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Environmental Research of Groundwater Chemical Composition and Pollution Characteristics in Tongchuan City, China

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Abstract

The investigation and assessment of groundwater chemistry and quality is a hot topic worldwide, triggering international attention from both researchers and policy makers due to its relevant link with environmental objectives and regional development. To master quality and pollution status of groundwater in Tongchuan City, China, 39 sets of groundwater samples were collected, and 17 inorganic conventional indicators, 9 inorganic toxicological indicators and 39 trace organic indicators were analyzed. Groundwater quality and pollution were assessed by "hierarchy step evaluation method". The results show that shallow water in Tongchuan City was in relatively poor quality in 2011. The samples that can be directly consumed or drunk after proper treatment account for 60% of the total, while 40% samples cannot be drunk. Shallow water quality is subjected to common influence of natural background and human activities, with total hardness, NO_3^-, SO_4^{2-} as the main influence indicators. Deep water is in relatively good quality, and water in all sampling points can be directly consumed or drunk after proper treatment. Deep water is mainly affected by natural background, with Fe as the main influence indicator. The results of pollution assessment show that the shallow water samples with pollution at levels 1, 2, 3, and 4 account for 44%, 16%, 32%, and 8% of the total, and the pollution is mainly distributed in Qishui River valley in the south of Jinsuoguan and north of Chuankou. The deep water pollution level is at level 1 without influence of human pollution.

Keywords: Tongchuan City, groundwater, hierarchy step evaluation method, pollution, environmental objectives

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INTRODUCTION

Groundwater constitutes an important part of China's water resources. According to statistics, about 20% of China's water supply derives from groundwater exploitation (Wen et al. 2012). With the development of the national economy and the increasing human demand for groundwater, human production and life influence the groundwater environment, resulting in a series of environmental issues (Wu et al. 2016). To master quality and pollution characteristics of regional groundwater, and then accordingly proceed with water conservation and rational development and utilization has become an important prerequisite for regional sustainable development, which means important practical significance for inland arid regions of western China lacking water resources.

The selection of evaluation method affects the evaluation conclusion to some extent. In recent years, scholars at home and abroad have proposed a variety of water quality assessment methods, such as single factor pollution index method (Zhang et al. 2012), comprehensive pollution index method (Chen et al. 2009, Yang et al. 2012), neural network method (Yang et al. 2017, Zhang and Gao 2016), fuzzy comprehensive evaluation method (Zeng et al. 2016), matter-element extension method (Zeng et al. 2016), principal component analysis method (Fang et al. 2009) and projection pursuit method (Shao et al. 2010), etc., which study the expression of water quality in different ideas. For pollution assessment, in addition to mastering water quality status, a more important issue is to judge whether the water quality deterioration is caused by natural background or human activities. The "Groundwater Quality and Pollution Hierarchy Step Evaluation Method" (Lin et al. 2017) recommended in "China Regional Groundwater Pollution Survey and Evaluation Specification (DZT0288-2015)" can

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distinguish the impact of natural background and human activities on groundwater. It respectively expresses groundwater quality and pollution level as an effective means to scientifically grasp groundwater environment status.

Tongchuan City with developed coal and building materials industries is an important energy and raw material industrial base in northwestern China. However, its water resources are scarce, and the city's per capita water resources are only 276 m^3. Groundwater, an important part of water resources in the region, is an important water source for domestic, industrial and agricultural water use. In recent years, with the rapid development of urbanization and industry in Tongchuan City, the discharge of domestic and industrial waste has caused a certain degree of pollution to the water environment, making the shortage of water resources more prominent and affecting sustainable development of the region. Through systematic sampling and testing of groundwater in Tongchuan City, this study grasps the chemical composition and content characteristics of groundwater, and evaluates groundwater quality and pollution level with "hierarchical step evaluation method" in an effort to provide scientific basis for prevention and control of groundwater pollution, protection of groundwater resources and guarantee of drinking water safety in Tongchuan City.

MATERIALS AND METHODS

Overview of the Study Area

Tongchuan City is located in the transition zone from Guanzhong Plain in Shaanxi Province to Loess Plateau in northern Shaanxi (E108°34'-109°29', N34°50'- 35°34'), with an area of 3882 km. Tongchuan City has a warm temperate continental climate with dry and cold winters, rare rain and snow. In summer, affected by warm and humid air masses from the Pacific Ocean, it is hot and humid with too much rain. It is dry in spring but with much waterlogging in autumn. The terrain of Tongchuan City is high in the northwest and low in the southeast, with a wide geographical difference which results in obvious climate differences in the city. Its average annual precipitation is 555.8~709.3mm, with average annual temperature at 8.9 ~ 12.3 ° C (Zhang et al. 2015). The surface water belongs to two major tributaries of Shichuan River and Luohe River. Where, the Qishui River and Juhe River, the tributaries of the Shichuan River, are the two main rivers in Tongchuan City which run through the whole investigation area from north to south.

Tongchuan City is located in the transition zone between Loess Plateau and Guanzhong Basin. There are six landform types: middle mountains, low mountains, hills, terraces, plains, and valleys. In general survey of the whole area, there are five landform areas: the western Ziwuling Mountain area, the northern loess ridge and hilly area, the central residual loess platform area, the southeastern Weibei-Beishan Mountain area and the southern plain area.

The stratum exposed in Tongchuan City is dominated by the Quaternary system. The whole area is extensively developed with Pleistocene loess, and the valley area is distributed with Quaternary alluvial layers. The stratum of the Pre-Quaternary is only exposed at bedrock mountains as well as the bottom and both sides of river valleys. From old to new, there are: Ordovician limestone, Carboniferous Upper mudstone and shale, Permian, Triassic sandstone and conglomerate, as well as Quaternary loose accumulation horizon. According to lithology and occurrence characteristics, groundwater can be divided into three types: clastic rock fissure water, carbonate rock fissure karst water and loose accumulation horizon pore water. Where, clastic rock fissure water and loose accumulation horizon pore water are the main types of groundwater for exploitation in the region, which are also the main objects of this study.

Sample Collection and Testing

In 2011, the Qishui River and Juhe River Basin with most concentrated human activities in Tongchuan City were selected for investigation involving New District, Yaozhou District, Wangyi District and Yintai District with a total area of 900 km^2. According to the investigation of hydrogeology, land use and pollution sources, sampling points are reasonably arranged to control regional water quality while taking into account the control of pollution sources such as refuse landfills, industrial areas, sewage rivers and large-scale farms. The sampling points consist of dispersed exploited well and centralized water supply well. Well was washed by pumping the day before sampling, and samples were taken the next day after the water level was restored.

A total of 39 groundwater samples were collected in this study, including 25 sets of shallow groundwater samples that consisted of alluvial water in the valley area, fissure water in the valley area, and fissure water in the northern mountainous area. With well depth within 30m, the water level was less than 20m, and the aerated zone was thin, mainly composed of silt and sand gravel. There were 14 sets of deep groundwater samples,

Table 1. List of groundwater test indexes in Tongchuan

Indicator Type	**Indicator Item**
inorganic conventional chemical indicators	TH($CaCO_3$), TDS, COD, Mg^{2+}, SO_4^{2-}, Fe, Ca^{2+}, Na^+, Mn, Zn, Al, Cl^-, NH_4^+, HCO_3^-, CO_3^{2-}, K^+, H_2SiO_3
inorganic toxicological indicators	NO_3^-, NO_2^-, F^-, Cr(VI), As, Pb, Cd, Se, I^-
trace organic indicators	vinyl chloride, 1,1-dichloroethylene, trans-1,2-dichloroethylene, cis-1,2-dichloroethylene, 1,1,1-trichloroethane, carbon tetrachloride, 1,2-dichloroethane, trichloroethylene, 1,1,2-trichloroethane, tetrachloroethylene, chloroform, bromodichloromethane, monochlorodibromomethane, bromoform, 1,2-dichloropropane, dichloromethane, chlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, benzene, toluene, ethylbenzene, m/p-xylene, o-xylene , styrene, benzopyrene, total hexachlorocyclohexane, alpha-BHC, beta-BHC, gamma-BHC, δ-BHC, total DDT, p,p'-DDE, p,p'-DDD, o , p'-DDT, p,p'-DDT, 1,2,4-trichlorobenzene, hexachlorobenzene

including alluvial-proluvial pore water in the southern Sichuan Plain, and fissure water under the loess area. With well depth above 100m, the water level exceeded 60m, with aerated zone mainly composed of thick loess and silt.

There were 65 indicators for sample testing, including 17 inorganic conventional indicators, 9 inorganic toxicological indicators, and 39 trace organic indicators. The specific indicators are shown in **Table 1**. Where, the inorganic heavy metal test sample was added with 0.1% by volume of 1:1 nitric acid as a protective agent, and the volatile organic test sample was added with 0.25% by volume of 1:1 hydrochloric acid as a protective agent. The organic test samples were placed in a freezer immediately after collection with temperature maintained at about 4 ° C and sent to the laboratory for testing within 7 days. The sample test was commissioned to Groundwater Mineral Water and Environmental Testing Center of the Ministry of Land and Resources.

Groundwater Quality and Pollution Assessment

In terms of the so-called "hierarchy step evaluation method", "hierarchy" is hierarchical classification of evaluation indicators, "step" refers to stepwise evaluation of on-site indicators, inorganic conventional chemical indicators, inorganic toxicological indicators and trace organic indicators so that groundwater quality evaluation is combined with groundwater pollution assessment. Referring to "China Groundwater Quality Standard (GBT14848-2017)", preliminary evaluation of groundwater quality was firstly carried out based on on-site test indicators and inorganic conventional chemical indicators. Then, groundwater pollution was evaluated based on inorganic toxicological indicators and trace organic indicators. Next, whether the groundwater quality type should be upgraded was judged based on inorganic toxicological indicators and trace organic indicators. If the pollution level is above or equal to the water quality level, the water quality level should be upgraded by one level; conversely, when the pollution level is below or equal to the water quality level, no upgrade is required. In this way, the final evaluation result is obtained.

The specific water quality classification is as follows: Class I, The groundwater has a low chemical component content and is suitable for various uses; Class II, The groundwater has a low chemical component content and is suitable for various uses; Class III, The groundwater has medium chemical component content and is mainly suitable for centralized drinking water sources and industrial and agricultural water use based on the sanitary standard of domestic drinking water; Class IV, The groundwater has high chemical component content and is suitable for agricultural and some industrial water use, which can be used as drinking water after proper treatment based on quality requirements for agricultural and industrial water use and a certain level of human health risks; Class V, The groundwater has high chemical component content and is unsuitable for domestic drinking water. Other waters can be selected according to the purpose of use.

The pollution level is divided as follows: Level 1, with natural background content reflecting groundwater chemical components or there is no obvious identifiable pollution source and water quality changes are unobvious. That is, with inorganic toxicological indicators and trace organic indicators not exceeding water quality standard class III, it is classified as unpolluted water; Level 2, Single inorganic toxicological indicator or organic indicator exceeds water quality standard class III, or two or more indicators exceed water quality standard class III but with over-standard intensity within 50%. With pollution source, it is classified as mildly polluted water, and needs to be treated for water supply; Level 3, When single inorganic toxicological indicator or trace organic indicator exceeds water quality standard class IV, or two or more indicators exceed water quality standard class III with over-standard intensity greater than 50%, it is classified as moderately polluted water and should not be used for water supply directly; Level 4, When two or

Table 2. Over-standard status of groundwater inorganic indicators

Test indicator①	standard② (mg/L)	shallow water				deep water			
		Range (mg/L)	average value (mg/L)	over-standard number (n)	over-standard rate (%)③	Range (mg/L)	average value (mg/L)	over-standard number (n)	over-standard rate (%)
TH	450	236.5-1450	651.16	17	68	96.16-387.1	230.03	0	0
TDS	1000	377.2-2343	1010.56	11	44	305.8-695.7	484.16	0	0
Mg^{2+}	50	16.2-126.5	51.85	11	44	15.64-41.56	27.18	0	0
SO_4^{2-}	250	56.51-897	307.68	10	40	13.18-185.5	68.85	0	0
Fe	0.3	0.012-1.017	0.19	5	20	0.019-0.897	0.28	5	35.71
COD	3	0.62-4	1.49	3	12	0.5-1.36	0.71	0	0
Ca^{2+}	400	55.03-457.2	175.24	1	4	12.71-90.26	47.31	0	0
Na^+	200	19.02-155.8	72.12	0	0	34.39-205.7	91.97	1	7.14
Cl^-	250	12.95-208.3	70.70	0	0	5.25-64.77	21.56	0	0
Zn	1	0.01-0.143	0.04	0	0	0.01-0.089	0.03	0	0
Mn	0.1	<0.001-0.05	--④	0	0	<0.001-0.036	--	0	0
NH_4^+	0.643	<0.04-0.12	--	0	0	<0.04	--	0	0
K^+	/⑤	0.31-31.6	4.24	0	0	0.76-2.63	1.37	0	0
HCO_3^-	/	213-488.1	346.96	0	0	279.2-621.7	364.10	0	0
CO_3^{2-}	/	0-5.66	0.23	0	0	0-33.97	5.05	0	0
H_2SiO_3	/	14.98-26.26	21.00	0	0	17.26-22.72	20.35	0	0
NO_3^-	88.57	11.9-482.50	138.05	14	56	6.98-59.50	22.62	0	0
NO_2^-	0.66	<0.002-4.20	--	3	12	<0.002-0.004	--	0	0
F^-	1.00	0.1-1.30	0.40	1	4	0.18-0.96	0.53	0	0
Cr(VI)	0.05	<0.004-0.015	--	0	0	<0.004-0.04	--	0	0
As	0.01	<0.001-0.002	--	0	0	<0.001-0.005	--	0	0

Note: ① The table only lists detected items; ② according to Chinese groundwater quality standard (GB/T 14848-2007); ③ shallow water statistics is based on 25 sets of samples, deep water statistics is based on 14 sets of samples; ④ beyond calculation; ⑤ no standard

Table 3. Detection of trace organic indicators in groundwater

Test indicator①	standard② (μg/L)	shallow water									deep water
		S05③	S06	S09	S10	S14	S18	S19	S23	S24	D02
β-BHC	/④	n.d.⑤	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.016	n.d.	n.d.
γ-BHC	2	n.d.	n.d.	n.d.	n.d.	n.d.	0.012	n.d.	n.d.	n.d.	n.d.
benzopyrene	0.01	n.d.	n.d.	n.d.	n.d.	0.008	n.d.	0.0022	n.d.	n.d.	n.d.
1,1-dichloroethylene	30	0.54	0.39	n.d.	0.63	n.d.	n.d.	n.d.	n.d.	0.55	n.d.
chloroform	60	n.d.	n.d.	1.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2-dichloroethane	30	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.02
1,2-dichloropropane	5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.06

Note: ① The table only lists detected items; ② according to Chinese groundwater quality standard (GB/T 14848-2007); ③ The table only lists detected items; ④ no standard; ⑤ not detected.

more inorganic toxicological indicators or trace organic indicators exceed water quality standard class IV with over-standard intensity within 200%, it is classified as heavily polluted water and is prohibited for direct water supply in principle; Level 5, Two or more inorganic toxicological indicators or trace organic indicators exceed water quality standard class IV, with over-standard intensity above 200%. With pollution source, it is classified as extremely heavy polluted water and is prohibited for direct water supply.

RESULTS AND DISCUSSION

Groundwater Hydrochemical Characteristics

The test results are shown in **Table 2** and **Table 3**. The shallow water and deep water in Tongchuan City have obviously different chemical compositions. For the shallow water in Tongchuan, anions are mainly HCO_3^-, SO_4^{2-}, the cations are mainly Ca^{2+}, the water chemistry types are mainly $HCO_3 \cdot SO_4$-Ca, followed by HCO_3-Ca, HCO_3-Ca·Mg, $HCO_3 \cdot SO_4$-Ca·Na. TDS is in the rang eof 377.2-2343 mg / L, with an average of 1010.56 mg / L. For the deep water, the anions are mainly HCO_3^-, the cations are mainly Na^+, the water chemical type is mainly HCO_3-Na. TDS is in the range of 305.8-695.7 mg/L, with an average of 484.16 mg/L, which is lower than that of shallow water.

In general, shallow water has higher inorganic and organic indicators than deep water, with more over-standard types than the deep water. In terms of inorganic conventional indicators, 7 indicators of total

Table 4. Evaluation results of Groundwater pollution

No.	type	initial water quality category	pollution level	final water quality category	No.	type	initial water quality category	pollution level	final water quality category
S01	SW①	V	3	V	S21	SW	IV	1	IV
S02	SW	III	1	III	S22	SW	V	1	V
S03	SW	V	1	V	S23	SW	IV	4	IV
S04	SW	V	3	V	S24	SW	IV	1	IV
S05	SW	IV	2	IV	S25	SW	IV	1	IV
S06	SW	IV	3	IV	D01	DW②	III	1	III
S07	SW	IV	2	IV	D02	DW	III	1	III
S08	SW	IV	3	IV	D03	DW	III	1	III
S09	SW	IV	2	IV	D04	DW	III	1	III
S10	SW	V	4	V	D05	DW	III	1	III
S11	SW	III	1	III	D06	DW	IV	1	IV
S12	SW	V	3	V	D07	DW	IV	1	IV
S13	SW	V	3	V	D08	DW	IV	1	IV
S14	SW	V	3	V	D09	DW	II	1	II
S15	SW	III	1	III	D10	DW	IV	1	IV
S16	SW	III	1	III	D11	DW	III	1	III
S17	SW	IV	2	IV	D12	DW	III	1	III
S18	SW	V	1	V	D13	DW	II	1	II
S19	SW	IV	3	IV	D14	DW	IV	1	IV
S20	SW	V	1	V					

Note: ① shallow gwater; ②deep water

hardness, TDS, Mg^{2+}, SO_4^{2-}, Fe, COD, Ca^{2+} in shallow water exceed the standard. Where, total hardness of 17 samples exceed the standard, with the highest over-standard rate of 68%; TDS, Mg and $SO_4^{2-}$of 11, 11 and 10 samples exceed the standard respectively, with over-standard rates at 44%, 44%, 40%; COD, Ca^{2+}, Na^+ of 5, 3, and 1 samples exceed the standard with relatively low over-standard rates of 20%, 12%, and 4% respectively. For deep water, only two indicators of Fe, Na^+ exceed the standard. Where, Fe of 5 samples exceeds the standard, with over-standard rate at 36%, Na^+ of 1 sample exceeds the standard, with over-standard rate at 7%.

Similarly, inorganic toxicological indicators of shallow water have significantly higher over-standard rate than those of deep water. In the shallow water, 3 indicators of NO_3^-, NO_2^-, F^- exceed the standard. Where, NO_3^- has the highest over-standard rate of 56%, with 14 samples exceeding the standard. NO_2^- and F^- have 3,1 samples exceeding the standard, with over-standard rate at 12% and 4%, respectively. The content of inorganic toxicological indicators in deep water is generally low, and none exceeds the standard.

Among the trace organic indicators of groundwater, 9 sets of samples in shallow water were detected with organic matter, and 5 indicators were detected, including β-BHC, γ-BHC, benzo(a)pyrene, 1,1-dichloroethylene, trichloromethane. The 1,1-dichloroethylene had high detection rate, which was detected in 4 sets of samples. Following benzo(a)pyrene was detected in 2 sets of samples. The remaining indicators were detected in 1 set of samples. In the deep water, only 1 set of samples were detected with organic matter, and the detection indicators were 1,2-dichloroethane and 1,2-dichloropropane. The organic indicators of all samples did not exceed the standard, and the detected value was much below the groundwater quality standard. That is, the groundwater had very low organic pollution level.

Groundwater Quality and Pollution Assessment

The quality and pollution assessment results are shown in **Table 4** and **Fig. 1**. Since the initial water quality categories are above or equal to the pollution level, the final water quality category is consistent with the initial water quality category.

The results of water quality evaluation show that there is no Class I and Class II water in shallow water, and there are 5, 10 and 10 sets of Class III, IV and V water samples in turn. Where, samples that can be directly consumed (Class III water) or drunk after proper treatment (Class IV water) account for 60% of the total shallow water samples, and 40% of samples are not suitable as drinking water sources (Class V water). In deep water, there are 2, 7 and 5 sets of Class II, III and IV water samples respectively. Samples that can be directly consumed account for 64% of the total deep water samples, and 36% of samples can be drunk after proper treatment. That is, all samples are drinkable.

The results of the pollution assessment show that there are 11, 4, 8, 2 sets of shallow water samples with

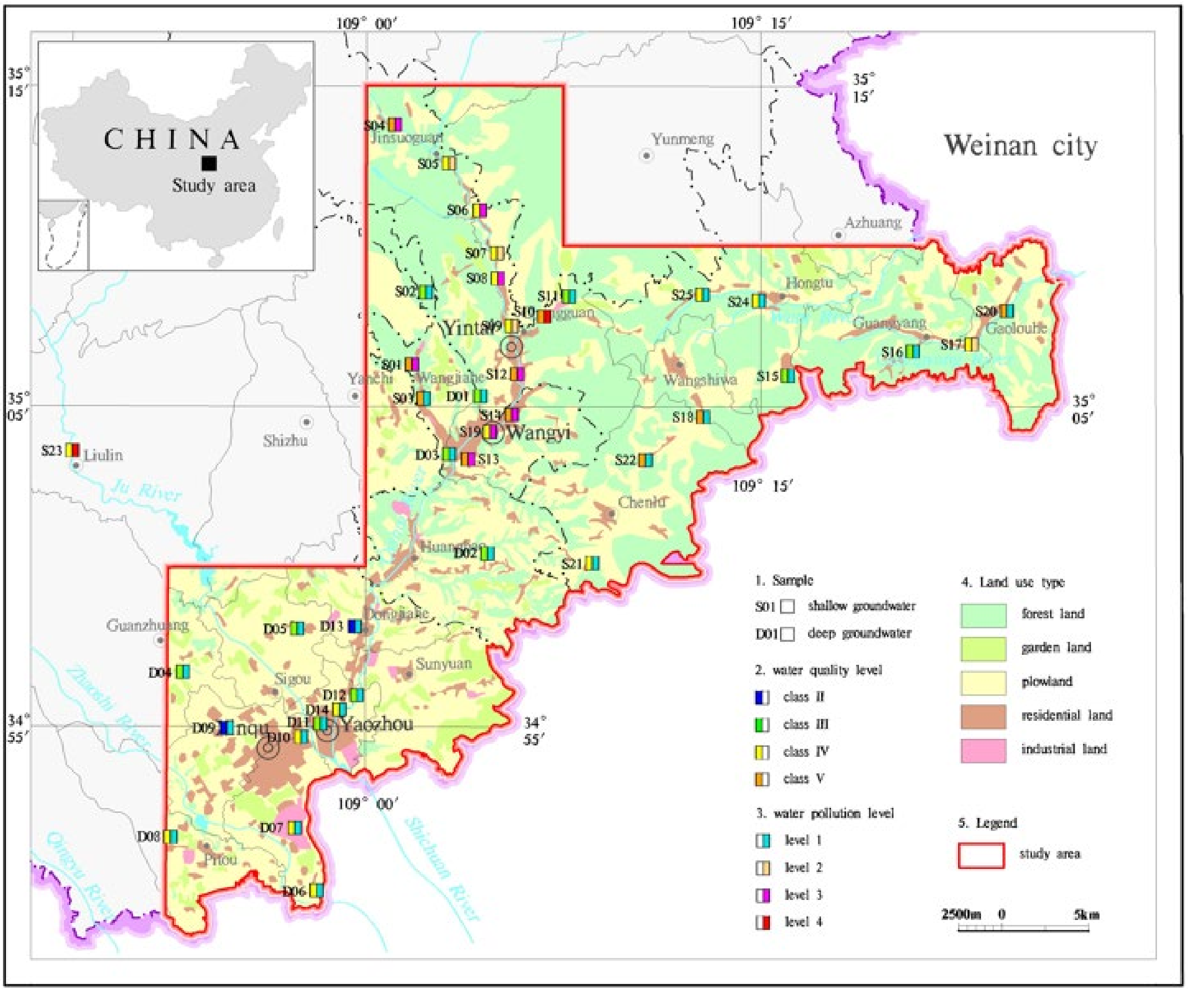

Fig. 1. Groundwater quality assessment and pollution assessment results

pollution at levels 1, 2, 3, and 4, respectively. That is, 44% of the samples are uncontaminated, and 66% of the samples are polluted. Where, samples with mild, moderate and heavy pollution account for16%, 32%, and 8%, respectively. Nevertheless, water pollution in deep water is all at level 1. That is, all samples are not affected by human pollution.

In summary, shallow water in Tongchuan City is in relatively poor quality, with total hardness, NO_3^-, SO_4^{2-} as the main influence indicators, and pollution is heavy. The deep water is in relatively good quality, with Fe as the main influence indicator, and it is basically not polluted by human activities.

Groundwater Quality and Pollution Distribution

The distribution of groundwater quality in Tongchuan City shows significant regional differences. In general, the water quality in the northern study area is poor, and that in the south is relatively good. Areas with poor water quality are concentrated in northern study area from Jinsuoguan to Chuankou, including valley area of Qishui River, upper reaches of Juhe River, Wujichuan River and the Guangyang River Basin. All water there is shallow water, with Class IV and V water in water quality. The Class III water has scattered distribution in the upper reaches. The high total hardness and high NO_3^- content are the main reasons for the poor water quality of the shallow water in these areas. The deep water in the southern study area is in relatively good quality. The groundwater in the loess area is mainly dominated by Class II, III water. The intersection area of Qishui River and Ju River in Yaoxian County may be affected by human activities, with Class IV water shown in terms of groundwater quality. The New District Industrial Park and Xinyao Waste Yard in the southern Yaoxian County have poor groundwater quality of Class IV water. The high Fe content is the main reason for the poor water quality in these areas.

The pollution distribution assessment indicates that the area from Jinsuoguan Town to Chuankou in the northern study area has the most serious pollution, with groundwater mostly in level 4 heavy pollution and level 5 extremely heavy pollution. NO_3^-,SO_4^{2-} , the main indicators causing the poor groundwater quality in this area, are also characteristic pollutant of human activities, demonstrating that the poor groundwater quality in this area is mainly owing to human pollution. However, although shallow water in other river basins has poor water quality, the pollution is relatively light. The deep water pollution level in the study area is in level 1. That is, there is no human pollution. The poor deep water quality is owing to the high content of Fe and Na. Mainly from original geological background, the deep water has little relationship with human pollution. Therefore, the deep water is unpolluted in the pollution assessment results.

Factors Causing Groundwater Pollution

According to the survey, groundwater pollution way in Tongchuan City is mainly the infiltration of contaminated surface water, so groundwater pollution shows a strip-like distribution along the river. Tongchuan City lacks water resources. Therefore, its urban residential areas, industrial and mining enterprises are built along the river, especially concentrated in both banks of Qishui River. Extensive industrial wastewater and domestic sewage on both banks are discharged to Qishui River, posing huge threat to groundwater environment on both banks of the river. The shallow water on both banks of river valley has a thin aerated zone, loose media, strong permeability and low antifouling performance, thus prone to pollution. After Qishui River passes Beiguan in Yintai District, the amount of sewage inflow gradually increases. Under its influence, pollutants such as NO_3^-, SO_4^{2-} are gradually enriched in the groundwater on both banks, leading to a gradual increase in total hardness and TDS as well as gradually aggravated water quality deterioration mainly caused by human pollution.

The deep water distributed in loess tableland has thicker aerated zones and strong resistance to pollution. Restricted by conditions such as sparse population, inconvenient transportation and shortage of water resources, the area has less distribution of enterprises and low pollutant amount. For the deep water in the southern Sichuan plain region, despite the relatively concentrated population and more distributed enterprises, groundwater is mainly confined, with not only thick aerated zone but also protection of upper confining bed on the top of the aquifer, so it is difficult for pollutants to enter the groundwater. Therefore, the deep water in the area is basically uncontaminated. The main reason for its poor water quality is that under the water-rock action, components like Fe, Na in the original geological background are gradually enriched in groundwater through ion exchange. After proper treatment, most deep water can be directly consumed after removing background indicators such as Fe.

CONCLUSION

The struggling economy resulted in few government investments, and therefore no funds arranged to support environmental studies. Shallow water in Tongchuan City is in relatively poor quality. The samples that can be directly consumed or drunk after proper treatment account for 60%, while 40% samples cannot be used as drinking water sources. It has 10 indicators exceeding the standard, including inorganic conventional indicators of total hardness, TDS, Mg^{2+}, SO_4^{2-}, Fe, COD, Ca^{2+} and inorganic toxicological indicators of NO_3^-, NO_2^-, F^-. Where, total hardness, NO_3^-, SO_4^{2-} are the main indicators influencing shallow water quality, indicating that shallow water quality is subjected to common influence of natural background and human activities. Deep water is in relatively good quality. The samples that can be directly consumed account for 64% of the total deep water samples, and 36% of the samples can be drunk after proper treatment. All the samples are drinkable. Only the 2 indicators of Fe, Na^+ exceed the standard. Where, Fe is the main indicator affecting deep water quality, indicating that the deep water quality is mainly affected by the original geological background.

The pollution assessment indicates that the groundwater pollution indicators in Tongchuan City are mainly nitrate and sulfate, with low organic matter content and very light pollution. Of the shallow water samples, 44% are uncontaminated and 66% are contaminated. The heavily polluted areas are mainly concentrated in Qishui River valley in northern study area from Jinsuoguan to Chuankou. The poor groundwater antifouling performance and large emissions of domestic and industrial pollutants are the main causes of serious shallow water pollution in the area. Deep water samples have not been contaminated by human, which is directly related to its good antifouling performance and relatively less pollution emissions in the environment.

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