Investigation and Evaluation of Water Resources in Maoping-Chajiao-steam Watershed, Maoping Town, Zigui County, Yichang City, Hubei Province, China

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Abstract. This study area is located in the Chajiao steam watershed, Maoping Town, Yichang City, Hubei Province, China. Considering the complex terrain and multiple seasonal rivers, it is necessary to carry out detailed water resources investigation and assessment. This provides a basis for developing subsequent projects in this area. To address these issues, we conducted a 10-day field reality survey from 7.16 to 7.26, 2022, which mainly covered groundwater systems, water quantity and quality, and water resource assessment. Among them, the investigation of the groundwater system, through the analysis of regional field outcropping springs, selected typical samples to assess the local water quality and manual visits to each water quality survey point after sufficient field investigation. The water quality analyzer measured PH, conductivity, temperature, and other field indicators in the evaluation process. The rest of the data was sampled and brought back for laboratory analysis. Anions (F^-, Cl^-, SO_4^{2-}, HCO_3^-, NO_3^-) and total nitrogen and phosphorus (N, P) were determined one by one using titration, cations (Na^+, Mg^{2+}, Ca^{2+}) were analyzed using ion chromatography, in the measured 21 water samples were selected among which PH, conductivity, F^-, Cl^-, SO_4^{2-}, NO_3^-, HCO_3^-, Na^+, Mg^{2+}, Ca^{2+} indicators were quantified and analyzed. It was found that the overall local water samples were also gradually increasing in TDS from upstream to downstream, and the water chemistry types were becoming more complex. Through the water budget calculation, we concluded that the local surface water resources have $1.950\times10^7 m^3$, the local groundwater resources have $8.04\times10^6 m^3$, and the local groundwater development and utilization have $8.04\times10^6 m^3$. This project provides a detailed discussion of water resources in Maoping Town, Yichang City, Hubei Province. It provides a better basis for water quality evaluation in the granite stream confluence area.

Keywords: Chajiao Steam Watershed; Water Resources Survey; Titration Method; Water Budget.

1. Introduction

Before 1856, the study of groundwater resources evaluation was limited to a low level of productivity, coupled with the relatively high complexity of groundwater research. Humans always stay on the qualitative research of groundwater. The discovery of Darcy's law in 1856 marked that the study of groundwater entered the stage of quantitative study. Subsequently, the formulas of unidirectional groundwater flow and good stable flow in the plane radial direction (Dupuit formula), unstable good flow formula of groundwater movement in confined water (Theis formula), and unstable good flow formula under the condition of overflow recharge exist. The Bolton formula considering the hysteretic drainage effect of the phreatic aquifer, the Newman formula considering the three-dimensional phreatic flow and the elastic release of the phreatic aquifer, and the unsteady flow formula of the incomplete well make the theoretical study of groundwater movement form a relatively complete system. In the 1950s, the idea of solving numerical solutions by numerical models appeared, but its development was limited due to the vast amount of computation. The rapid development of electronic technology in the 1960s enable computers to be gradually used for large-scale data calculation. During 1970-1980, the advantages of numerical simulation methods were discovered by more and more practitioners, and more and more groundwater resource assessment projects were completed by numerical simulation.

China's research in most areas of natural science is later than that of Western countries. The study of water resources in China only gradually start in the middle of the last century. Between 1950 and

1960, China almost entirely counted the river runoff of the larger rivers throughout the country; between 1960 and 1970, China unified and compiled the basic information of the hydrological stations that existed at that time; after the 1980s, a nationwide water resources assessment is carried out, giving the whole country a basic concept and outline of the current situation of water resources. During this period of development of the theoretical basis of water resources assessment, many advanced people in the industry put forward many insightful theoretical and practical methods, which lay the foundation for later in-depth studies. In 2001, the National Integrated Water Resources Plan (NIRWP) gave people a deeper understanding of how to conduct water resources evaluation. Various researchers and scholars conducted water resources evaluations one after another. In the contemporary process of sustainable development, human beings are demanding more and more details in water resources evaluation. Water resources evaluation has gradually evolved from the simple static form of crude and simple measurement followed by a correction to the multi-dimensional dynamic form of *measurement separation coupling modeling evaluation.*

This paper, the investigation and evaluation of water resources, its investigation is mainly for the water quality, water quantity, and groundwater system of Chajiao steam. The water quality is investigated by regional sampling. Twenty-one typical water sample points are selected to determine their anion, PH, conductivity, and other data, where PH, conductivity, F^-, Cl^-, SO_4^{2-}, NO_3^-, HCO_3^-, Na^+, Mg^{2+}, Ca^{2+} indicators are quantified and analyzed. To analyze their river pollution, some samples are selected to determine total nitrogen and phosphorus. The water resources survey estimates the groundwater flow system using the simplified water balance method. The groundwater flow system is centrally analyzed using topographic features, lithology, and outcropping spring points. To ensure the accuracy of the data, all sampling samples are titrated on the same day.

2. Survey of Water Resources in Maoping River-Chajiao Steam Watershed

2.1 Overview of Survey Sites

The geographic coordinates of the Chajiao steam sub-basin in the survey area are: N30.82°~30.78°, E110.92°~110.96°, the catchment area of the sub-basin is about 30.6km^2, and the area of the thematic survey area is about 12km^2. The average rainfall of the Chajiao steam sub-basin ranges from 1200~1400mm, the daily rainfall is 40~50mm, and the number of precipitation days is about 120 days. The inter-annual rainfall varies widely, and the annual rainfall is unimodal, mainly from May to August.

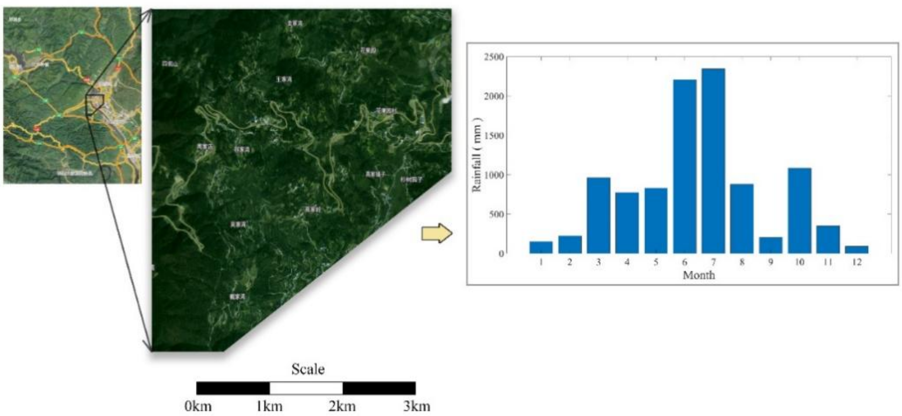

Figure 1. The situation display map of the survey site

2.2 Investigation of Local Groundwater Conditions

There are several springs outcropping in the southern tributaries' upper reaches, and the springs' outcropping elevation can be seen as the water level of groundwater. The water level of the southern streams is in the range of 100-300m, and the outcrop elevation of the springs is above 360m. Springs are the natural concentrated surface exposure of groundwater, which is the phenomenon of groundwater gushing out from underground aquifers or water-bearing channels in the form of point exposure and is a concentrated form of groundwater discharge. The groundwater level upstream is generally higher than the surface water. The TDS of the southern water samples from the upstream to the downstream is also gradually increasing, and the water chemistry type is becoming more and more complex. Therefore, it can be inferred that the groundwater within the watershed of the southern tributary flows to the river and recharges it.

3. Water Resources Assessment of Maoping River-Chajiao Steam Watershed

3.1 Field Experiments

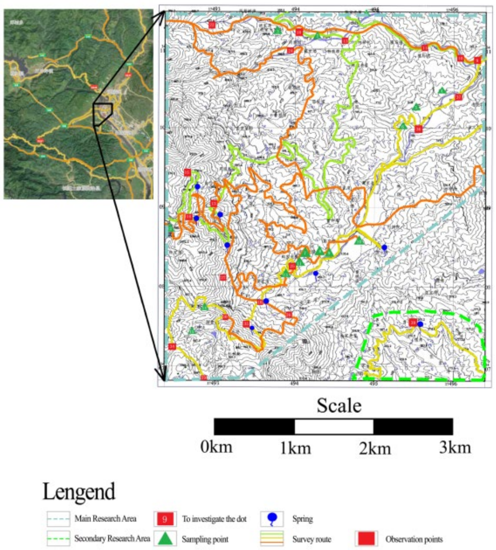

Figure 2. Field survey route display map
(the right line in the figure represents the survey route)

The actual work division of this field experiment is shown in Table 1.

Table 1. Division of Investigation Work

Project	Number of samples	Date (2022)	Number of employees
Water sample	21	7.22—7.23	5
Anion test	21	7.22—7.23	3
Field index inspection	21	7.22—7.23	2
Cation test	21	7.22—7.23	1
Total nitrogen and total phosphorus test	4 pictures	7.23	3
Flow estimation	1 pictures	7.21	3
Lithological sampling	7	7.21-7.22	6

After visiting residents in the internship area, we learned that it is rich in water resources and has high rainfall, but its water quality and quantity vary in different areas. In the relatively high altitude area, the springs are well developed, and the pollution index in the groundwater is low. During the actual survey, we found no drinking water well in the area. The residents use nearby sources or draw water from the Luojia water plant in Yichang City, Hubei Province, China. In addition, residents in the survey area generally build large cisterns on the hills for living and farming. The springs in the practice area are exposed in the southern tributary of Chajiao steam, and no springs were found in the northern tributary during the survey visit.

3.2 Water Quality Assessment in the Study Area

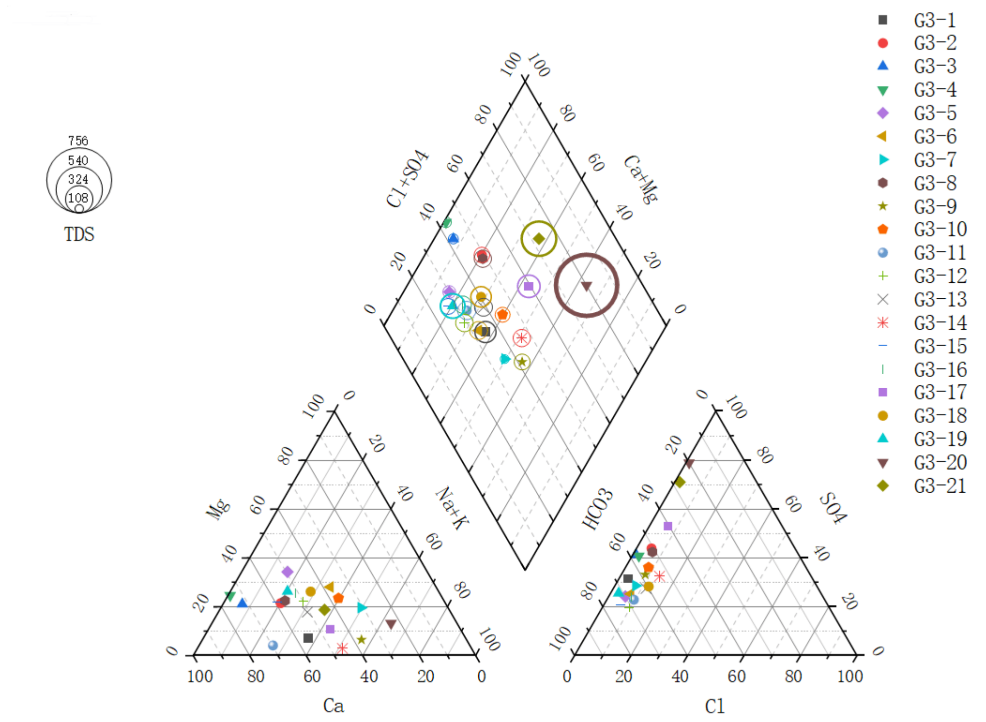

Figure 3. Sampling point water chemistry trilinear diagram

Table 2. Water chemistry data sheet of sampling sites

Water samples	pH	Electrical conductivity	F	Cl	NO_3	SO_4	Ca	Mg	HCO_3	Na+K	TDS	Water chemistry classification
G3-1	7.53	151.4	0.401	3.561	18.09	46.27	37.6	2.88	122.04	28.93	259.77	$HCO_3 \cdot SO_4$-Ca type
G3-2	7.64	154.0	0.235	4.081	26.44	45.63	30.4	6.72	67.12	12.09	192.78	$HCO_3 \cdot SO_4$-Ca type
G3-3	7.65	152.0	0.043	0.872	0.97	1.56	32.8	5.76	79.33	3.57	124.90	HCO_3-Ca type
G3-4	7.55	148.2	0.176	1.820	4.72	10.12	32.8	7.68	73.22	0.41	130.94	HCO_3-Ca·Mg type
G3-5	7.48	104.4	0.364	3.898	13.79	21.58	20.8	8.64	79.33	7.85	156.24	HCO_3-Ca·Mg type
G3-6	7.82	124.6	0.541	7.301	8.84	34.16	22.4	10.08	115.94	23.68	222.98	HCO_3-Ca·Mg type
G3-7	7.91	40.0	0.270	3.264	10.22	17.18	8.8	3.36	48.82	16.31	108.22	$HCO_3 \cdot SO_4$-Ca·Mg type
G3-8	7.38	146.9	0.211	5.772	18.39	51.64	32.0	7.68	79.33	13.95	208.98	$HCO_3 \cdot SO_4$-Ca·Mg type
G3-9	6.95	88.9	0.238	4.635	57.06	24.51	18.4	1.92	54.92	32.07	193.75	$NO_3 \cdot HCO_3$-Ca·Na type
G3-10	7.09	103.8	0.253	4.187	58.24	24.84	17.6	6.72	48.82	21.81	182.47	$NO_3 \cdot HCO_3$-Ca·Mg type
G3-11	7.42	158.7	0.157	8.062	33.70	26.05	40.8	1.44	97.63	17.60	225.58	HCO_3-Ca type
G3-12	7.62	145.1	0.745	8.160	27.59	22.46	28.8	7.68	103.73	18.51	217.78	HCO_3-Ca·Mg type
G3-13	7.61	143.2	0.810	7.455	65.69	23.86	29.6	6.24	67.12	21.14	222.36	$HCO_3 \cdot NO_3$-Ca·Mg type
G3-14	7.71	113.5	0.714	8.230	61.73	26.12	24.8	0.96	54.92	32.02	209.60	$NO_3 \cdot HCO_3$-Ca·Na type
G3-15	7.73	137.2	0.227	4.599	22.54	21.73	30.4	6.72	97.63	11.03	194.95	HCO_3-Ca type
G3-16	7.82	137.6	0.234	6.897	28.02	27.25	28.8	8.64	97.63	15.34	212.81	$SO_4 \cdot HCO_3$-Ca·Mg type
G3-17	7.76	174.0	0.175	7.521	32.34	81.23	34.4	4.80	79.33	37.15	276.93	$SO_4 \cdot HCO_3$-Ca type
G3-18	7.52	173.5	0.257	10.101	57.25	31.87	30.4	10.56	85.43	21.96	251.52	$HCO_3 \cdot NO_3$-Ca·Na type
G3-19	7.73	210.0	0.247	3.844	11.05	46.24	42.4	12.48	164.75	18.49	299.50	HCO_3-Ca·Mg type
G3-20	7.80	421.0	0.476	4.040	4.16	398.96	49.6	16.80	128.14	154.98	757.16	HCO_3-Na·Ca type
G3-21	8.27	263.9	0.286	3.614	5.60	200.13	52.8	13.44	97.63	50.99	424.49	$SO_4 \cdot HCO_3$-Ca·Mg type

The 21 water samples from this study area contained the major ions HCO_3^-, SO_4^{2-} , NO_3^- , Ca^{2+} , Mg^{2+} , Na^++K^+ (which were calculated jointly because they could not be measured), and the water samples taken contained a minimal amount of CO_3^{2-} , which was negligible.

The primary ions of water samples from Qinglinkou Reservoir, Yichang City, Hubei Province, China are Na^++K^+ ,Ca^{2+} ,Mg^{2+} ,SO_4^{2-}, and the primary sources of water samples are atmospheric precipitation and groundwater from the surrounding high mountains. The principal ions of the water samples are Ca^{2+},Mg^{2+},HCO_3^-,SO_4^{2-}, both of which are similar in composition, and the groundwater types are typical bedrock fracture water. A large number of quartz-gold veins originally existed in the study area. The strata contained a large number of quartz, feldspar, mica, and other silica-aluminate minerals, which were formed at high temperature and pressure deep underground, so they were thermodynamically unstable in the surface and soil zone, and even in the aquifers, hundreds and thousands of meters deep underground, and they produced hydrolysis when in contact with water. Due to the difference in solubility of each mineral, non-allosteric dissolution occurs, as a result of which: Na^+,K^+,Ca^{2+},Mg^{2+},HCO_3^- enter the water. The anions in the water are dominated by HCO_3^-, and the cations tend to be dominated by Na^+, followed by Ca^{2+}. The dominant anions are converted to SO_4^{2-} and Cl prolonging the water flow path.

The main ions in the water samples of the tailing reservoir are Ca^{2+}, Mg^{2+}, HCO_3^-, which are not very different from the water chemistry of the bedrock fracture water. After laboratory analysis: N:13.3mg/L, P:14.2mg/L.The nitrogen and phosphorus contents are all much higher than the data of the water samples taken in the Yueliangbao area, Yichang City, Hubei Province, China, which is presumed to be a slight leakage of the impermeable system of the tailing pond, or the slag from the mining output of the mine has affected the groundwater and soil during the treatment process, making changes in the groundwater quality.

The primary ions of Yanjiawan Reservoir, Yichang City, Hubei Province, China water samples are Ca^{2+} , Mg^{2+}, and HCO_3^-, and the main anions are different compared with the indicators of Qinglinkou Reservoir water samples, which are presumed to be related to the rock composition and runoff path of the surrounding mountains.

The chemical composition of the water samples from Qinglinkou Reservoir, Yichang City, Hubei Province, China and Qingquanshishangliu, Yichang City, Hubei Province, China is similar, the difference is that the cation content of the water samples from Qinglinkou Reservoir is Na^++K^+,Ca^{2+} ,Mg^{2+} from high to low, and the cation content of the water samples from Qingquanshishangliu is Ca^{2+} ,Mg^2,Na^++K^+ from high to low, and the anion content of the two is the same, it is presumed that the water in Qinglinkou Reservoir infiltrates from the bedrock fissure to Qingquanshishangliu. When the cation exchange and adsorption occurred between the cation and the surrounding rock and soil, the Na^++K^+ in the water sample exchanged with Ca^{2+} in the bedrock, which increased the Ca^{2+} content and decreased the Na^++K^+ content in the water sample from the upper stream of Qingquanshishangliu.

Table 3. Summary of special water samples

Sample number	Sampling location	Total phosphorus content(mg/L)	Total nitrogen content(mg/L)
G3-18	Yueliangbao Tailings Storage	14.2	13.3
G3-13	Upstream of Mingfeng Tea Factory	4.8	9.5
G3-12	Downstream of Mingfeng Tea Factory	5.9	9.2
G3-20	Qinglinkou Reservoir	2.5	6.1
G3-21	Qingquanshishangliu	1.7	5.1
G3-17	Upstream of Ni Lake Farm	1.8	4.2
G3-9	Downstream of Ni Lake Farm	2.3	4.8

3-9, G3-10, G3-14 group of nitrate content is unusually high, presumably: these three water sample sites are closer to the local residential areas, and there is anthropogenic activity pollution.

For the primary surface sources of pollution in the Chajiao steam watershed, we investigated three industrial pollution sites, namely, a farm, a tea factory and a tailings pond, and an agricultural pollution control site at the Yueliangbaoni Lake Farm in Yichang, Hubei Province, China, with data organized as follows.

According to the surface water environmental quality standard (GB3838-2002), it can be found that the watershed of Chajiao steam is Ш class water. The phosphorus and total nitrogen content in the water samples taken from the farm, tea factory, and tailing pond are all higher than the national standard. The source of pollutants may be the organic matter in animal manure and the residue of chemical fertilizers used in cultivation.

As seen in Table 3, the total nitrogen content of the rivers in the watershed decreases after passing through the pollution source, while the total phosphorus content increases slightly. The data from Ni Lake Farm shows that the total nitrogen and phosphorus are significantly higher downstream than upstream. Combined with the analysis of field observation records, the organic matter content in the water flowing through this area increases. The water quality decreases due to sewage discharge from fish farms, livestock breeding sites, and domestic human water. This further affects the springs transported downstream after converging into Chajiao steam and significantly impacts the local water environment.

3.3 Water Assessment in the Study Area

Chajiao steam is the first-class tributary of the Maoping River in Yichang City. The watershed of Chajiao steam is well-developed and rich in water resources, with many small tributaries intersecting it. The source of river recharge is mainly atmospheric precipitation, which is recharged into the tributaries utilizing spring outflow, surface runoff, and recharge area. The two first-order tributaries of Chajiao steam are distributed in the upper reaches of the northern stream. At the same time, the southern part is mountainous, with steep terrain and dense vegetation, making it challenging to form large-scale surface runoff recharge. The tributaries are relatively few and primarily distributed in the upper reaches of the southern stream. There are no lakes in the region, only small reservoirs, and there is Qinglinkou Reservoir in the west and Yanjiawan Reservoir in the southwest, totaling two reservoirs.

The precipitation recharge for the year based on the average annual rainfall and average annual evapotranspiration is:

$$W_{total} = (1518-1428) \times 30.6 \times 10^6 = 2.754 \times 10^7 m^3$$

According to the survey, the multi-year average runoff volume of Chajiao steam, W runoff = $1.950 \times 10^7 m^3$, is calculated according to the water balance equation: W total = W runoff + W groundwater.

$$W\ groundwater = W\ total - W\ runoff = 8.04 \times 10^6\ m^3$$

According to the data survey, the subsurface runoff modulus α is $7.46\ l/s \times km^2$ for the granite and amphibolite bodies distributed in Huangling backslope. According to the calculation of runoff modulus, the groundwater runoff in Chajiao steam basin is: W groundwater runoff=$F \times \alpha = 30.6 \times 7.46 \times 3600 \times 24 \times 365/1000 = 7.2 \times 10^6 m^3$. The difference between the amount of rainfall recharge to groundwater and the annual groundwater runoff, W, is the amount of local exploitation of groundwater each year.

Through the calculation of water balance method, we get that the local surface water resource has $1.950 \times 10^7 m^3$, the local groundwater resource has $8.04 \times 10^6\ m^3$, and the local groundwater development and utilization has $8.04 \times 10^6\ m^3$.

4. Conclusion

We conducted a 10-day field survey of the Chajiao steam watershed in Maoping Town, Yichang City, Hubei Province, which mainly included groundwater quality analysis and assessment and water resources estimation. The main points that can be drawn from the work of this paper are as follows.

(1) The distribution of water resources under the Chajiao steam watershed in Maoping Town, Yichang City, Hubei Province, shows the spatial characteristics of uneven distribution, with precipitation mainly concentrated in May-August and a single-peak type in time.

(2) Groundwater levels in the local southern tributaries are higher than surface water, from which it follows that groundwater flows to and recharges the river within the local watershed.

(3) The TDS of water samples in the southern part of the region gradually increases from upstream to downstream, the water chemistry type gradually becomes more complex, and the mineral components in the upstream move to the downstream basin through transport.

Acknowledgments

We have a certain method reserve when conducting this analysis. The team has applied for a patent for the pretreatment method of multi-stage evaporation and concentration of groundwater tritium sample based on Rayleigh fractionation, which will play a guiding role in this experiment.

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