Study on Site Selection of Water Supply Reservoir at High Geological Background Area along the Angqu River

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Abstract: There is abundant water resource in the Angqu river, but it is excessive of arsenic, iron, manganese and other substances, which seriously threatens the water supply safety in Changdu City. It is imperative to build a water reservoir that is safe and reliable as a water source, but it is not easy to identify its site. For this, field surveys, laboratory tests and mathematical simulation were used to analyze the impact of water quality of the Angqu River on the site selection of water supply reservoirs, stimulate and predict the changes on water quality of the proposed reservoir. The results showed that arsenic and iron contents were excessive in the Angqu River due to the geological background conditions. Arsenic content in the water of Angqu River increased with hot spring containing high concentration of arsenic flowing into. The adsorption experiment and water quality stimulation implied that the arsenic content in water of the proposed large reservoir at upper reach of Zongtongka Village could meet the Class III standard of surface water quality, and the iron concentration in the river reach in front of the dam could meet the limit of surface water quality standard. It is suggested to conduct long-term water quality safety monitoring and evaluation of the Angqu River, and divert and purify the branches excessive of As.

1 INTRODUCTION

Changdu City is located in the eastern part of the Tibet Autonomous Region, situated in the Hengduan Mountains and the Three-river (Jinsha River, Lancang River, and Nujiang River) basins. The freshwater resources of Changdu City are more than 77 billion m^3 (Dava, 2015). At present, there are three water plants under the jurisdiction of Changdu City. The water sources of the plants are distributed in Angqu River, Zhaqu River, and Lancang River near the urban areas and the raw water of each water plant is substandard. According to the analysis of historical data from the national basic quality monitoring stations and related literatures(Song et al., 2013; Zhang et al., 2014), the content of arsenic and iron (Fe) in the reach of Zhaqu River, Angqu River, and Lancang River near the urban areas seriously exceed the Class III standard of Environmental quality standards for surface water (GB3838-2002). Currently, there is no stable and adjustable urban water supply source in Changdu City, and the safety risk of water supply is high. The problem of unqualified water quality in urban areas of Changdu City severely constraints regional economic and social development.

In order to find suitable water supply reservoirs and provide guarantees for the safety of water supply in Changdu City, this paper will study the Angqu River (from the Angqu River estuary to 90 kilometers upstream) based on the local hydrogeological conditions. By investigation, experimental simulation, mathematical model prediction and other means (Chen, 2016; Huang et al., 2017; Cho et al., 2016), the current status of water quality in the study area (focus on As, Fe, Mn, and Cr) and its impact on site selection of water

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supply reservoir will be analyzed to provide technical supports for the site selection of proposed reservoir with regulation and storage capacity.

2 MATERIAL AND METHODS

2.1 Distribution of Sampling Sites

A total of 34 sampling sites were set in the main stream and branches of Angqu River respectively in normal season (October 2015), dry season (March 2016), flood season (June 2016), based on geo-environmental conditions (Zhang et al., 2014). Figure 1 shows the specific sampling sites locations. Among of them:

(1) Water sampling sites: 14 sites in the main stream of Angqu River (No.1, 2, 10, 14, 15, 19, 20, 21, 24, 26, 30, 31, 32, 33, 34). 17 sites in branches (No. 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 16, 18, 22, 23, 25, 27, 29). 2 sites in hot springs (No.17, 28).

(2) Solid sampling sites: 1 site of rock (No.21), 2 sites of soil (No.15, 21), 1 site of sediment (No.15).

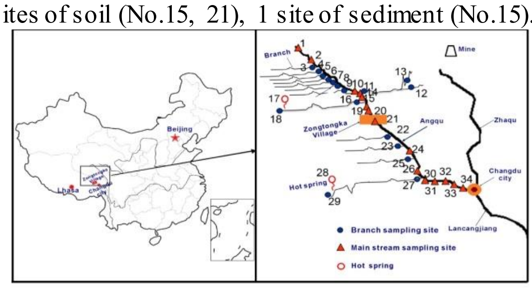


Figure 1: Map of sampling sites in the Angqu river and branches.

Note: 1-90km upstream of Angqu estuary, 2-80km upstream of the estuary, 3-branch(79km upstream of the estuary), 4-branch(77km upstream of the estuary), 5-branch(76km upstream of the estuary), 6-branch(74km upstream of the estuary), 7-branch(73km upstream of the estuary), 8-branch(72km upstream of the estuary), 9-branch(70km upstream of the estuary), 10-69km upstream of the estuary, 11-Mangda branch(67km upstream of the estuary), 12-left branch(5km upstream of Mangdaqu branch), 13-right branch ditch(5km upstream of Mangdaqu branch), 14-66km upstream of the estuary, 15- 65.5km upstream of the estuary, 16-Engdaqu branch(65km upstream of the estuary), 17-hot spring(Endaqu branch), 18-10 km upstream of the Endaqu branch(1km upstream of hot spring), 19-64.5km upstream of the estuary, 20-64km upstream of the estuary, 21-60km upstream of the estuary, 22-branch(55km upstream of the estuary), 23-branch(46km upstream of the estuary), 24-45km upstream of the estuary, 25-Langda branch(34km upstream of the estuary, 26-29km upstream of the estuary, 27-Xiebaqu(28km upstream of the estuary), 28-hot spring(Zhugu Temple), 29-Zhugu Temple karst water, 30-27km upstream of the estuary, 31-20km upstream of the estuary,32-10km upstream of the estuary,33-2km upstream of Angqu estuary,34-Angqu

2.2 Experimental Methods

Inductively coupled plasma-mass spectrometry (ICP-MS) was used to detect the content of As, Fe, Cr, Mn in samples by reference to Water quality – Determination of 65 elements- Inductively Coupled Plasma-Mass Spectrometry (HJ 700-2014) and Soil and sediment-Determination of mercury, arsenic, selenium, bismuth, antimony-Microwave dissolution/Atomic Fluorescence Spectrometry (HJ 680-2013). Referring to Solid waste-Extraction procedure for leaching toxicity-Horizontal vibration method (HJ 557-2010), leaching toxicity tests (Wang et al., 2018; Ning et al., 2012) were conducted with typical solid samples in the areas of Angqu River. Firstly, the solid samples were dried at 105℃, then the extractant (pure water) was added at a solid-liquid ratio of 10:1(L/kg) and was shaken at a frequency of 110±10 times/min at room temperature for 8 hours. The leachate was filtered with 0.45μm millipore filter after standing for 16 hours, and then tested by ICP-MS.

EFDC, a commercial software, was used to establish a 3D mathematical model of water sand-water quality, to simulate and predict changes in water quality parameters such as arsenic and iron in the reservoir area after the reservoir established in Zongtongka Village.

3 RESULTS AND DISCUSSION

3.1 Investigation Results of the Angqu River Water Quality

The water quality monitoring result of the Angqu River was shown in Table1. During normal season, the content of As, Fe, Mn and Cr all met the Class III of the National Standard (GB3838-2002) in all sampling sites at the main stream except that the content of Fe was excessive at 0km upstream of Angqu River estuary (located downstream of Zongtongka Village). During dry season, the content of Mn and Cr all met the standard limits of Class III except that most samplings were excessive of Fe and some were excessive of As. During flood season, the content of As, Mn and Cr all met the standard limits of Class III of the National Standard (GB3838-2002) except that the content of Fe was excessive in most samplings.

Table 1: Investigation results of the Angqu River water quality (μg/L).

	Normal season	Dry season	Flood season	Class III standard
As	0.4-13.39	17.8-62.0	0.4-17.3	50
Fe	0.0-493.3	5.0-501.7	40.0-487.7	300*
Mn	1.1-30.2	15.6-26.7	7.5-22.7	100*
Cr	0-7.9	1.9-19.2	0-0.3	50

3.2 Variation Features of As, Fe in Water along the Angqu River

3.2.1 Variation Features of As

Figure *2* shows the detection results of As in samples collected from the main stream and branches of Angqu River during three seasons. The content of As exceeded the Class III of standard for surface water in two branches upstream of Zongtongka Village respectively at 67km and 65km upstream of Angqu estuary. The content of As in 34km upstream of Angqu River estuary (Langda branch) exceeded the Class III of standard for surface water downstream of Zongtongka Village.

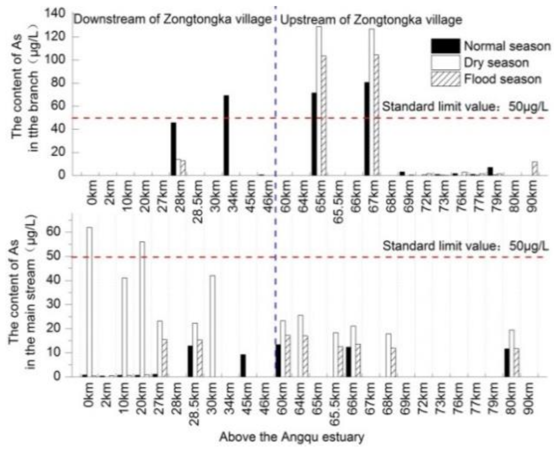


Figure 2: As content in the main stream and branches of Angqu River during different seasons (normal, dry, flood season).

It was known from the analysis of water quality features in different seasons: the content of As along Angqu River rose gradually, and obviously rose after the three branches flowed into during normal and flood season, which indicated the entrance of branches would influence the content of As in the Angqu River. Compared results in different seasons, the As content in the main stream of Angqu River was lower during flood and normal season than dry season, which may be due to the As was diluted caused by large flow.

3.2.2 Variation Features of Fe

The detection results of Fe at the main stream of Angqu and branches during different seasons were shown in Figure.3. As can be seen from the figure, most branches and one site in the main stream of Angqu River were excessive of Fe during normal season. Most main stream sites and only two branches were excessive of Fe during dry season. During flood season, Fe in most main stream sites and three branches exceeded the standard. In view of the distribution of Fe content along the river, when the branch water with a higher Fe content flowed into the main stream, the Fe concentration in the main stream water did not increase obviously.

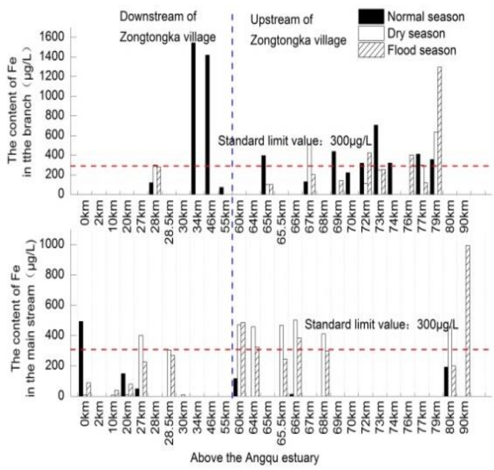


Figure 3: Fe content in the main stream and branches of Angqu River during different seasons (normal, dry, flood season).

This showed that Fe in the main stream did not mainly originate from the influx of branches, but might be caused by local geological conditions.

3.3 Influence of Local Geological Background on Site Selection of the Water Reservoir

Result in Table 2. implied that there is a problem of excessive As and Fe in No.17 and No.28 hot spring during dry and flood season, and there is much higher concentration in No.28. According to the field investigation, it was found that the No.17 hot spring (Endaqu, located upstream of Zongtongka Village) water was discharged directly to the branch (Endaqu branch) 65km upstream of Angqu River estuary, and the No.28 hot spring (Zhugu Temple Hot Spring) water was discharged directly to the branch (Xiebaqu) 28km upstream of the estuary. The As content in water of the main stream rose obviously by the influx of Endaqu branch and Xieba branch to the Angqu River (as shown in Figure 2.). It suggested that the influx of the branch with high As concentration affected by hot spring (As content was 50 times of the standard) led to the rise of As content. However the Fe content in the branch did not rise obviously (as shown in Figure 3.) with the influx of hot spring water, mainly due to the relatively low Fe content (4 times of the standard) and water quantity of the springs.

Typical rock samples (Zongtongka Village), soil samples (Mangda Bridge, Zongtongka Village) and sediment samples (Endaqu branch) along the Angqu River were selected to conduct leaching toxicity tests. Results (as shown in Table 3.) suggested that there was no problem of excessive heavy metals in the leachate of the rock, while Fe in the leachate of the soil and sediment were generally exceeded the standard limit, and the leaching concentrations of other metals (As, Mn, Cr) all met the Class III standard or standard limit. It was known that the leaching of Fe in the sediment of Angqu River and the surrounding mountain soil posed a potential threat to the water quality, and is an important reason for the excessive content of Fe in the Angqu River (Liu et al., 2009). It is related to the local geological background that As and Fe content exceeded the standard due to no other pollution sources from surroundings.

Table 2: Heavy metals content in hot spring water (μg/L).

Name of sampling site	As		Fe		Mn		Cr	
	Dry season	Flood season	Dry season	Flood season	Dry season	Flood season	Dry season	Flood season
No.17-hot spring	552.1	494.2	407.7	7.9	<0.12	<0.12	12.0	<0.11
No.28-hot spring	2499	2337	1215	379.9	15.75	55.88	<0.11	<0.11
Class III standard/limit	50		300		100		50	

Table 3: Heavy metals content in the leachate of rock, soil and sediment in normal season (μg/L).

Sample / Metal	Rock in Zongtongka	Soil in Mangda Bridge	Soil in Zongtongka	Sediment in Endaqu branch	Class III standard
As	27.62	3.81	2.19	35.73	50
Fe	276.4	1689.1	353.5	544.1	300*
Mn	4.30	28.29	8.04	13.03	100*
Cr	0.42	3.60	0.59	0.88	50

Table 4: Water quality monitoring data at the main stream of Angqu River in March,2016 (μg/L).

Name of sampling site	As	Fe	Mn	Cr	Location
80km upstream of Angqu estuary (End of Zongtongka reservoir)	19.4	455.0	26.7	16.1	Angqu main stream, upstream of Zongtongka
69km upstream of Angqu estuary	17.8	411.9	20.4	<4.0	
67km upstream of Angqu estuary	21.3	411.4	19.6	16.2	
65.5km upstream of Angqu estuary	18.3	467.3	19.5	17.7	
64.5km upstream of Angqu estuary	25.5	459.0	21.5	16.2	
60km upstream of Angqu estuary	23.3	471.1	19.3	15.3	
29km upstream of Angqu estuary	22.3	306.5	15.6	16.0	Angqu main stream, downstream of Zongtongka
27km upstream of Angqu estuary	23.2	400.7	18.2	19.0	

3.4 Preliminary Analysis of Site Selection of the Water Supply Reservoir in Angqu River

Based on the investigation results above, it could be seen that the state of water quality upstream of Zongtongka Village was good overall, which satisfied the Class III of water quality standard and the requirements for water source (except Fe during some seasons). In addition, there had been no industrial and mining enterprises upstream of Zongtongka Village, and was rich in natural vegetation with relatively high vegetation coverage. Therefore the conditions of the water conservation and sand prevention are pretty good.

The water quality upstream of Zongtongka Village was affected by nearby hot springs. The influx of hot spring water highly mineralized with high content of As and Fe had a significant impact on the water quality of the Angqu River. As well as the content of As and Fe in the nearby hot spring water (No.28) was much higher than that in the hot springs (No.17) upstream of Zongtongka Village. It was also indicated by the monitoring data that the downstream of Zongtongka Village was excessive of As and Fe, while the water quality had a trend to get worse along the river (As shown in Table 4.).

In conclusion, the water quality upstream of Zongtongka was better than downstream. So the upstream of Zongtongka was the optimal water source.

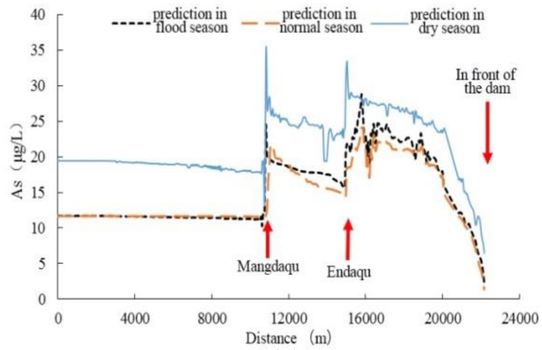
3.5 Water Quality Simulation, Prediction and Countermeasures

The water quality upstream of Zongtongka Village was good and could serve as the water source. Sediment adsorption experiment (Peng et al., 2016; Tang et al., 2015; Ying et al., 2012; Chen et al., 2008) and research on water quality simulation and prediction had been conducted to understand the reservoir water quality after the reservoir established. The simulation parameters referred to the Guoduo Reservoir at Zhaqu river， whose geological background conditions and geographic location are similar to the proposed reservoir. Suspended sediment's absorption of As and Fe had been analyzed by conducting absorption experiment, it had been indicated that sediment had a better adsorption of As and Fe, and reached adsorption equilibrium within a short time. The time of adsorption equilibrium of As and Fe were 3 hours and 1 hour respectively. And the equilibrium time of sediment on Fe is shorter than As.

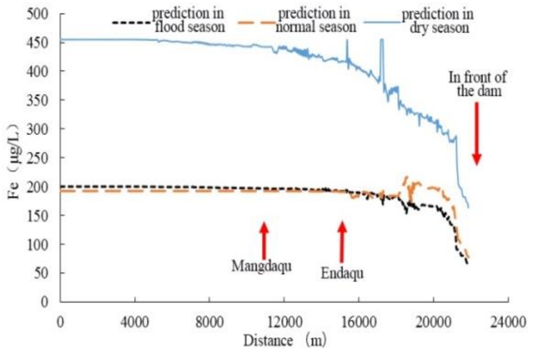
The water quality parameters-(distribution coefficient) of the model was determined by the combination with the consequences of absorption experiments and the simulation parameters from Guoduo Reservoir at Zhaqu river. Then the adsorption, desorption, migration and transfer processes of As and Fe in the water of reservoir after the impoundment was simulated to predict changes of water quality along the river by using the mathematical model of the 3D sediment water quality in the proposed Zongtongka reservoir. Figure 4 shows the simulated prediction results which suggested the As concentrations in the main stream of the reservoir during three water seasons all met the Class III standard after the proposed Zongtongka reservoir established. The content of Fe met the standard during flood season and normal season. It was excessive of Fe concentration from the end reservoir to the 3km upreach of the dam and met the standard in the reach near the dam during dry season. For the Zongtongka Reservoir was unbuilt, the content of As and Fe in water of the Guoduo reservoir built at the Zhaqu River was used to validate the model. Compared with the stimulation results and monitoring data of water quality variation along Guoduo Reservoir area, the model fit the observed data.

It had indicated that, after the reservoir established at Zongtongka Village, the water quality could meet the Class III standard except for some local areas. The high Fe content in the dry season of local areas was mainly related to the local geological environment. However, the sediments adsorption would be beneficial to the sedimentation of Fe and As after the reservoir impounded.

Based on the comprehensive analysis of the Angqu River water quality and the water quality simulated predictions upstream of Zongtongka Village, it had been clear that upper reach from Zongtongka Village is the most ideal water source for Changdu City. At the same time, it had been recommended to carry out long-term monitoring and evaluation of water quality safety in the Angqu River to grasp the pollution characteristics and pollution changes of the water quality in real time, and to divert and purify the branches excessive of As in the reservoir area to ensure the water supply safety of the proposed reservoir.



(a)



(b)

Figure 4: The prediction results of variation of As(a) and Fe(b) along the reservoir in Zongtongka Village.

4 CONCLUSIONS

The water environment state of Angqu River had been investigated and studied, and effects of local geological background on the selection of water supply reservoir site had been analyzed. At the same time, the changes of water quality after the reservoir established had been simulated and predicted, and corresponding water quality protection countermeasures had been put forward. Followed are mainly conclusions.

The field investigation has indicated that the Angqu River was excessive of the As and Fe content while other indicators met the water quality requirements of water source.

It has been found that the upper reach of Zongtongka Village is relatively optimal water source compared with the Angqu River, based on the analysis of Angqu water quality and the effects of local geological background on site election.

According to the adsorption experiments and the study of water quality simulation and prediction, it is found that the As content could meet the Class III standard for surface water in main stream of the proposed Zongtongka reservoir. The Fe concentration in the main stream of the reservoir during flood season and normal season could meet the standard limit for surface water, and water in the area of 3 km before the dam also met the limit. The area upstream of Zongtongka Village is an ideal water source in the region has been verified at the same time.

It is suggested that carrying out long-term water quality safety monitoring and evaluation of the Angqu River to grasp the pollution characteristics and pollution changes in real time, and diverting and purifying the springs around the proposed reservoir.

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