in the process of circulation to form the chemical composition of natural water [1], while regional mineralization, leaching, rock weathering, topography and human activities can also affect the chemical composition of surface water [1-4]. Under the joint influence of a variety of natural and human factors, water bodies form complex and diverse hydrochemical systems, which directly affect the quality of water [5-6]. It can be seen that determining the influencing factors of hydrochemical characteristics and ion sources plays an important role in the protection and utilization of water resources, human survival and development, and regional economy.

At present, there are a lot of research achievements on the influencing factors of hydrochemical

*e-mail: fengsongbao123@163.com

characteristics of natural water and water quality evaluation. Kabour et al. [6] studied the hydrochemistry type and its influencing mechanism of groundwater in Be´Char City by Gibbs model and ion ratio diagram, and the results showed that the groundwater chemistry type was controlled by water-rock interaction and human pollution factors. Seth Rose [7] used element ratio and isotope analysis to study the influence of CRB-based flow chemistry, and the results showed that the input of man-made pollution sources was the leading factor affecting river water quality in the process of urbanization. Hua Kun et al. [8] used ternary diagram, fuzzy membership function and correlation analysis to study the chemical characteristics, material sources and influencing factors of Fen River water, and the results showed that rock salt weathering was the main influencing mechanism. However, studies on factors influencing the hydrochemical characteristics of surface water in porphyry polymetallic mining areas are rarely reported [9-12]. In view of this, this paper studied the surface water in the study area from two aspects of influencing factors of hydrochemical characteristics and water quality evaluation. The hydrochemical types and sources of surface water and their influencing factors were analyzed by means of mathematical statistics, hydrochemical diagrams and spatial interpolation. Comprehensive water quality index (WQI) was used to evaluate drinking water quality and irrigation water quality. The research results provide a theoretical basis for the protection, rational allocation and utilization of surface water resources in the district, and also provide a background for the changes of chemical components of surface water after mining in Chating mining area.

Materials and Methods

Study Area

Located in the polymetallic metallogenic belt of the middle and lower reaches of the Yangtze River, Chating mining area is a porphyry copper and gold deposit of hydrothermal origin. The study area of this paper is located in The Chating Mining Area, northeast of Xuancheng District, Xuancheng City, Anhui Province. The coordinate interval is between 118°50’20”~118°51’45” EAST longitude and 31°12’30 “~31°13’40” north latitude, as shown in Fig 1. A subtropical humid monsoon climate, adequate sunshine, rain and heat at the same time, moderate precipitation. According to the data, the annual average temperature in the research area is 16.0ºC, the average temperature of the lowest month (January) is 3.3ºC, the average temperature of the highest month (July) is 28.0ºC, and the annual average temperature difference is 24.7ºC. The annual average precipitation is more than 1000 mm, mainly concentrated in May to October, with the highest precipitation in June. The terrain is mainly plain and hilly, generally speaking, the terrain is not fluctuating.

Sample and Analysis

In November 2021, systematic water sample collection was carried out in Chating Mining Area, and a total of 33 water samples were collected. The distribution of sampling points is shown in Fig 1. When collecting surface water samples, the sample bottles that have been cleaned with pure water should be rinsed for three times with pre-collected water samples, then bottled until overflow, labeled and sealed for preservation. GPS toolbox (China Little Wolf Information Technology Co., LTD.) was used to record the longitude and latitude information of sampling points on site. The pH, TDS (total dissolved solids) and EC (electrical conductivity) were measured and recorded on the spot with a portable tester. The other hydrochemical indexes were tested in Anhui Key Laboratory of Mine Water Resources Utilization. The samples were filtered by 0.45 μm membrane and stored at 4ºC low temperature, followed by main ion test. Cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (SO_4^{2-}, Cl^-) were detected and analyzed by ICS-600 and ICS-900 ion chromatographs made by Thermo Fisher Scientific in the United States. HCO_3^- and CO_3^{2-} were measured by titration with acid standard solution.

Results and Discussion

Analysis of Water Chemical Types and Water Chemical Characteristics

The results of statistical analysis on the water chemical indicators of 33 water samples collected from the Chating mining area were shown in Table 1. The cations in the surface water of the study area were mainly Ca^{2+}, and the ion mass concentration accounted for 46.19% of the total cations, with an average concentration of 14.61 mg/L, the average mass concentration of cations is in the relationship of Ca^{2+}>Mg^{2+}>Na^+>K^+. The main anions were HCO_3^-, whose mass concentration accounted for 78.95% of the total anions, and the average concentration is 73.69 mg/L. The anions showed the relationship of HCO_3^->SO_4^{2-}>Cl^-. The pH value of surface water ranged from 6.40 to 8.90, with an average value of 8.16. TDS content ranged from 32.00 mg/L to 101.00 mg/L, with an average value of 76.09 mg/L. On the whole, TDS value of surface water in the study area was small and the water quality was good [13], which belonged to fresh water type. EC ranged from 41.00 μs/cm to 211.00 μs/cm, with an average value of 154.88 μs/cm. Except for Mg^{2+}, the coefficient of variation of surface water hydrochemical parameters did not exceed 1. To sum up, the hydrochemical components of surface water in the study area were relatively stable.

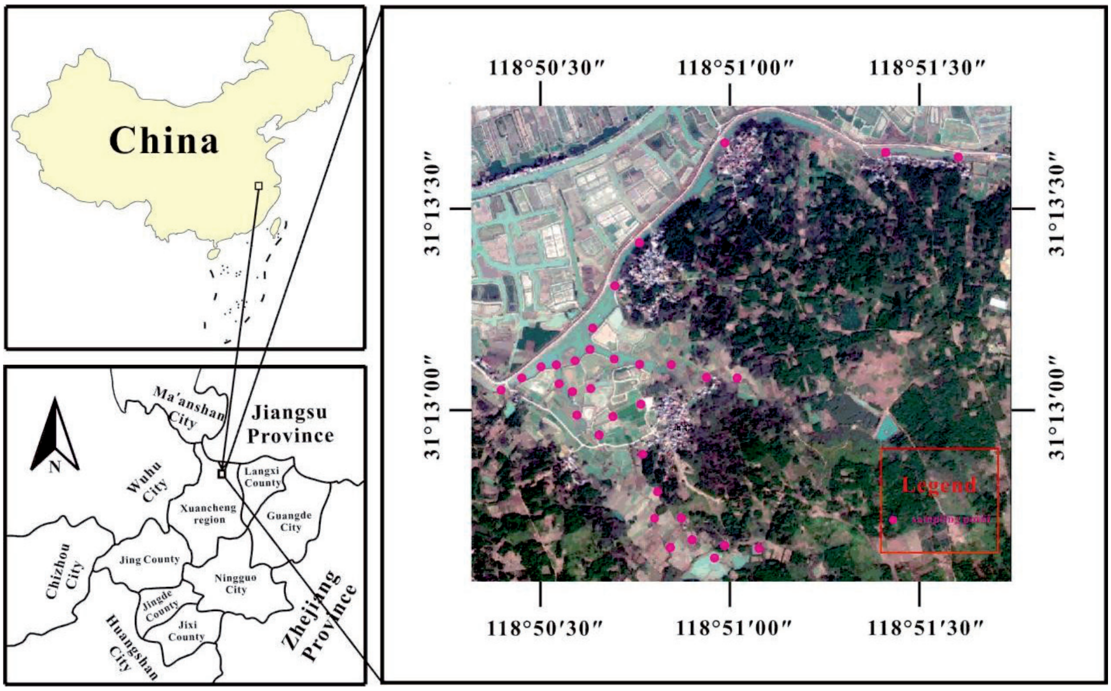

Fig. 1. Geographical location of the study area and distribution of sampling points.

Piper diagram is mainly represented by the mg equivalent percentage of cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (SO_4^{2-}, Cl^-, HCO_3^-, CO_3^{2-}), and is commonly used to show the hydrochemical types and characteristics of different water bodies [14]. Based on the surface water test results, a surface water Piper map was drawn, as shown in Fig 2. The surface water cations in the study area were mainly concentrated in the lower left corner of the cation triangle, near the end of Ca^{2+}, and a few in the upper right corner, near the end of Mg^{2+}, indicating that the surface water cations were dominated by Ca^{2+}, followed by Mg^{2+}. The anions are mainly distributed along the boundary line of anion triangle HCO_3^-+CO_3^--SO_4^{2-}, indicating that the anions were mainly HCO_3^- and SO_4^{2-}, and HCO_3^- was dominant. In conclusion, the main hydrochemical type of surface water in the study area is Ca-HCO_3, with a small amount of Mg-HCO_3 and Ca-SO_4.

In order to further determine the hydrochemical types of water samples in the study area, Schoeller diagrams in the hydrochemical diagram method were used. Schoeller's diagram can directly express the concentration changes of water chemical components in water samples [15-16]. In this study, cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (SO_4^{2-}, Cl^-, HCO_3^-) were selected as indicators for analysis. Due to the low

Table 1. Statistical analysis of the chemical characteristic values of surface water water.

Index	Max	Min	Mean	SD	C. V	Sample no.
Ca^{2+}	24.59	2.50	14.61	7.44	0.51	33
Na^+	8.10	2.31	5.37	1.26	0.23	33
K^+	5.17	0.72	2.81	1.15	0.41	33
Mg^{2+}	27.25	1.99	8.84	8.88	1.02	33
Cl^-	10.93	3.92	7.95	2.12	0.27	33
SO_4^{2-}	55.73	6.88	11.70	8.11	0.69	33
HCO_3^-	111.30	26.47	73.69	26.60	0.36	33
PH	8.90	6.40	8.16	0.40	0.05	33
TDS	101.00	32.00	76.09	18.03	0.24	33
EC	211.00	41.00	154.88	42.46	0.27	33

Note: pH is dimensionless, EC unit is μs/cm, and other units are mg/L.

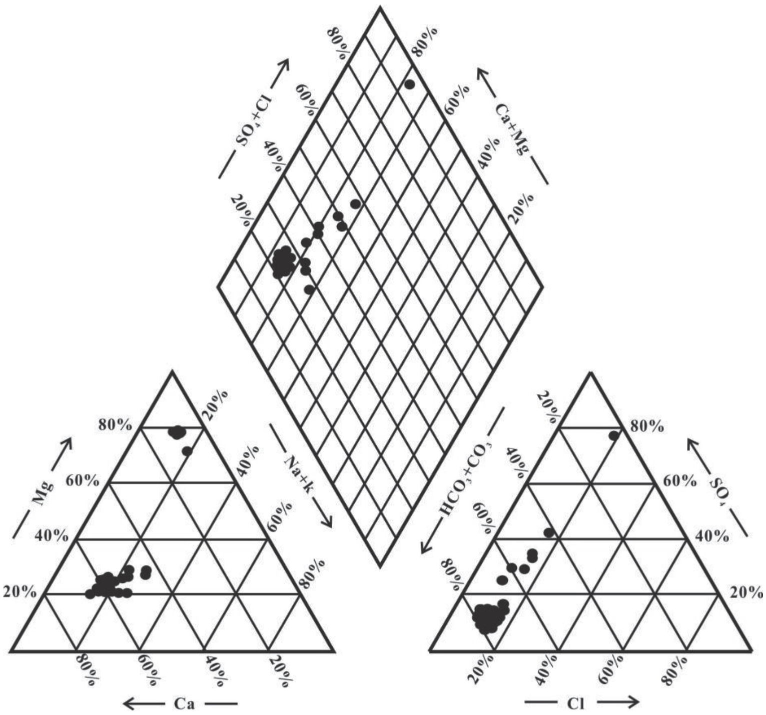

Fig. 2. Piper map of surface water in Chating Mining Area.

average content of Na^+ and K^+, their combinations were analyzed. The variation trend of two or more polylines in the figure was similar or parallel, indicating that each polyline represented the same hydrochemical type of samples [17]. It could be seen from Fig. 3 that the peak value of broken line trend of most samples was HCO_3^- and Ca^{2+}, and a small amount is HCO_3^-, Mg^{2+} and SO_4^{2-} and Ca^{2+}, indicating that the hydrochemical type of surface water in the study area is mostly Ca-HCO_3, and a small amount is Mg-HCO_3 and Ca-SO_4. The analysis results were consistent with those of Piper diagram. Further confirm the hydrochemical type of surface water in the study area.

Control Factors of Water Chemical Composition

Gibbs [18] studied the relationship between TDS and $Na^+/(Na^++Ca^{2+})$ and $Cl^-/(Cl^-+HCO^{3-})$ of most of

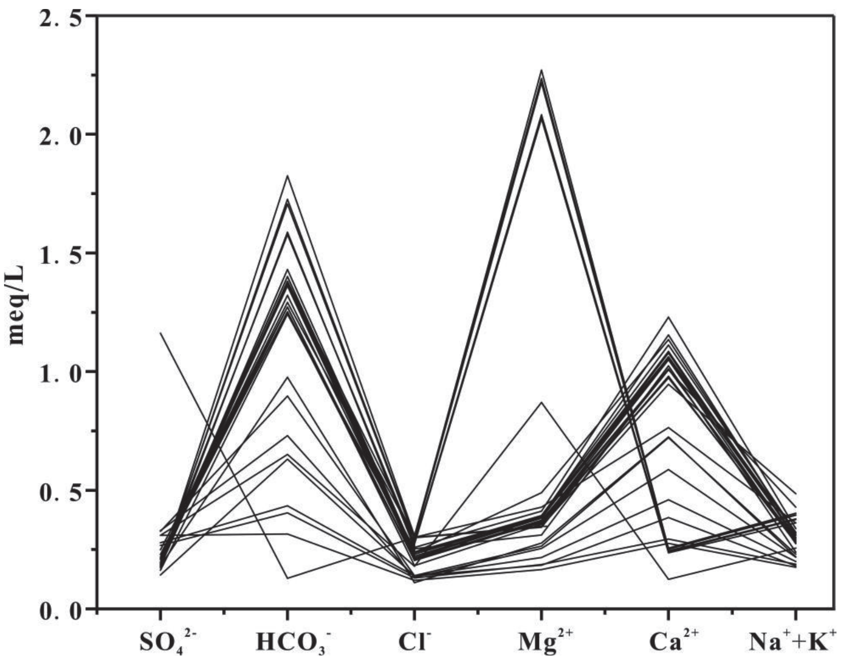

Fig. 3. Schoeller diagram of surface water in Chating Mining Area.

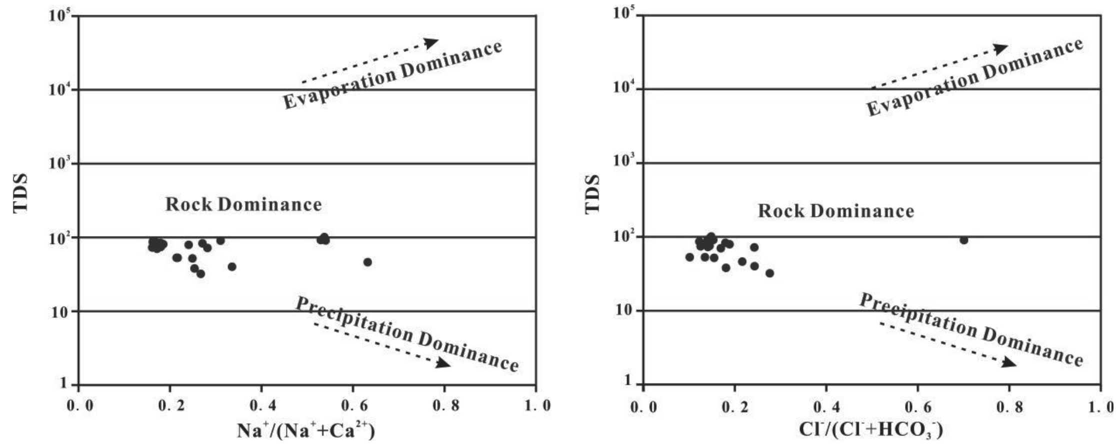

Fig. 4. Gibbs diagram of surface water in Chating Mining Area.

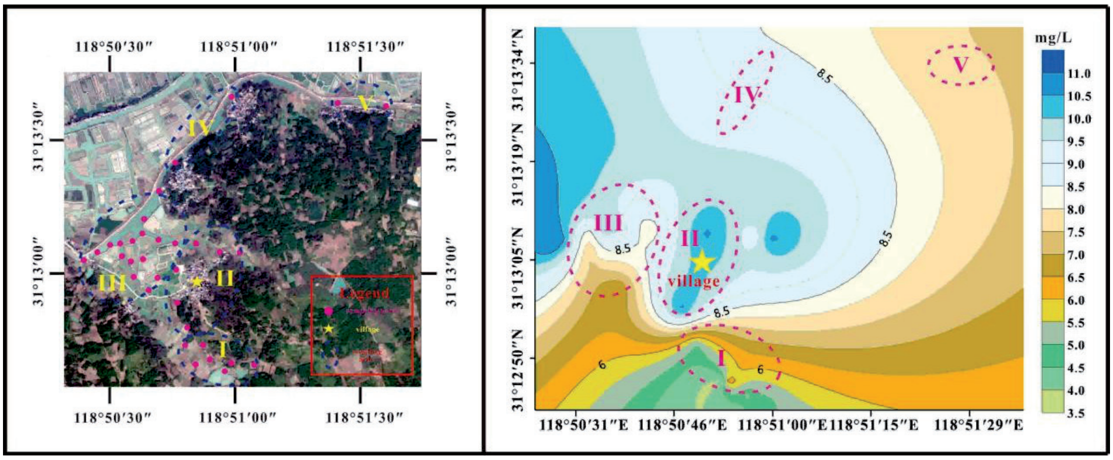

Fig. 5. Spatial distribution of Cl^- content.

the world's surface water, and summarized the three controlling factors affecting the chemical composition of surface water: Evaporation Dominance type, Rock Dominance type, Precipitation Dominance type [19]. When the content of soluble substances is low and the ratio of $Na^+/(Na^++Ca^{2+})$ or $Cl^-/(Cl^-+HCO_3^-)$ is close to 1, the points with this characteristic are distributed in the lower right corner of Gibbs model, indicating that the source of surface water ions is mainly controlled by precipitation. When the content of soluble substances is medium and the ratio of $Na^+/(Na^++Ca^{2+})$ or $Cl^-/(Cl^-+HCO_3^-)$ is less than or near 0.5, the hydrochemical composition of the surface water is dominated by rock weathering, and this characteristic point is distributed in the middle left of Gibbs model. When the content of soluble substances is high and the ratio of $Na^+/(Na^++Ca^{2+})$ or $Cl^-/(Cl^-+HCO_3^-)$ is close to 1, the characteristic point of the surface water is located in the upper right corner of the model, indicating that the ion source of the surface water is mainly controlled by evaporation and crystallization. [20-21] The mass concentration of dissolved substances in the study area was medium, the ratio of $Na^+/(Na^++Ca^{2+})$ was 0.16~0.34, and the ratio of $Cl^-/(Cl^-+HCO_3^-)$ was 0.10~0.70. As shown in Fig. 4, 97.0% of the water samples were distributed in the central left-leaning rock weathering control area. This was because the recharge conditions of surface water in the study area were relatively good and evaporation was relatively weak, thus formed low TDS water dominated by filtration [22]. In conclusion, the chemical composition of surface water in the study area was mainly controlled by rock weathering.

Impact of Human Activities

Human activities are one of the important factors affecting the chemical composition of water bodies, which mainly affect the surface water resources from the aspects of industry, domestic wastewater, pesticide spraying, poultry excreta and aquaculture. Cl^- can be used as an indicator element of the influence of human activities on the chemical characteristics of water bodies [14]. As can be seen from Fig. 5, the content of Cl^- in Area II is significantly higher than that in other sampling areas. In Area II, where residents gather, domestic wastewater, aquaculture and poultry excreta

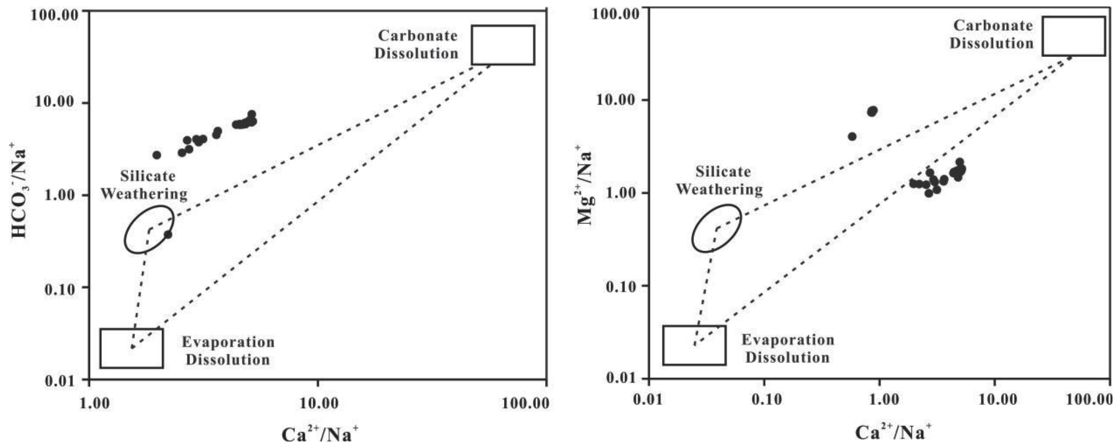

Fig. 6. Relationship between Ca^{2+}/Na^{+} and HCO_3^-/Na^+, Mg^{2+}/Na^+.

were the main reasons for the high content of Cl^-. However, according to the data in Table 1, the content of Cl^- was relatively low, indicating that human activities had little influence on the chemical characteristics of surface water in the study area.

Ion Source Analysis

The hydrochemical composition of surface water mainly come from the weathering dissolution of rocks. Ca^{2+} and Mg^{2+} were mainly from the dissolution of carbonate rock, silicate rock and evaporite rock, Na^+ and K^+ were mainly from the dissolution of evaporite rock and silicate rock, SO_4^{2-} and Cl^- were mainly from the dissolution of evaporite rock, HCO_3^- was mainly from the dissolution of carbonate rock and silicate rock. Hybrid maps are commonly used to reveal the sources of ions produced by chemical weathering in surface water [14]. Fig. 6 shows that the ion concentration ratios of Ca^{2+}/Na^+, HCO_3^-/Na^+ and Mg^{2+}/Na^+ in water samples

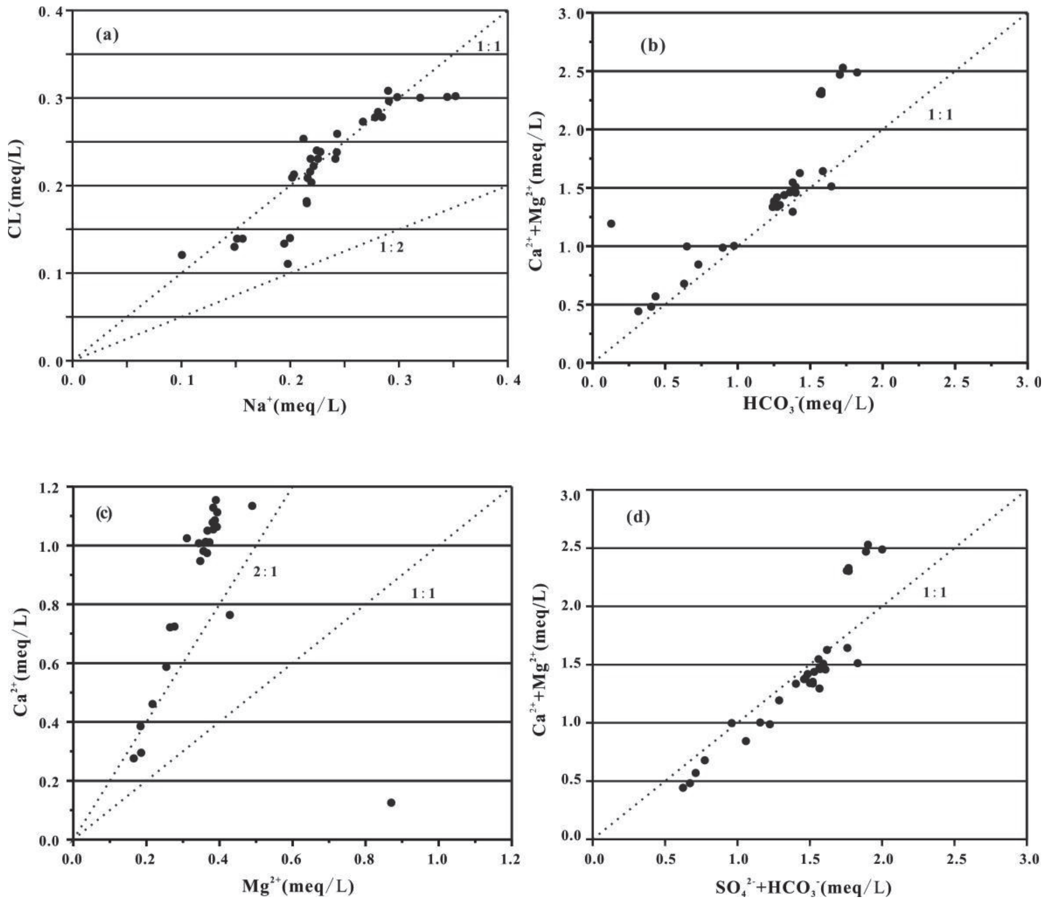

Fig. 7. Relation diagram of main ion ratio of surface water in Chating Mining Area.

Table 2. Weight values of each chemical parameter.

Parameters	WHO Standard	Weight	Relative Weight
Na^+	200	5	0.1613
K^+	12	2	0.0645
Mg^{2+}	100	4	0.1290
Ca^{2+}	300	4	0.1290
Cl^-	250	3	0.0968
SO_4^{2-}	250	3	0.0968
HCO_3^-	500	2	0.0645
pH	6.5-8.5	3	0.0968
TDS	1000	5	0.1613

of The Chating mining area were distributed between silicate rock and carbonate rock, indicating that the ion source was influenced by the interaction of water and rock, such as the weathering of silicate rock and carbonate rock.

In order to further reveal the sources of water chemical components in surface water, the main ion equivalent ratio diagram was used to further analyze them. In the hydrochemical composition, the difference in concentration ratio among components could be used to reflect the hydrochemical genesis [23]. Based on the sample analysis results, the ratio diagram of main ions in surface water of Chating Mining area was drawn, as shown in Fig 7. Fig 7a) showed that the concentration ratio of Cl^- and Na^+ in 15 water samples was distributed at 1: Above the isoline 1, the ratio of Na^+ to Cl^- was between 1.00 and 1.79, reflecting that the content of Cl^- in water samples was higher than that of Na^+, which might be related to the ion exchange between Ca^{2+}, Mg^{2+} and Na^+ in surface water [24]. The remaining water samples were distributed near and below the isoline near Na^+. It indicated that Na^+ source was not only related to salt rock dissolution, but also closely related to silicate mineral weathering [25]. Fig 7b) showed that 31 samples of surface water were distributed near and above $(Ca^{2+}+Mg^{2+})/(HCO_3^-) = 1$, namely, the dissolution of carbonate rocks was dominant in the study area, and there might be dissolution of sulfate to provide Ca^{2+} and Mg^{2+} higher than HCO_3^-. Fig 7c) showed that the vast majority of surface water samples were distributed above $Ca^{2+}/Mg^{2+} = 2$, that is, there was dissolution of silicate rock or sulfate rock in the study area [26]. Fig. 7d) showed that 72.73% of the surface water samples were distributed below $(Ca^{2+}+Mg^{2+})/(SO_4^{2-}+HCO_3^-) = 1$, which might be caused by the weathering of silicate rock [24]. According to comparison Fig 7b), SO_4^{2-} balanced the $Ca^{2+}+Mg^{2+}$ higher than HCO_3^-. Furthermore, the influence of sulfate dissolution on surface water in the study area was verified [25]. In conclusion, the main ion sources in the study area were mainly related to the weathering and dissolution of silicate rock, carbonate rock and sulfate, and cation exchange also had a certain influence on the main ion sources.

WQI Drinking Evaluation

Comprehensive water quality Index (WQI) is widely used in the evaluation of surface water and groundwater quality [27]. According to the World Health Organization (WHO) Criteria for Water Quality Parameters, fourth edition [28], see Table 2, the WQI of each sample is calculated by the weighted arithmetic index method [29]. In this study, nine indicators, Na^+,

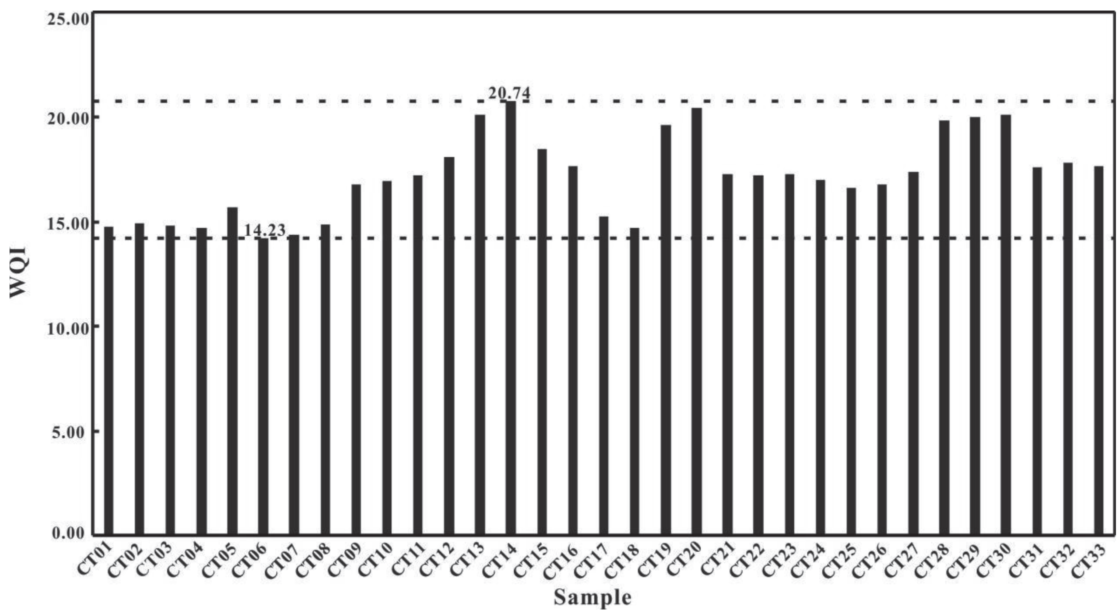

Fig. 8. WQI value of surface water in Chating Mining Area.

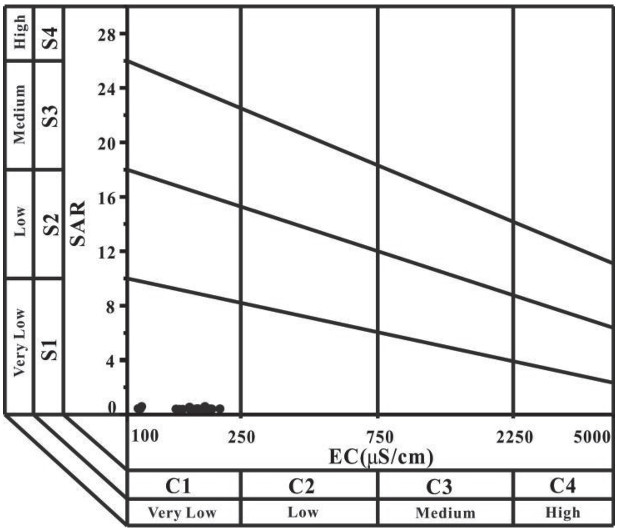

Fig. 9. Irrigation water quality classification in the study area ([31]).

K^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, pH and TDS, were selected for WQI drinking evaluation of surface water, and the calculation process was shown in reference [30]. Based on WQI, water quality can be divided into five categories: WQI<25, indicating excellent water quality; 26<WQI<50, indicating good water quality; 51<WQI<75, indicating poor water quality; 76<WQI<100, indicating extremely poor water quality; WQI>100, indicating that the water quality is not suitable for drinking [30]. Fig. 8 showed that the WQI values of all surface water samples in the research area were between 14.23 and 20.74, and their WQI values are all below 25, indicating excellent surface water quality in the research area.

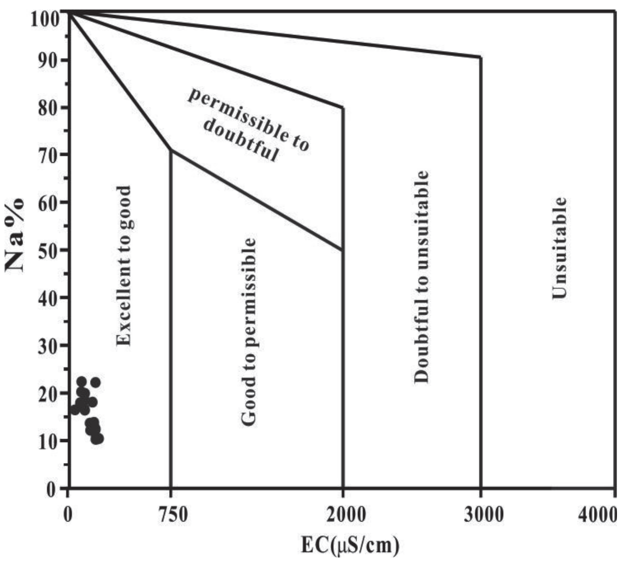

Fig. 10. Irrigation water quality classification in the study area ([32]).

Evaluation of Irrigation Water Quality

The quality of irrigation water has a significant impact on the growth of crops and the physical and chemical properties of soil [33]. Too much salt will form reverse osmotic pressure, which is toxic to crops, and too much sodium ion can cause soil alkalization. EC (electrical conductivity) and SAR (sodium adsorption ratio) were usually important indexes for evaluatd soil salinization degree and irrigation water quality in agriculture. [34] In this regard, EC, SAR and Na% (sodium percentage) were selected as the evaluation parameters of irrigation water quality in the study area, and the irrigation water classification maps (Fig. 9 and 10) were drawn based on the USDA irrigation water quality classification standard and Wilcox graphical method, respectively, to evaluate the irrigation water quality of the surface water in the study area. The results showed that 28 samples in Fig. 9 were distributed in the C1S1 area, that is, the degree of salt and alkali damage was very low, and the EC values of the remaining 5 samples was lower than 100 μs/cm, indicating that the surface water in the study area met the requirements of irrigation water quality and could be used for irrigation. The 33 samples in Fig. 10 were all distributed in areas with excellent water quality, indicating that surface water in the study area could be directly used as irrigation water.

Conclusions

In this study, mathematical statistical analysis, hydrochemical graphic methods (Piper diagram, Schoeller diagram, Gibbs diagram, principal ion ratio), spatial interpolation method and water quality evaluation index were used to reveal the hydrochemical characteristics and influencing factors of surface water in Chating mining area, identify the source of ions and clarify the water quality. The following conclusions have been achieved:

(1) The surface water of Chating Mining area was fresh water (TDS<101.00 mg/L), which was weakly alkaline (6.40<pH<8.90). The main cations in surface water were Ca^{2+}, and the mass concentration of Ca^{2+} accounted for 46.19% of the total cations, followed by Mg^{2+}; The main anion was HCO_3^-, and the mass concentration of HCO_3^- accounted for 78.95% of the total anion, followed by SO_4^{2-}.

(2) The main hydrochemical types of surface water in the study area were Ca-HCO_3, and a few were Mg-HCO_3 and Ca-SO_4.

(3) The surface water in Chating mining area was dominated by rock weathering. The source of water chemical composition was mainly affected by the weathering and dissolution of silicate rock, carbonate rock and sulfate, but was less affected by human activities, and cation exchange also had a certain influence.

(4) The results of WQI drinking evaluation showed that the surface water quality of Chating mining area was excellent and reached the drinking standard under certain conditions. Irrigation water quality evaluation results showed that all surface water samples in the study area could be directly used as irrigation water, and rational utilization would not cause soil salinization.

Acknowledgments

This work was financially supported by the Demonstration Teaching Organization of Anhui Education Department (2020SJSFJXZZ416), the Dual-abillity Teaching Team Project of Suzhou University(2020XJSN06), and the Green Mine Research Center of Suzhou Univerisity (2021XJPT53), the Academic Funding for Top-talents in Disciplines of Universities in Anhui Province (gxbjZD2022075), Collaborative Innovation Foundation of Regional Development in Suzhou Area (2014SZXTKF01ZD).

Conflict of Interest

The authors declare no conflict of interest

References

1. LI R., ZHANG F., GAO Y.X., ZHOU M., WANG D.F., LI X.H. Changes in dry and wet seasons of surface water chemistry in Lake Aibi area and its controlling factors. Glacier and Permafrost, **38** (05), 1394, **2016**.
2. SUN Y., ZHOU J.L., NAI Y.H., ZENG Y.Y., LI B. Characteristics and genesis of hydrochemistry of surface water in The Kashgar River Basin, Xinjiang. Journal of arid land resources and environment, **33** (08), 128, **2019**.
3. CAO Y.F., ZHANG M.J., QU D.Y., WANG S.J., QIU X., MA Z.Z., DU Q.Q., CHE C.W. Spatial and temporal variation of surface and groundwater hydrochemistry in the eastern qilian mountains. China environmental science, **40** (04), 1667,**2020**.
4. KOU Y.C., HUA K., LI Z. Hydrochemical characteristics and controlling factors of surface water and groundwater in tributaries of jinghe river. Environmental science, **39** (07), 3142,**2018**.
5. YAN Z.X., FENG M.Q. Hydrochemical Characteristics and Driving Factors of SURFACE Water in Changhe Basin. Environmental Chemistry, **41** (02), 632,**2022**.
6. ABDESSELEM K., AZEDINE H., LYNDA C., YOUNES S. Wastewater Discharge Impact on Groundwater Quality of Béchar City, Southwestern Algeria: An Anthropogenic Activities Mapping Approach. Procedia Engineering, **33**, 242, **2012**.
7. ROSE S. The effects of urbanization on the hydrochemistry of base flow within the Chattahoochee River Basin (Georgia, USA). Journal of Hydrology, **341** (1-2), 42, **2007**.
8. HUA K., XIAO J., LI S., LI Z. Analysis of hydrochemical characteristics and their controlling factors in the Fen River of China. Sustainable Cities and Society, **52**, 101827, **2019**.
9. XIAO J., JIN Z.D., WANG J., ZHANG F. Hydrochemical characteristics, controlling factors and solute sources of groundwater within the Tarim River Basin in the extreme arid region, NW Tibetan Plateau. Quaternary International, **380** (5), 237, **2015**.
10. OBIEFUNA G.I., ORAZULIKE D.M. The Hydrochemical Characteristics and Evolution of Groundwater in Semiarid Yola Area, Northeast, Nigeria. Research Journal of Environmental & Earth ences, **3** (4), 400, **2011**.
11. MA J., GUI H.R., MENG Z.M., WU C.C., GONG W. Conventional ion sources and multivariate statistical analysis of water in Zhuxianzhuang, northern Anhui. Coal engineering, **48**, 148, **2016**.
12. RAWAT K.S., TRIPATHI V.K., SINGH S.K. Groundwater quality evaluation using numerical indices: a case study (Delhi, India). Sustainable Water Resources Management, **2018**.
13. WU L.N., SUN C.J., HE Q., CHEN W., ZHANG Y.Q. Analysis of the temporal and spatial characteristics of hydrochemistry in a typical inland river basin in the Central Tianshan. Research on Soil and Water Conservation, **24** (05), 149, **2017**.
14. YANG J.Y., YANG Y.H., HU Y.C., FENG X.C., ZENG K.K., WU L.P. Hydrochemical characteristics and controlling factors of surface water in the Kashi River Basin, Ili, Xinjiang. Environmental Chemistry, **2022**.
15. CHOELLER H. Geochimie des eauxsouterraines application aux eaux de gisements de petrole, Revue Inst. Petrole et Ann des Combustibles Liq- uids, **10** (181), 219, **1962**.
16. MAGHRABY E.M. Hydrogeochemical characterization of groundwater aquifer in Al - Madininah Al -Munawarah City,Saudi Arabia. Arabian Journal of Geosciences, **8** (6), 4191, **2015**.
17. J T.S., Qu C.X., WANG M.Y. Chemical characteristics and genesis of shallow groundwater in Beijing pinggu plain. Journal of arid land resources and environment, **31** (11), 122, **2017**.
18. GIBBS R.J. Mechanisms Controlling World Water Chemistry. Science, **170** (3962), 1088, **1970**.
19. TU C.L., MA Y.Q., LINGHU C.W., HE C.Z., CUN D.X. Hydrochemical characteristics and evolution law of the Zhawai River Basin in the coal mine agglomeration area of the eastern Yunnan Plateau. Science and Technology and Engineering, **21** (29), 12470, **2021**.
20. YI Y.N., SUN X.Y., WANG F.Q., KANG P.P., ZHANG R.J. Analysis on hydrochemical characteristics and influencing factors of wetland in Sanmenxia Reservoir area. Yellow River, **2021**.
21. SUN P.F., YI Q.T., Xu G.Q. Hydrochemical characteristics and influencing factors of water body in water area of coal mining subsidence in Lianghuai River. Journal of China Coal Society, **39** (7), 9, **2014**.
22. DING Q.Z., ZHOU J.L., ZENG Y.Y., LEI M., SUN Y. Hydrochemical characteristics and influencing factors of groundwater in Balikun Basin, Xinjiang based on multivariate statistical method. Journal of Water Resources and Water Engineering, **32** (5), 7, **2021**.
23. YANG S., LI Y.L., JIANG F.C., YANG G.D. Hydrochemical characteristics and water quality evaluation of Gaodianzi area. Geological Science and Technology Information, **38** (02), 226, **2019**.
24. CHEN K., SUN L.H. Analysis on chemical composition and controlling factors of groundwater in renlou coal mine. Coal science and technology, **47** (10), 240, **2019**.

25. WU Y.Z., PAN C.F., LIN Y., CAO F.L., WANG Z.J. Hydrogeochemical characteristics and controlling factors of main water-filled aquifers in typical North China coal mine area. Geological science and Technology Information, **37** (05), 191, **2018**.
26. ZHANG T., WANG M.G., ZAHNG Z.Y., LIU T., HE J. Hydrochemical characteristics and controlling factors of surface water in ranwu lake basin. Environmental science, **41** (09), 4003, **2020**.
27. WAN J.F., GUO X.C., HU E., SUN C.S. Water quality assessment of typical urban dam-controlled landscape river in Weihe River basin based on WQI and TLI. Environmental Engineering, **2022**.
28. WHO. Guidelines for drinking-water quality-edition 4. Geneva:World Health Organization, **2011**.
29. GAGANDEEP S. Multivariate analysis and geochemical signatures of groundwater in the agricultural dominated taluks of Jalandhar district, Punjab, India. Journal of Geochemical Exploration, **2020**.
30. YA H., ZHOU P.Y. LI L.L. Solute geochemistry and groundwater quality for drinking and irrigation purposes: a case study in Xinle City, North China. Geochemistry, **2020**.
31. RICHARDS L.A. Diagnosis and Improvement of Saline and Alkali Soils. Aibs Bulletin, **120** (3), 290, **1954**.
32. WILCOX L.V. The quality of water for irrigation use. Technical Bulletins, **113** (4), 277, **1948**.
33. LI J.Y., PENG Y.H., LIU Z.Y., WEI Q. Evaluation and Analysis of Surface Water Irrigation Quality in Heilongjiang Province. Journal of Irrigation and Drainage, **38** (12), 115, **2019**.
34. HE J., FAN J.J., LIU Y.Q., FU L., LI W.P. Hydrochemical characteristics and irrigation water quality evaluation of brackish water in cangzhou area. Yellow River, **38** (05), 134, **2016**.