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Study on the Countermeasures of Ensuring Drinking Water Security in Shanshan County of Xinjiang Autonomous Region, China

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Abstract: China has paid more attention to improve urban and rural drinking water security in recent years. Ensuring the security of drinking water in urban and rural areas is the fundamental condition for protecting the basic interests of the public, and it is also an important aspect of building a moderately and all-sided prosperous society in China. Taking the Shanshan County in Turpan City of Xinjiang Autonomous Region as an example, this study analyzed the countermeasures of ensuring drinking water security. Firstly, this paper discusses the current quo of drinking water security in Shanshan. In terms of urban drinking water, problems are shown as follows: 1) drinking water sources are polluted to varying degrees; 2) water treatment technologies lag behind when compared to the social development; 3) high leakage rate of water supply pipe network, and 4) low emergency handling capability. In terms of the rural drinking water, small-scale drinking water security projects are on low construction standard, which resulted in low water supply guarantee rate, and poor water source protection and water quality supervision. Secondly, based on the analysis of current problems, the quantity of the water resources guaranteed is put forward. This paper divides Shanshan County into three units, Karuqi area, Ertanggou area and Kekeya area, based on urban or rural land use. This paper proposed the optimal distribution of regional water plants and water supply network for the optimal allocation of regional water resources. Thirdly, for water quality improvement, a corresponding water purification program is developed for raw water quality problems, which includes centralized and decentralized water quality treatment, as well as an intelligent water flow control process. At the same time, some management measures such as water source conservation and risk control measures are proposed in order to promote the security of drinking water. This paper also puts forward relevant strategic suggestions for ensuring the security of drinking water in Shanshan County, which includes enhancing the equipment for the project, modulizing the system of devices, developing instrumentation of the management system and establishing intelligent water management platform. This study has certain reference value for solving the problems of drinking water security in urban and rural areas in the arid regions in northwest China and similar areas around the world.

Keywords: drinking water security; water resources allocation; pipe network construction

1. Introduction

Ensuring drinking water security in urban and rural areas is an important part of building a well-off society in an all-round way, and it is also a basic requirement for safeguarding the fundamental interests of the general public. However, the current urban and rural drinking water security in northwest China is facing a serious situation. There is a series of problems in engineering technology and system mechanism. For example, the guaranteed rate for water supply of drinking water security project is low; the amount of water supply is insufficient; water resources are polluted; water purification capacity is relatively backward; emergency capacity is low. [1]. According to the requirement from the central government to gather urban-rural development and completely establish the assurance for drinking water security in well-off societies, it is necessary to further accelerate the process for establishing drinking water security projects for people and livestock in the northwest region in China. Besides, the reform of the management system for water supply projects need to be intensified. The improvement for the long-term mechanism of project operation and the socialized service system should be done as well. Moreover, strengthening the protection for water resources and the assurance for water quality, improving the living conditions and environment for sural residents, and increasing residents' health level are also significant as supports to achieve the goal of establishing new socialist countryside and moderately prosperous societies. [2]. Taking Shanshan County of Turpan Area in Xinjiang Autonomous Region as an example, this study aims to further improve regional urban and rural water supply guarantee rate, water quality pass rate, the popularization rate of tap water in rural areas and the project operation and management level. Measures such as improving the quality and efficiency of drinking water security, promoting the integrated management system of urban and rural water supply, and promoting the comprehensive, coordinated and sustainable eco-social development of urban and rural areas in the region should be taken so as to build a model for ensuring drinking water security in counties of northwest China.

2. Study Area and Data

This paper takes Shanshan County as the research are. It is located at the southern foot of Bogda Mountain in the eastern part of Tianshan Mountains, and it is also in the south of Turpan basin. It lies between 89°30′28″～91°54′00″ E and 41°12′10″～43°33′00″ N, with a total area of 39,500 km^2. Shanshan County has a temperate inland desert climate. The average annual rainfall is less than 26mm. Local river system is constituted of mountain streams, which are, Ertanggou, Kekeya and Karuqi from the west to the east respectively. Due to the tectonic uplift of Huoyan Mountain, Shanshan County is divided into two hydrogeological units, namely the northern and southern basins. The groundwater in the northern basin is dominated by phreatic aquifer, and the south basin is dominated by confined aquifer. Shanshan County administered five townships, five towns and a horticultural market. By the end of 2014, the county's total population has reached 242,700, of which agricultural population accounted for 74.90%.

Based on the status of urban and rural drinking water, this study collected basic economic data such as social and economic indicators, development and utilization of water resources in Shanshan County, which is mainly from data published by Statistics Bureau of Turpan Prefecture and Shanshan County. These data include Statistical Yearbook of Turpan Prefecture, Shanshan County Drinking Water Security and Network Transformation Report,

the county development overall planning, land use planning, and county water conservancy development planning. As for those lacked statistical data, they are collected by field investigations and typical survey in this study, and the data used were carefully reviewed and amended to ensure that the basic information is true and reasonable.

3. Methods

Based on the current security status of urban and rural drinking water in Shanshan County, the study aims to optimize the allocation of water resources, waterworks and pipelines, enhance water purification projects, and improve management system and mechanisms by providing solutions for the existing water quantity, water quality and management problems, see Figure 1 [3]. Based on the forecast of regional water supply and water demand, the research optimizes the allocation of water resources and achieves a balanced spatial distribution of water resources, which provides water resources support for the layout of drinking water projects. According to the differences in the status of water supply project and drinking water security in the region, rational distribution and optimization of the waterworks and water supply network are carried out [4]. As for the existing problems and development goals of drinking water security, it actively adopted new technologies, new processes, new materials and new equipment to build intelligent monitoring and control programs for better quality and efficiency of water purification projects, which includes automatic control of waterworks, intelligent management of water purification processes, and smart online water monitoring. For the lack of drinking water security management, it is proposed to strengthen water source protection and risk prevention and ensure water supply security. In this research, enhancing the equipment for the project, modulizing the system of devices, developing instrumentation for the management system and establishing intelligent water management platform of drinking water security protection will be realized through the collection strategy of engineering, technology and management so as to push forward the Urban and Rural Drinking Water Security Project in the northwest China. [5].

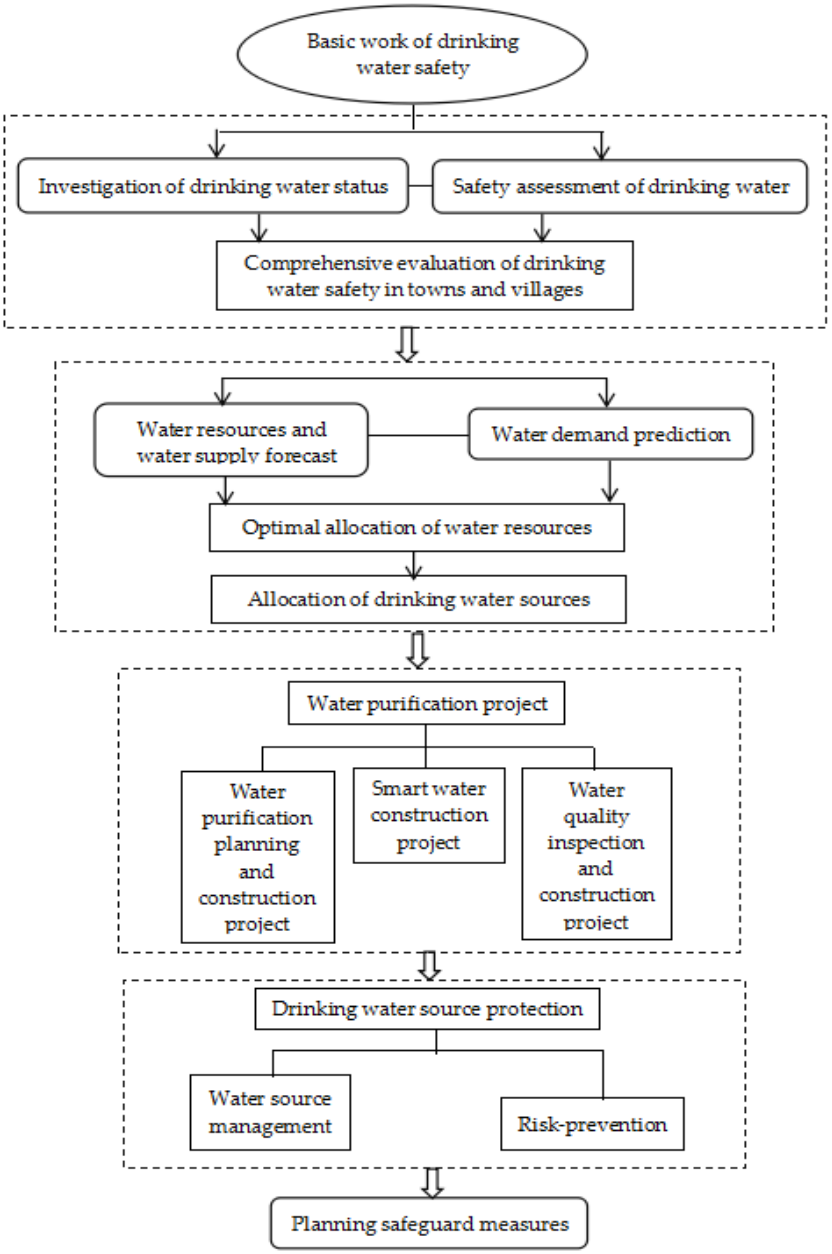


Figure 1. Technical roadmap of the study methods.

4. Results and Discussion

4.1 Analysis of the status quo

Water in Shanshan county town is supplied by two water supply companies, namely The First Water Supply and Drainage Company and The Second Water Supply and Drainage Company. The water source of The First Water Supply and Drainage Company is the groundwater. The Second Water Supply and Drainage Company's water source used to be underground deep well water [6], but now it is gradually changed to surface water. Shanshan's rural drinking water is primarily centralized water supply. Rural supply network basically covers all the villages and towns. There are mainly four waterworks: the ShanNan Water Work, the Qiketai Water Work, the Suburban Water Work, and the Lianmuqin Water Work. The task of drinking water security in Shanshan is very difficult. In 2014, the population without safe drinking water in towns and villages was about 416,000, which accounted for 16.5% of the total population of county. In general, the problems are water

pollution to different degree, low water purification treatment technology, higher water supply pipe network leakage rate, insufficient water quality monitoring and detection ability, and the low emergency response ability. The main problem is that the water quality is not up to standard. The water pollution is mainly due to domestic sewage and industrial waste water discharge, and the water quality does not meet the national drinking water hygiene standards or rural drinking water hygiene standards. The water quality test results showed that for two consecutive years, the total numbers of colony in 80% ~ 85% of the drinking water engineering was beyond the limit, and the turbidity, chroma, chlorides, and total hardness are all under standards.

4.2 water resources and water supply optimal allocation

Through the analysis of available surface water and groundwater supply at Shanshan, as well as the analysis of the current status of water supply project, the status of the water supply in the region was evaluated. At the same time, it is also necessary to predict the socio-economic conditions in the region to know the future water demand of the residents, agriculture, industry and tertiary industry [7]. Taking the promotion of water saving in production and living in the future into account, water resources will be allocated between water use units and water users (domestic, industry, agriculture, animal husbandry, fisheries, and ecology) following the optimal allocation, see Table 1. Under the frequency of 50% (almost at the long-term average level), the actual water supply in the status quo is $42175.7*10^4$ m^3, of which $10685.1*10^4$ m^3 is over-exploited, and groundwater over-mining is even more serious in the dry years. In 2020, it is planned to broaden water sources and reduce water use through agriculture and industry (especially agriculture) by measures such as further developing agriculture water saving facilities to improve water use efficiency. Through the optimal allocation of water resources among the various water use units, it is possible to ensure a more adequate domestic water supply and provide water security for urban and rural drinking water. The balance of water supply and demand at Shanshan is shown in Table 1.

Table 1. Supply and demand balance table of current and planned years in Shanshan under 50% frequency（10^5m^3）

Source of water	**Type**	**Current year allocation**	**Optimal allocation of planning level year**			
		Shanshan	Ertanggou	Kekeya	Karuqi	Shanshan
surface water	Domestic water	42.88	48.50	0.00	0.00	48.50
	Industrial water	421.61	52.53	103.50	244.29	400.31
	Conventional farmland	1147.59	131.27	382.82	46.33	560.42
	Conventional garden	4802.16	833.32	1415.20	98.58	2347.09
	Efficient farmland	2295.72	720.99	1420.14	280.77	2421.89
	Efficient garden	5482.34	2247.86	2695.62	847.48	5790.97
	Animal husbandry water	53.15	18.72	19.81	14.62	53.15
	Fishery water	48.00	18.00	15.00	15.00	48.00

	Ecological water use	32.20	8.90	10.00	23.40	42.30
	Subtotal	14325.64	4080.09	6062.09	1570.47	11712.65
ground water	Domestic water	808.65	436.54	328.32	152.92	917.78
	Industrial water	983.75	122.56	241.49	570.01	934.07
	Conventional farmland	2022.30	288.13	544.10	101.69	933.93
	Conventional garden	8782.14	1829.04	2011.43	216.37	4056.84
	Efficient farmland	4230.04	1582.48	2018.45	616.26	4217.19
	Efficient garden	10653.63	4933.80	3831.31	1860.13	10625.24
	Animal husbandry water	79.73	28.08	29.72	21.92	79.73
	Fishery water	0.00	0.00	0.00	0.00	0.00
	Ecological water use	289.80	80.10	90.00	210.60	380.70
	Subtotal	27850.03	9300.74	9094.83	3749.91	22145.48
Total water supply		42175.67	13380.83	15156.92	5320.38	33858.13
Groundwater overdraft		10685.14	2434.78	1198.98	1346.83	4980.59

4.3 Waterworks and pipe network optimization layout

On the basis of water supply sources protection, the rational layout and optimization design of urban and rural waterworks and water supply network is carried out [8]. The scale of rural tap water supply is calculated by considering the water for domestic use in rural areas, water for livestock use, water for township enterprises, the amount of water leaked from the pipe network, and the amount of water consumed by the waterworks; the urban tap water supply size calculation considers urban domestic water, industrial water, and the use of waterworks themselves. By the rural water supply estimation, the total water supply of the two waterworks in the towns should be up to 32600m^3/d, and the total water supply of 4 water plants in rural areas should reach 8900m^3/d by 2020. Considering the rapid population growth in the region, the existing waterworks will be rebuilt in the near future to fully meet the needs. When conditions permit, industrial and domestic water supply may also be realized in a decentralized manner to reduce the water supply costs. Investigations showed that Shanshan water main line pipe network has basically covered the whole territory, so the future pipe network extension is mainly on the branch pipe network and the pipe network to each house. For those places where there are indeed difficulties in extending the pipe network, only decentralized water supply could be adopted. Appropriate water supply measures should be implemented according to local conditions to build small independent water supply systems in rural areas with water purification and disinfection facilities. The shallow groundwater areas should use shallow water supply project; mountain stream areas should use the construction of water diversion facilities. Karez projects could be used in areas where there is water shortage or where development and utilization are difficult.

4.4 Water purification project design

From the analysis above, it is obvious that the current water treatment technology is relatively poor, and the water quality is not up to standard. Besides, water treatment automation degree is low as well. According to the characteristics of water source and water

treatment technology status, when the water purification project is designed, Internet, networking, and cloud computing technology were applied in the plant operation process automation control, water purification process intelligent control, and intelligent water online monitoring of water information technology used in water purification engineering.

4.4.1. Equipment and modularization of water purification project

The traditional drinking water projects have many problems such as large workloads, high operating costs and difficult maintenance, while integrated water purification engineering facilities are suitable for the water supply plans for areas that are lack of water resources, have diversified water pollution, or are economically underdeveloped. Standard modular design can be selected for free combination and integrated treatment according to different water quality and construction conditions. It can comprehensively deal with a variety of water pollution problems, and each module can be highly integrated through structure optimization to minimize occupied space. The measure of centralized water supply plan is to select a centralized water source with standardized water quality and stable water volume to supply water via distribution network. As foor the area with relatively large population and high demand of water supply in Shanshan, centralized water supply plan should be adopted, which is the process that the raw water in the water source enters into the reservoir through the water intake structure, and then the water in the reservoir is lifted by the water pump to enter the subsequent treatment units. The coagulant will be added in the front terminal of pipeline mixer, so that the colloids, suspended solids, microorganisms and the others in the raw water will be conducted flocculated through the adsorption of electric compression layer and bridge under the role of coagulant. The water through mixed flocculation enters into the highly efficient integrated water purifier to carry out highly efficient flocculation reaction, separation, precipitation, filtration and removal for the substances in water. The fully automatic operation of the equipment is important to achieve the automatic management of waterworks. The middle reservoir plays a major role in regulating the water volume and water quality, and the water in the middle reservoir is lifted by the booster pump to enter the subsequent treatment units. During ultrafiltration membrane screening process, the pressure difference between the two sides of the membrane will be applied as the driving force and the ultrafiltration membrane will act as the filter medium. When the stock solution flows through the membrane surface, only water and small molecules are allowed to pass through the micro-pore that closely set on the membrane surface to become permeate liquid, while other substances are intercepted. This process will help to achieve the purification, separation and concentration of the stock solution. Full-automatic disinfection device mainly uses chlorine dioxide for sterilization, and it takes host, material tank, water ejector and electric contact pressure gauge as the whole, which can customize the procedure to achieve automation and network. The decentralized water supply plan is a water supply method adopted for the presence of special pollutants in local areas, which builds waterworks and pipelines in villages to achieve the purpose of sub-quality water supply. As for different water quality problems, the treatment steps may include high-fluorine water treatment process, brackish water treatment process and water treatment process of iron and manganese removal and so on.

4.4.2. The instrumentation and intelligence of project management

（1）Automatic control system of waterworks operation process

The main controller of the automatic control system in the operation process of the water plant adopts the high performance programmable controller, which constitutes a secure and stable industrial network control system. The system consists of intelligent water access terminal, intelligent water terminal, intelligent water supply terminal, water quality

monitoring terminal, pipe network monitoring terminal and water control terminal.

The intelligent water intake terminal is installed in water source or water intake terminals of waterworks for real-time monitoring and protection of water intake equipment, as well as delivering the water from water source or water intake terminal into the water purification system. The water purification system of the waterworks installs the intelligent water-making terminal; it integrats the process requirements, which can automatically and intelligently regulate the operation of the water purification devices and monitors and protects the devices in real time, so as to ensure the water volume and water quality of the water purification equipment. The water supply terminal of the waterworks is equipped with intelligent water supply terminal; it can intelligently control the water supply devices to supply qualified water to the users through constant pressure or constant flow, and timely monitor and protect the water supply devices at the same time. The water intake terminal, the water supply terminal and the pipe network of the waterworks are equipped with the intelligent water quality monitoring system which monitors the water quality indicators in real time to ensure the safety for water withdrawal, water supply and drinking water. The pipe network within the water supply scope of the waterworks have pipe network monitoring terminal which monitors running status of pipe network and transfers pipe network operating data back to the central control room in real time to achieve quantitative management of pressure and flow for water supply. Water control terminal monitors water pressure and water flow for users in real time, to ensure the satisfaction of demands.

(2) Intelligent control of water purification process

The intelligent control technology of water purification process combines the automatic control technology, intelligent monitoring and management technology organically, forms the integrated solution of intelligent control system of water purification plant. Water quality parameters are timely displayed. With the networking module, water quality parameters of water sources in Shanshan are real-time monitored, displayed and stored in PC computer in the network center room and the smart water platform. Shanshan's six water plants apply real-time monitoring in production, and the water purification process is shown in pictures on PC computer dynamically, which displays the change of water quality index, water purification process, equipment status, water flow direction, and water supply data. Through the accumulation and analysis of data, the real-time trend curve and the historical trend curve can be generated as needed, see Figure 2(a).

Waterworks in Shanshan automatically collects data of water purification process, and automatically generate statistical analysis reports with the intelligent control system. The data reports can be exported at any time, which providies first-handed information for water plant management decision-making. The production report control picture is as shown in Figure 2(b).

Shanshan Central Control Room has set alarms for the abnormality, fault, diagnosis and prompt failures in monitoring of water quality, equipment or pipeline to facilitate the management of personnel in a timely manner to avoid or respond measures, see Figure 2(c).

(3) Intelligent water online monitoring system

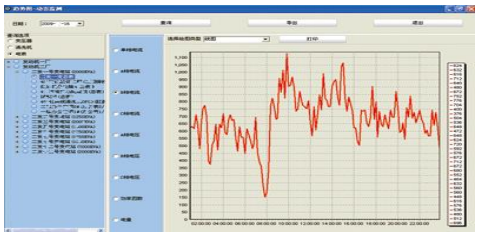
Intelligent water online monitoring system will apply the Internet of Things technology and it helps to improve the level of automation management, see Figure 2(d). The project of intelligent water online monitoring system includes:

1) On-line water quality monitoring of water wells.
   On the one hand, it conducts real-time monitoring and feedback to the water sources, on the other hand the water pollution would been sent to the designated person in the form of text messages at the first time.
2) On-line monitoring of water quality.
   It monitors water level, water flow, water pressure, turbidity, conductivity, pH, dissolved oxygen, residual chlorine, toxicity and other parameters to ensure water

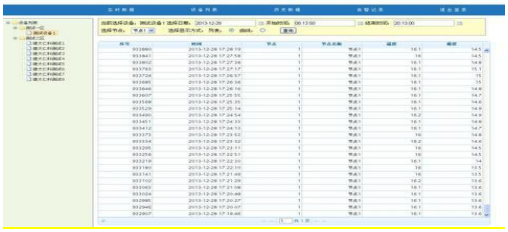
supply safety.

3) Online monitoring of water supply network.

The water supply network of six waterworks in Shanshan realizes on-line monitoring, which helps to monitor the water pressure, water flow, water quality changes in the water supply network, residual chlorine at the end of the pipe network, and the other relative parameters (Figure 3).



(a) The historical graphic record



(b) Water quality monitoring storage data

(c) Alarm and time management screen

(d) Water quality monitoring storage data

Figure 2. Sketch map of the intelligence of project management

Six waterworks control centers in Shanshan would set dispatch information platform. Based on achieved daily pipe network data collection, the target for the next day will be timely set up. By relying on these data, it generates scheduling solutions to assist the water network operational optimization scheduling management. It can realize data sharing through the network, and the production scheduling data could be directly used in office automation system to achieve the integration of monitoring, control and management. At the same time, intelligent water online monitoring system has a perfect early warning and emergency management mechanism of pollution incidents. Combined with internet of things module, spatial data and attribute data of the water supply network and the drainage are taken as the core with the advanced computer software technology, communication technology, graphics processing technology; it could establish timely and stable alarm emergency management system. Based on a large amount of data, statistical analysis of water quality data is conducted to provide decision support for treatment of water pollution incidents and ensure the safety of water for people in the region.

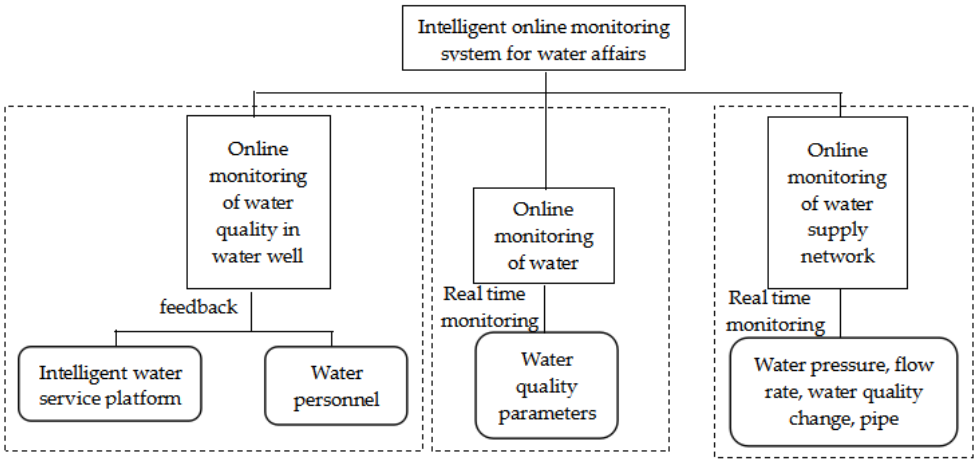


Figure 3. Flow chart of online monitoring system for intelligent water affairs

4.5 Water Protection and Management

Water conservation is long-term and crucial. On the one hand, it is necessary to strictly implement the Environmental Impact Assessment (EIA) of the building project and the planning projects, and it is forbidden to enter into the protected area with newly-built projects that would pollute drinking water. On the other hand, it should intensify the supervision of the original enterprises in the protected areas of water sources, give full play to the supervision role of the masses, and conduct inspections from time to time to standardize the pollution discharge by enterprises. Meanwhile, it should increase the supervision of agricultural sources of pollution, livestock and poultry breeding survey to promote the use of organic fertilizer on farmland. In addition, it needs to take appropriate precautionary measures to strengthen investment in environmental infrastructure for drinking water sources, special rectification of solid waste, sewage, and garbage. It also needs to strengthen the dynamic monitoring of groundwater and improve the protection of development and utilization of Karez wells in the area [9].

5. Conclusion

Based on the current situation of drinking water security in urban and rural areas in Shanshan county, this study puts forward a plan to strengthen its water supply and water quality assurance, which is to improve the water supply guarantee rate of drinking water through the optimal allocation of water supply and water plants & pipe network optimization layout. Water purification project quality and efficiency would be improved by enhancing the equipment for the project, modulizing the system of devices, developing the instrumentation of the management system and establishing intelligent water management platform, to achieve the wisdom of water management. The article also puts forward corresponding management measures for water source protection. Drinking water security protection project of the materialization and intelligence construction will be of a great significant to the integration of information resourcesand intelligent realization of the comprehensive utilization of water. It would comprehensively improve the ability of water management and public service, enhance the quality of people's life, and promote the clustering and development of related industries.

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