MASTER THESIS

Research on the Assessment Method of Zouping County Rural Drinking Water Safety

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ABSTRACT

The background of the research is that it is difficult to find a sustainable drinking water source for Zouping County, Shandong Province, China. Zouping County is a severely water-scarce area. With the rapid economic and social development and the increase of population, the demand for water has been continuously increasing. Over-exploitation and utilization of groundwater have led to regional over-exploitation, resulting in a continuous decline of groundwater level, depletion of aquifers, and deterioration of water quality. The random discharge of industrial wastewater has led to the pollution of drinking water sources. A series of ecological and environmental problems have seriously restricted the sustainable economic and social development in Zouping County.

The aim of the research is two-folds, both theoretically and practically aspects. The objective of this research is to identify drinking water pollutants in Zouping County, find appropriate drinking water treatment technologies, assess the current drinking water manage system and modify the system based on regulatory framework. Major conclusions are listed below:

(1) The water quality in Zouping County is generally low. The unqualified items were mainly COD, microbial indicators and total hardness.

(2) The most suitable drinking water treatment technology in Zouping County is chlorine dioxide disinfection. In order to solve the problem of uneven distribution of water resources, the water resources of Zouping County should be optimally allocated.

(3) The state should increase investment and support for drinking water safety in Zouping County. It should expand financing channels, formulate preferential policies, reduce the cost of tap water, and encourage residents to use tap water.

Key words: Water management, Drinking water treatment, Water configuration optimization

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Chapter 1. Introduction

1.1. Background

Since China adopted the policy of reform and opening up, the economy has continued to grow at a rapid rate, and the gross domestic product (GDP) has greatly increased year after year. At the same time, however, China’s environmental pollution has become increasingly serious. With the large amount of untreated discharges of industrial wastes, agricultural pollutants, and living pollutants, the pollution of groundwater and surface water is increasingly intensifying, resulting in the pollution of drinking water sources. The situation of unsafe drinking water in China is very intensive.

Groundwater and surface water are important drinking water sources in China. Nearly 70% of the population in China consumes groundwater (Ministry of Environmental Protection The People’s Republic of China, 2017). However, water pollution is aggravating the groundwater crisis in China. Nearly 80% of the country’s groundwater has suffered from various degrees of pollution, of which 20% is seriously polluted (Ministry of Environmental Protection The People’s Republic of China, 2017). According to the statistics of the Ministry of Health, about 65.4% of the population in China does not meet drinking water standards. The problem of unsafe drinking water in rural areas is even more pronounced. In China's rural areas about 300 million people are drinking unsafe water, including 190 million people drink contaminated water, which contains excessive levels of harmful substances. Safeguarding the safety of drinking water has become one of the most important livelihood issues for the government and the people in China.

In recent years, the central government and local governments have increased investment in rural drinking water safety protection and adopted a series of engineering and management measures to solve some of the farmers' drinking water problems. However, a 2016 report from China’s National Audit Office found that RMB17.62 billion, or USD$2.56 billion, that was allocated to preventing water pollution in 2015 had not been used effectively, the rural drinking water situation is still severe (Willis, n.d.). With the development of the rural economy, the majority of farmers have higher requirements for quality of life. At the same time, due to economic development and over-exploitation of resources, rural drinking water sources are polluted and water resources are depleted. The problem is that these issues are increasingly threatening the health of farmers' drinking water. In addition to other sources of pollution, the large-scale use of chemical fertilizers and pesticides has contaminated the source of groundwater in rural areas, and most of the villagers have directly extracted shallow groundwater by hand-pressing wells. Therefore, rural areas have often become the most direct victims of groundwater pollution.

1.2. Problem Statement

In the 11th Five-Year Plan, the Central Government of China proposed to solve the 100 million rural residents' drinking problem and plan to solve the problem of rural drinking water insecurity by the end of 2015 (The State Council of People's Republic of China, 2014). All local governments have also formulated corresponding rural drinking water safety control targets. The formulation of goals should lead to a significant improvement in the safety of drinking water in rural China. However, recent surveys have shown that rural drinking water standards are not well implemented and nearly 300 million farmers still face unsafe drinking water problems. The current enforcement of drinking water regulations is insufficient, rural drinking water monitoring points are not fully covered, and rural drinking water information is not published. The ability of government to provide safe drinking water for rural residents has been repeatedly questioned in recent years. The sanitation problem of drinking water in rural areas has caused many rural residents to suffer from different kinds of diseases, of which Zouping County is a typical example.

Zouping county is located on the northern edge of the mountainous central portion of Shandong province. It is under the administration of Binzhou City. The permanent population of 796,000 (2015). Daily per capita water consumption 120L. The total area is 1250 square kilometers. The county administers 11 towns which contain 858 administrative villages. Zouping County is one of China's top 100 comprehensive strength counties. Zouping County is located at the junction of Beishan Mountain and Yellow River Flood Plain. The main low hills are in the south, Yellow River Flood Plains are in the north and northwest, and the piedmont plains are in the east. The climate is warm temperate continental monsoon climate, rainy season and hot season are in the same season.

Zouping County not only facing the groundwater scarcity but also facing the groundwater pollution issues. By solving drinking water problems in Zouping County can provide reference materials for other villages and towns with similar conditions.

1.3. Research Objective

The objective of this research is to identify drinking water pollutants in Zouping County, find appropriate drinking water treatment technologies, and assess the current drinking water management system in order to give recommendations to the relevant government agencies and authorities.

Chapter 2 Literature review

2.1. China's Drinking Water Status

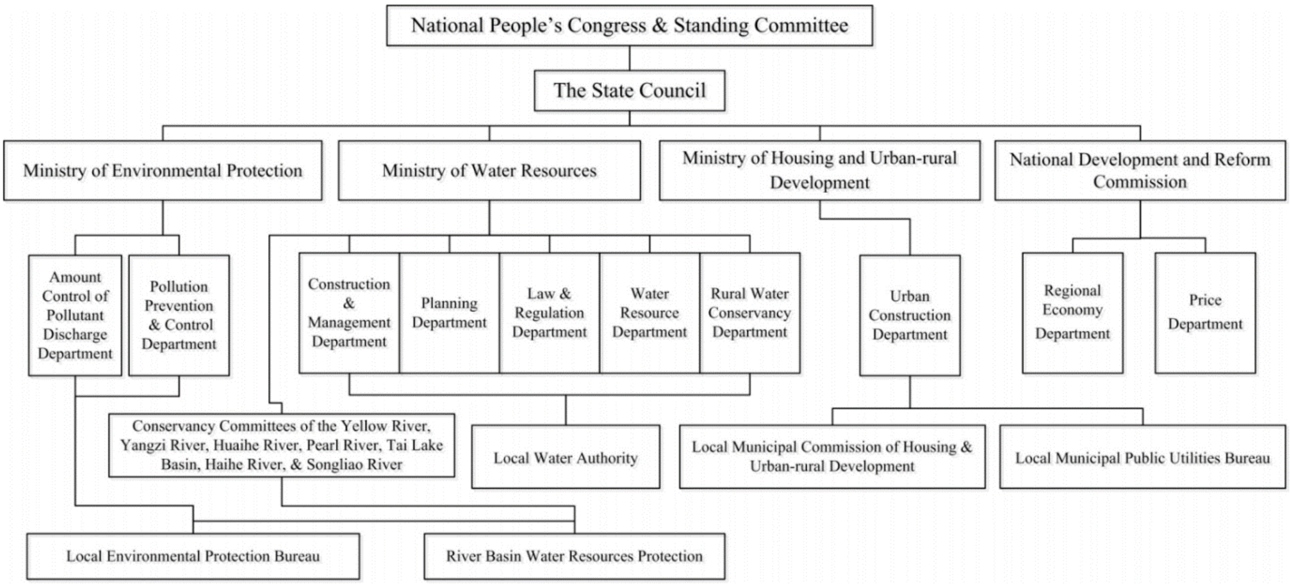
China's per capita availability of renewable water resources is about a quarter of the world average (J. Liu & Yang, 2012). The water resources of China are affected by both severe water shortages and severe water pollution. Water demand and water pollution increased accompanying with the growing population and rapid economic development as well as lax environmental supervision. Every year, 190 million people in China fall ill and 60,000 people die from diseases caused by water pollution such as liver and gastric cancers. Two-thirds of China's 669 cities have water shortages, more than 20% of its rivers are severely polluted, 80% of its lakes suffer from eutrophication, and about 300 million rural residents lack access to safe drinking water (Tao & Xin, 2014).

China has invested a lot in raising rural drinking water hygiene. However, by the end of 2010, there was still nearly 300 million rural residents still have no access to safe drinking water ("WPRO | Drinking water and sanitation," n.d.). Because the lack of safe drinking water sources, many rural residents have to use surface water, shadow groundwater and rain water to be their drinking water sources. To date, 42% of the total rural population cannot get their drinking water through modern tap water systems, and 85.72 million rural citizens have to draw water directly from rivers, streams or ponds (Yu et al., 2015).

The rural population is large in number and there are many villages. There are more than six hundred thousand administrative villages in China and about 590 million live in rural regions ("List of villages in China," 2018; "China," n.d.). For the concentrated areas of villages and towns, the drinking water project is mostly a large-scale water supply facility constructed in a centralized manner. However, for villages with scattered villages and relatively few populations, remote areas, etc., it is impossible to achieve centralized water supply, and no more water treatment facilities or slow filter tanks and reservoirs are built. Survey data indicate that there are sources of pollution around 60% of rural water sources. Some pits, ponds, streams and rivers are shared by people and livestock, which are both sewage outlet and drinking water supply sources. At present, rural water supply generally lacks the necessary water treatment facilities, disinfection facilities, and water quality testing equipment. Even if there are water treatment facilities, most of them still have various problems. In the rural areas, decentralized water supply and small-scale centralized water supply are almost no water treatment facilities. The source of drinking water has caused serious problems in exceeding the standard of bacteriological indicators, pollutants, and harmful minerals in drinking water. Therefore, it is particularly important to strengthen the protection of rural drinking water sources.

2.2. Administrative System for Water Resources in China

Figure 1. China's Water Administrative Framework



Source: Yu et al., 2015

The existing water resource administrative system in rural China is shown in Figure 1. Water resources are managed by both the central and the local governments. However, the cooperation between several agencies are not close due to division of responsibilities. "Everyone with power is prone to abuse of power. This is an experience that has never changed." In order to restrict power, the state's supervisory power is dispersed among the party's disciplinary inspection organizations, the government's supervisory organs, and the procuratorate, and they are relatively independent and separate from each other. Cooperation have formed a parallel situation in China's anti-corruption troika. From the practical point of view, the "Troika" has assumed the responsibility of anti-corruption to a certain extent. Because it belongs to different systems, and each has its own constraints, each is in power and lacks unified command (Xun Yu, 2016).

From a national perspective, the Ministry of Water Resource (MWR) is responsible for water resources protection, responsible for ensuring the rational development and utilization of water resources, formulating water conservancy strategic plans and policies, and guiding the management and protection of water conservancy facilities; The Ministry of Environmental Protection (MEP) is responsible for the supervision and management of environmental pollution prevention and control. Formulating and implementing water pollution control management system, coordinating with relevant departments to supervise and manage environmental protection work for drinking water sources, and organize and guide comprehensive environmental improvement work in urban and rural areas; the Ministry of Housing and Urban-rural Development (MHUD) is responsible for urban water supply and conservation activities, implementing urban sewage disposal facilities and the construction of network accessories (Yu et al., 2015); and the National Development and Reform Commission (NDRC) organizes the formulation and coordination of energy resource conservation and comprehensive utilization, development of circular economy planning and policy measures, and participates in the preparation of environmental protection plans, policy measures for water resources protection and comprehensive utilization, and water prices. Such a fragmented administrative system poses a serious challenge to effective and efficient water management (Yu et al., 2015). Those agencies are not subordinated to one another, the lack of a leading agency result in the water-related jurisdictions involved in these institutions are not clear. This problem also exists at the local level, which exacerbates the situation. The current rural drinking water safety management faces many problems, including inadequate management system mechanisms, engineering nature and project property rights are not yet clear, many specific links in construction and operation management need to be standardized, and the most important issue is the development of policies and rules and regulations is not enough and legal effectiveness is not high (Rural Drinking Water Safety Proceedings Editorial Board, 2009).

2.3. Water Management Regulations

The Standing Committee of National People's Congress issued three important laws that related to water management, which are the 'Water Law of the People's Republic of China', the 'Law of the People's Republic of China on Prevention and Control of Water Pollution' and 'Environmental Protection Law of the People's Republic of China'. In order to adapt to rapid development, the 'Water Law of the People's Republic of China' was revised in 2002 and has become China's key water legislation. The 2002 Water Law addressed watershed issues because the watershed management has become more crucial. The central and regional governments have realized that the watershed territories are not same as political territories, the cross-regional collaboration are needed. The 'Law of the People's Republic of China on Prevention Control of Water Pollution' was amended in 2008 in order to ensure the safety of drinking water, prevent and control water pollution and protect the nature environment. The major revision is in the fourth section of the fourth chapter, outlining how to deal with pesticides, fertilizers, wastewater containing livestock manures and aquiculture wastes, as well as how to recover local water-related ecosystems and how to improve irrigation water quality (Yu et al., 2015). In general, the 'Environmental Protection Law of the People's Republic of China' was enacted to protect China's entire environmental system. The chapters on rural China are about protecting surface water and rationally developing groundwater resources, maintaining good water quality and strictly manage and protect agricultural water. In addition, the State Council proposed the 'Resolution of Accelerating Developments of Water Conservancy Reform in 2010 and the 'Suggestion of Implementing the Strictest Water Management System' in 2012.

At the ministry level, the MWR announced the 'Principle of Enhancing Management of Rural Water Supply Projects' in 2003 and the 'Regulation of License System of

Drawing Water' in 2008. Moreover, the MEP requires local governments to compile the '12th five-year planning of prevention and controlling water pollution in key watersheds' and the 'prevention and controlling water pollution planning (2011–2015) in midstream and downstream of Yangtze River' in 2010. These regulations provide fundamental principles for local government even though they are lower than the national regulations (Yu et al., 2015).

However, a substantial number of studies find that the enforcement bodies of environmental regulations in developing countries are mostly weak institutions with low bureaucratic status (Yu et al., 2015). As a water quality monitoring agency, the local environmental protection agency is unable to actively cooperate with other bureaucracies, especially bureaucratic institutions that related to the polluting industries. This creates serious obstacles to the effective implementation of water-related regulations. Those environmental officials often lack the full support of external constituencies and cannot work effectively. This lack of support has seriously affected their commitment to their agencies which further weakening their effectiveness. Lack of rules, legal support or funding, and heavy workloads make the problem more complicated. Under this circumstance, most law enforcement officials only pay attention to law enforcement in urban areas, resulting in ineffective and inefficient law enforcement in rural China (Yu et al., 2015). Moreover, enterprises in rural area are usually small and medium-sized enterprises. Most of them have relatively low environmental awareness and often believe that environmental protection is a heavy burden. Decentralized SMEs are more difficult to manage than large companies. In fact, most SMEs currently facing difficulties such as obsolete equipment and technology, untrained and inexperience workers, and inadequate financial resources. Their products usually caused significant negative impacts on local environment. As a result of this, rural residents face the similar issues and do not have the appropriate knowledge of compliance. Therefore, provincial and municipal governments should consider how to formulate appropriate economic incentives, improve law enforcement, and provide necessary financial support for rural enterprises and farmers.

2.4. The Threats of Drinking Water in Rural Area

Rural drinking water sources have territorial special problems. In general, China's rural drinking water faces the following threats.

First is severe water pollution. With the transformation of urban economic development and the acceleration of urbanization in rural areas, many heavily polluting heavy industries in cities have been transferred to rural areas. According to research conducted by researcher from Chinese Academy of Environmental Sciences, most of the major cities in China adopt the method of relocating industrial pollution, and rural areas have begun to withstand environmental pollution that is difficult to load (W. Li, 2009). Small-scale paper mills, tanneries, chemical plants, printing and dyeing plants in townships have gradually grown. These immature companies often have lagging technology and aging facilities. The discharged wastewater is highly toxic and contains heavy metals that far exceed the standards. However, due to the drive of economic interests, protectionism prevailed in many local governments. Although many companies have been exposed by the media for many times, they are still operating.

The rural diffuse pollution mainly refers to nitrogen, phosphorus and other nutrients, pesticides and other pollutants in the agricultural production process flow from surface water runoff to groundwater which lead to the water pollution. Comparing to urban situation, the rural diffuse pollution is more serious (H. Zhang, 2005). With the rapid increase in the economic level in rural areas, the amount of fertilizer applied has increased year by year in certain regions with higher economic levels. Because 12.5% to 45% of the spent nutrients cannot be absorbed by crops and it directly flows through the soil into the groundwater, increasing the content of nitrates, nitrites, and heavy metals in the groundwater. Some pesticides cannot be decomposed in the soil even for several years. Residue pesticides also flow into groundwater to destroy water bodies through precipitation, irrigation, etc., and cause pollution to various water bodies such as runoff water, rivers, shallow layers and deep groundwater.

Secondly, the water volume is endangered. In rural areas, water supply equipment is particularly lacking. Most watercourses, rivers, ponds, springs and shallow wells are the main sources for rural people to obtain drinking water. However, due to the low precipitation in some seasons and the drought caused by climate instability, lead to the reduction of river water, groundwater level decreased, and so on. Therefore, resulting in insufficient of drinking water in a part of rural areas. With the rapid development of aquaculture and planting in rural areas, the amount of water used has also increased. In some rural areas, due to improper land exploitation, grassland is degraded and vegetation is scarce. As a result, the natural environment is deteriorated and degraded, and water-holding capacity is reduced which caused a water crisis in drinking water sources (Wu, 2015).

Decentralized water supply refers to the method of water supply where dispersed households directly take water from water sources without any facilities or only simple facilities (Ministry of Health of China, 2006). The characteristics of decentralized drinking water is widely supervision work has a certain degree of difficulty, and the quality of water sources is extremely easy suffered from pollution from different sources, the safety hazards are outstanding. In rural areas, there are a large number of decentralized drinking water sources, for instance wells, streams, rivers, etc. (H. Liu, Zhu, & Fan, 2011). Most households have toilets, poultry, pesticides, fertilizers, and other sources of pollution. In addition to a few simple disinfection and precipitation treatment process, such as simple sand filtration and alum precipitation (Greenovation:hub, 2013), there are no specific drinking water safety treatment measures on the wells or water towers before enter the pipe network and directly drink. This shows that in the rural areas of China, decentralized drinking water sources is easily to be polluted.

2.5. Drinking Water Safety in Zouping County

2.5.1. Current condition of drinking water supply chain in Zouping County

Although China has established a series of standards and regulations for the safety of drinking water in rural areas, such as choosing the rural drinking water safety as one of the key projects for new rural construction in the ‘Eleventh Five-Year Plan’. Many government-stock draught projects have been built since 2008, but so far this has not significantly materialized. However, due to the constraints of economic and technological factors, it is impossible to fully monitor the quality of drinking water in rural areas, especially the decentralized water supply sites (Y. Zhang, 2010).

Shadow grounder water is the main drinking water source in Zouping County (Jin, Gao, & Li, 2015). The per capita water resources of Zouping county is 336 m^3, which is 1/6 of the national average, and it is a resource-based, water-quality, and development-based water-shortage county. According to the results of the “Survey of Underground Water Overdraft Zones in Shandong Province 2014” (Shandong Provincial Bureau of Hydrology, 2014), the water overexploitation of the Zouping County was 6.413 million m^3/year, and the water extraction rate of superficial pore water in the county was 3.373 million m^3/year. The overexploitation of deep confined water is 3.40 million m^3/years. Due to the long-term over-exploitation of the water from the water source area, the supply is seriously insufficient. Currently, 31 of the 118 water wells are nearly dry. With the use of nearly 50% of the normally used water wells cannot pumped water occasionally (Tang & Cheng, 2017). At present, the non-compliance areas of drinking water are mainly distributed in the central and northeastern plains of Zouping County, and the areas where the water source guarantee rate which is not meet the standard are mainly distributed in the mountainous towns in the southern part of Zouping County. At present, in addition to the 267,000 people in 6 towns which the rural water company has unified dispatching of water supply, the rest of the rural residents rely entirely on local wells for drinking water or buy barreled water for drinking.

2.5.2. Problem of drinking water sanitation in Zouping County

Before the 1970s and 1980s, there were several wells in the county, and each household took water by hand. Around the reform and opening up, everyone successively drilled wells in their own homes and shook hands. However, with the reform and development, there are more and more factories constructed in the counties in recent decades. Factories often discharge sewage to underground directly without any treatment process, because they do not need to invest in pollution control afterwards by doing this. Therefore, the well water has been polluted, and people cannot find other usable water sources for daily use. In recent years, the number of cancer patients in the village has increased significantly. Industrial pollution is considered to be the main cause of high incidence of cancer, and the contamination of drinking water is obviously related to this situation (Y. Liu, 2011).

Brackish water is mainly distributed in the Yellow River Flood Plain in the northwest of Zouping County, affected 41 villages and 32,000 residents (J. Li, 2013). The salt-water and freshwater interface in this area are staggered and interacts with each other. The type of shallow groundwater in this area is chloride water. The general concentration of chloride in the county is 1-3 g/l but the mineralization degree up to 20 g/l in some areas of Jiuhu Town. Partial of the area is bicarbonate water, and the salinity is less than 1 g/l. The villagers in the region have been drinking local high salt water for a long time, resulting in a decline in physical quality of the people and the proliferation of diseases, which has seriously affected the lives of the people.

The wastewater from the lower reaches of the Xiaofu River crosses the territory of Zouping and is the main source of pollution for local drinking water, leading to cross-strait communities hard to drinking water from this source. The sewage in the upper reaches of the Xiaofu River is excessively discharged, and sometimes the water quality exceeds Class V water. The main excess project are suspended solids, total hardness, ammonia nitrogen, volatile phenols, and oils. Contaminated surface water penetrates underground, causing groundwater pollution, many farmers have to buy barreled water to drink.

Due to the scattered layout of many villages, it is difficult to connect villages and villages. The villagers' draughts rely on the water wells in the village. With the lack of water sources, some villages have hit deep wells. However, due to the quality water shortage, deep wells still cannot meet the drinking water needs. In previous years, the construction of the tap water project in the villages solved the problem of the pipe network, but the source pollution of safe drinking water has never been solved fundamentally.

The treatment of groundwater pollution of local rivers which has been polluted by the industrial wastewater of Zouping County is an important way to solve the problem of local drinking water safety in addition to the original geological water.

2.6. Drinking Water Treatment Technology

2.6.1. Slow Sand Filtration

Slow sand filtration is a process of natural filtration that is created in an artificial environment for the specific purpose of filtering water (Ray & Jain, 2011). Slow sand filtration is also called surface filtration, which is a very simple technology. It mainly utilizes the filter layer to intercept and hold pollutants and uses the surface of the filter layer to form a sticky "filter" microorganism by algae, organic matter and protozoa, thereby removing suspended solids, bacteria, plankton, etc. in the water. The filtered water can generally reach the hygienic standard of drinking water. The water quality before and after the filtration should be measured frequently, and the growth condition of microorganisms in the sand filter layer need to be observed regularly. When the head loss reaches a predetermined value, it is needed to shovel the intercepted materials to re-filter the water. In addition, after a few sand shovels, new sands need to be added. The construction and management of the slow sand filtration are relatively simple. While the disadvantages are less water production, slow filtration rate (<10m/d), large land occupation, and labor-intensive cleaning of the filter material.

2.6.2. Membrane Filtration

Membrane filtration technology refers to pressure-driven membrane separation technology, which is an advanced water treatment. Under a certain pressure, when the undiluted fluid flows over the membrane surface, many fine pores on the surface of the membrane allow only water and small molecules to pass through and become permeate, and the substances in the undiluted liquid having a volume larger than the pores size are trapped in the liquid inlet side of the membrane and becomes a concentrated liquid, thus achieving the purpose of separating and concentrating the raw liquid.

2.6.3. UV Irradiation

UV irradiation disinfection is a fast and efficient physical inactivating process on microorganisms. This process uses the special wavelength of UV light to destroy the molecular structure of DNA (deoxyribonucleic acid) or RNA (ribonucleic acid) in the cells of microorganisms, causing growing cell death and/or regenerative cell death, which means they lose their ability of reproduction, in order to achieve the effect of sterilization. It has advantages of no additives (the physical and chemical properties of the water are unchanged), wide range of sterilization, short processing time and a small footprint.

2.6.4. Ozone

Ozone is an excellent disinfectant. All the sterilization processes of ozone are biochemical oxidation reactions due to its strong oxidation ability. Although ozone has a significant inactivation effect on almost all bacteria, viruses, fungi and protozoa as well as oocysts, there are some organic compounds are difficult to be oxidized which include many solvents, most pesticides and compounds that cause taste and odor (2-methylisobornyl and goemin), which are produced during algae growth and decay. These saturated organic substances are hardly oxidized by ozone in a short time (M Kritševskaja, 2008).

2.6.5. Chlorine Gas

Chlorine disinfection is a method that using chlorine gas to oxidize harmful materials in order to disinfect the water. Its benefits are low cost, mature technology, stable and reliable. Since the chlorination method usually requires a minimum 30-minute contact time, the contact tank is bulky; in addition, chlorine is a very toxic dangerous product, and the gas cylinder that stores chlorine is a high-pressure container, posing a potential threat.

2.6.6. Ion Exchange (IO)

IO is able to remove any ionic (charged) substance from the water but is typically used to remove hardness and nitrate from groundwater in drinking water processes (National Drinking Water Clearinghouse, 2005). Compared with the RO (reverse osmosis) device which has been very popular in recent years, it has the advantages of a higher ionic impurities removal, a lower water pretreatment requirement and a lower equipment cost.

Table 1. Comparison of several drinking water treatment technologies

Drinking Water Treatment Technology	Degree of difficulty	Effectiveness	Cost
Slow sand filtration	Easy	Not effective enough	Low (can be costly when deal with large volume)
Membrane filtration (Pressurized Systems / Gravity-Fed Systems)	Medium / Easy	Highly effective / Effective only when volume is sufficient	High / Medium
UV Irradiation	Medium	Effective	Low
Ozone	Medium	Effective	Medium
Chlorine Gas	Easy	Effective but bring in byproducts	Medium
Ion Exchange (IO)	Difficult	Highly effective	Medium

Chapter 3. Current water pollutants and their sources in Zouping County

3.1. Water pollutants

The water resources in Zouping County are divided into surface water (water reservoir water) and underground water (shallow well water, deep well water).

There are 5 major rivers passing through Zouping County. Namely Xiaoqing River, Xinghua River, Xiaofu River, Zhangqi Ditch and Shengli River.

According to the research results made by Shandong Environmental Protection Department in 2017 (the results will be shown in following Table 2.), in the 11 sections of 6 rivers in Xiaoqing River Basin, 6 water sections (sites) met Grade IV water quality standard, taking up 54.5%; 2 water sections (sites) met Grade V water quality standard, taking up 18.2%; 3 water sections (sites) failed to meet Grade V standard, taking up 27.3%.

Figure 2. Zouping County

Source: Google Map

Table 2. Binzhou City Main River Water Quality Category (Partial interception)

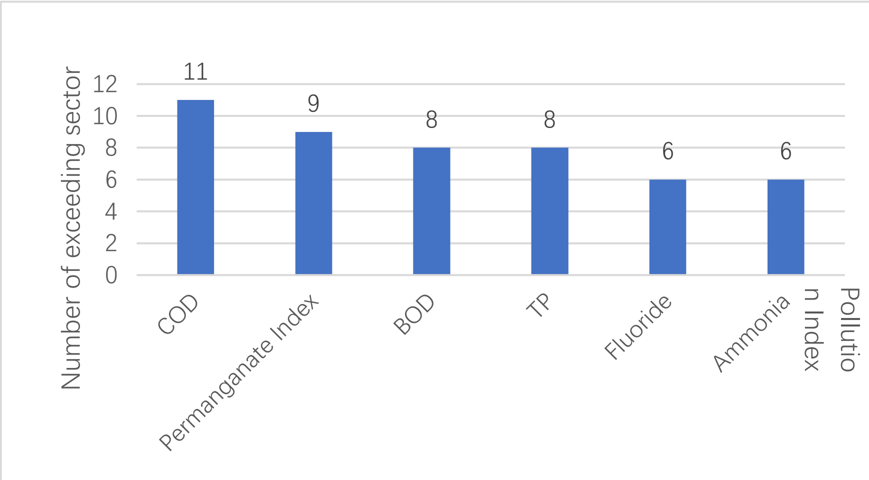
Number	Name of River	Name of Section	Upstream and Downstream Cities (Counties)	Location	Water Quality Category		Name of Watershed
					2017	2016	
1	Xiaoqing River	Xizha	Zibo City-Binzhou City	Xingbo County	V	V	Xiaoqing River watershed
		Fanli	Binzhou City-Dongying City	Xingbo County	IV	Below grade V	
		Tangkou	Binzhou City-Zibo City	Zouping County	Below grade V	-	
		Weiqiao	-	Zouping County	Below grade V	Below grade V	
2	Xinghua River	Zhangguanzhuang	Binzhou City-Zibo City	Zouping County	Below grade V	Below grade V	
3	Xiaofu River	Changshan	Zibo City-Binzhou City	Zouping County	IV	IV	
		Yuanjiaqiao	-	Zouping County	IV	-	
4	Zhangqi Ditch	Entrance to Xiaoqing River	Jinan City-Binzhou City	Zouping County	IV	IV	
5	Shengli River	Entrance to Xiaoqing River	-	Zouping County	IV	-	

Source: Binzhou Daily, 2017

Shandong Environmental Protection Department investigated major pollutants in Xiaoqing River Basin in 2017 (the results will be shown in following Figure 5.).

The research result shows that 91.67% sectors fail to meet the COD standard, 66.67% sectors fail to meet the BOD and TP standard, and 50% sectors fail to meet the standard of Fluoride and Ammonia.

Figure 3. Statistics of Major Pollution Indicators in Xiaoqing River Basin



Source: Binzhou Daily, 2017

In another research made by Wang Yan (Wang Yan et al., 2016) shows that the major excessive test items in Zouping County are sulfate, total hardness and microorganism.

Table 3. Different Rural Drinking Water Items Detection in Zouping County

Items	Number of Samples	Qualified Numbers	Pass Rate (%)
Sulfate	72	56	77.78
Total hardness	72	57	79.17
microorganism	72	59	81.94

Source: Wang Yan, Sun Haowen, & Liu Ping, 2016

Researcher tested 8 shallow well water, 8 reservoir water and 56 deep well water. The test result shows that the qualified rate of deep well water quality in Zouping County (61.11%) is higher than that of shallow well water (25.00%) and reservoir water (25.00%)(Wang Yan et al., 2016). The difference is statistically significant (χ^2=6.37, $P<0.05$).

Table 4. Different Sources of Water Quality Testing

Water Source	Number of Samples	Qualified Numbers	Pass Rate (%)
Shallow well water	8	2	25.00
Reservoir water	8	2	25.00
Deep well water	56	34	61.11
Total	72	38	52.78

Source: Wang Yan, Sun Haowen, & Liu Ping, 2016

3.2 The sources of pollutants

Considering natural factors, Zouping County is located in the overlapping area between River flood plain and Thaiyi Mountainous area. The water source of River flood plain in the northwest of Zouping County is primary geological brackish water. Because of the impact of mountainous regions, the total water hardness, total dissolved solids, sulphate, arsenic, fluoride, etc. are exceeded limits (Wang Yan et al., 2016).

Some human factors also need to be taken into account. Firstly, the alternation of water source and the surrounding environment are flawed. The ground surface is polluted by municipal solid waste, and the water quality is not effectively purified and disinfected after extraction.

Secondly, the local village enterprises are mostly heavily polluting manufacturing industries and those enterprises discharge wastewater without proper treatment. According to a survey conducted by the Shandong Environmental Protection Department, there are a number of industrial enterprises that discharge industrial wastewater into ditches, ponds, and rivers without any measures to reduce pollution. These enterprises are mostly small and medium-sized chemical plants, electroplating factories and knitting factory for instance. The wastewater discharged by these companies contains heavy metals (Hg, Pb, Cr, Cd, etc.) and other toxic inorganic substances (such as fluorides, arsenide, nitrites, etc.). In addition, there are many chemical industries in Zouping County, which lead to exceeding concentration of phenol, benzene, chloroform, carbon tetrachloride, and synthetic detergents in the water (Qu Haiyan, 2014).

Drinking water might also be polluted during transport process. Zouping Water Supply Pipeline is aging after more than 30 years of operation. At present, the leakage rate of partial water supply pipes is nearly 20%, which indirectly affecting the disinfection effect and sensory traits of water quality (Tang Ning & Cheng Hua, 2017).

Chapter 4. Possible solutions for drinking water dilemma

4.1. Drinking Water Standards

The mountainous area in the southern part of Zouping County accounts for 20% of the county's area, and more than 50% groundwater in the plain area is high salinity water (Zouping County Water Bureau, 2015).

Now Zouping County is facing two drinking water dilemmas. One is the current hygienic status of rural drinking water cannot meet the standard.

The proposed solutions should be able to meet the relate provision of ‘Rural drinking water safety and health evaluation index system’, which set by the MWR and Ministry of Health.

Another problem is the shortage of volume. Hilly area in Zouping County cannot access the Yellow River water, the only drinking water source is groundwater supply (“People.cn,” 2018).

The nearby coking plant extracted groundwater for industrial using. The depth of the well reached 100 meters, which seriously affected the villagers' use of well water irrigation.

1. Water quality standard

According to the ‘Rural drinking water safety and health evaluation index system’ set by the MWR and Ministry of Health in 2004, drinking water meets the requirements of the ‘National Hygiene Standards for Drinking Water’ is safe water; drinking water meets the requirements of the ‘Guidelines for Implementing Drinking Water Sanitation Standards in Rural Areas’ is the basic safety water.

Due to the vastness of China’s territory, the water quality is complex and the rural economy has been unevenly developed. According to the specific situation, the requirements for water quality classification in rural areas were put forward by the Ministry of Ecology and Environment (Gao Fenghua, 2007).

Therefore, the quality of water supply for new construction projects should generally meet Class I requirements. If there are no other alternative sources of water and treatment conditions are limited, they must be within the maximum limit of allowable relaxation, i.e., meet the tertiary water quality requirements.

2. Volume standard

According to the relevant regulations of ‘Rural drinking water safety and health evaluation index system’ formulated by the MWR and the Ministry of Health in 2004, the amount of water available per capita per day not less than 40-60 liters is safety; not less than 20-40 liters per capita per day is basic safety.

According to climate characteristics, topography, water resources conditions and living habits, China is divided into 5 different type of areas, different areas have different specific water standards. Shandong Province is in three types of areas. According to Table 7, the safety standard is 50 liters per capita per day and the basic safety standard is 30 liters per capita per day.

4.2. Possible options for water sanitation

For areas in Zouping County which can access to tap water supply network, the first thing to do would be pipeline network transformation. Since the water pipe network in the old town of Zouping County was built in 1982, the operation time has been more than 30 years. At present, the leakage rate of some water supply pipes is as high as nearly 20%. There is a big gap with the national standard of 6% or less (Tang Ning & Cheng Hua, 2017). Since water leakage and instable water pressure has occurred these years, it would be inefficient to disinfect water without rebuilt pipeline.

Since the water sources in Zouping County are original geological brackish water, brackish water desalination is needed. It is possible to reduce the fluorine content in drinking water in high fluorine areas by implement the fluorine reduction and water improvement project or use physical technology. Because high-fluorine water is mainly distributed in shallow groundwater, deep wells can be used as drinking water source in the high-fluoride areas. Physical technology can also be used to reduce fluorine. Such as coagulation and sedimentation. Added lime and calcium chloride or aluminum salt to water and form a colloidal precipitate with fluorine to achieve defluorination (Jin et al., 2015).

The assessment of technologies should involve two major dimensions. One is the characterization of a technology's economic aspects, another one is the significance of a technology (Bhatnagar & Jancy, n.d.).

Economic factors are one of the primary considerations when implement drinking water treatment technology in rural areas. The cost of technology should be relatively low and the operation process should be as easy as possible.

Slow sand filter might be the cheapest and simplest water treatment method under suitable circumstances (Huisman,L. & Wood,W.E., 1974).

However, slow sand filter cannot fully treat highly turbid water. Therefore, settling tanks or pre-filtration sand-sieves should be added to reduce the water turbidly before treated by slow sand filter (Ray & Jain, 2011).

The flow rate of slow sand filtration range from 0.015 to 0.15 m^3/m^2h which can be as much as an order of magnitude lower than other technologies per unit output. Thus, for large water volume, large filter beds are needed (Ray & Jain, 2011).

Those factors increase the investment of slow sand filtration. And make the advantage of slow sand filter not that significant.

UV disinfection does not produce any harmful by-products and does not affect the odor and mouthfeel of the water; while chlorine disinfection may produce trihalomethanes, and ozone may produce bromate. The cost of a UV unit is one third of ozone disinfection technology (Zhenxing Yao et al., 2013).

Although UV has a high inactivation rate for various pathogens, UV does not have the same disinfecting ability as chlorine disinfection. UV units only kill bacteria at one point in a water system which means UV disinfection does not maintain continuous disinfection protection of water in the pipe network. Bacteria cells are not removed in a UV unit. Cells are converted into pyrogens and become a food source for any bacteria that survive downstream of the UV unit. In order to solve these problems, UV is usually used in combination with other disinfectants.

The applicable conditions for UV disinfection are harsh, and the requirements for water treatment are relatively high. The appearance of organic substances will contaminate the UV lamp, and its disinfection effect will be reduced, requiring regular cleaning and maintenance. Changing a light bulb doesn't requires much knowledge, but it requires significant knowledge of which specific type of bulb is needed (Issam Najm & R.Rhodes Trussell, 1999).

Due to the limitation of use and water supply scope, rural township water plants in China are basically small and medium-sized, with a small amount of water supply and a short pipe network which cannot guarantee sufficient contact time of water and disinfection media. Most rural areas are poor by income, and the cultural level of water managers is generally not high. Therefore, the disinfection technology and equipment selected by rural water plants usually have the characteristics of rapid disinfection, easy operation, low construction and operation cost (Lu et al., 2017). Chlorine disinfection is the main disinfection technology used by rural water plants, mainly using sodium hypochlorite for disinfection. Since the 1990s, more and more small and medium-sized water supply projects in China have begun to use chlorine dioxide for disinfection. At present, the chlorine dioxide disinfection method for drinking water mostly uses a composite chlorine dioxide generator which reacts with hydrochloric acid and sodium chlorate (Lu et al., 2017). Since, the consumers lack complete awareness of use and long-term benefits of new technologies, implementing new practices are more of an uphill task both for the local and central government.

Unlike chlorine, chlorine dioxide does not hydrolyze in water (Evoqua water technologies, 2017). Since chlorine dioxide is present in a molecular state almost 100% in water, it easily penetrates the cell membrane. At the same time, the effective chlorine content of chlorine dioxide is 263 %, its oxidizing property is 2.6 times that of liquid chlorine, and the bactericidal effect is significantly higher than liquid chlorine (Dai Yuanyuan et al., 2011). Chlorine dioxide disinfection reduces the production of chloroform in water by 90% and systematically prevents the formation of chlorophenol odors. In addition to killing common bacteria, it has a good killing effect on spores, viruses, algae, iron bacteria, sulfate reducing bacteria and fungi.

Studies have shown that chlorine dioxide compared with other reagents, according to its redox potential: O_3(2.07) > ClO_2(1.511) > Cl_2(1.36) > OCl^-(0.89); disinfection persistence order: ClO_2 > NaClO > $C1_2$ > O_3 (Dai Yuanyuan et al., 2011). It is concluded that chlorine dioxide is a good disinfectant and a strong oxidant. Chlorine dioxide is the best in the concentration required to achieve the same disinfection effect under the same conditions, and has a continuous sterilization ability (Dai Yuanyuan et al., 2011).

4.3. Possible options for water shortage

To solve water shortage, drinking water configuration optimization is needed. Optimized scheduling of available water sources, ending the drinking water problem of unsafe drinking water.

The most common water supply methods in rural China are large-scale centralized water supply, joint village water supply and single village water supply. For those areas which use plain reservoir or shadow groundwater as water source, large-scale centralized water supply can be the promising option for water supply. Under the condition that the water quality and quantity of water source meet the requirements, several villages can form a water supply unit to jointly supply water. For the remote location of the village, when there is a certain water source, the single village water supply mode can be adopted (Gao Fenghua, 2007).

According to water resource condition, Zouping County can be divided into 3 parts, which are high salt area in northwest, Xiaofu River area and Xinghua River contaminated area and deficient water area.

The high-speed economic development in Zouping County recent years, result in serious industrial water pollution. The shallow groundwater in Xiaofu River area and Xinghua contaminated area are no longer suitable for drinking. Therefore, these areas can base on deep well water supply and develop deep underground water according to local conditions in the near future. High salt area in northwest can use dock reservoir as water source.

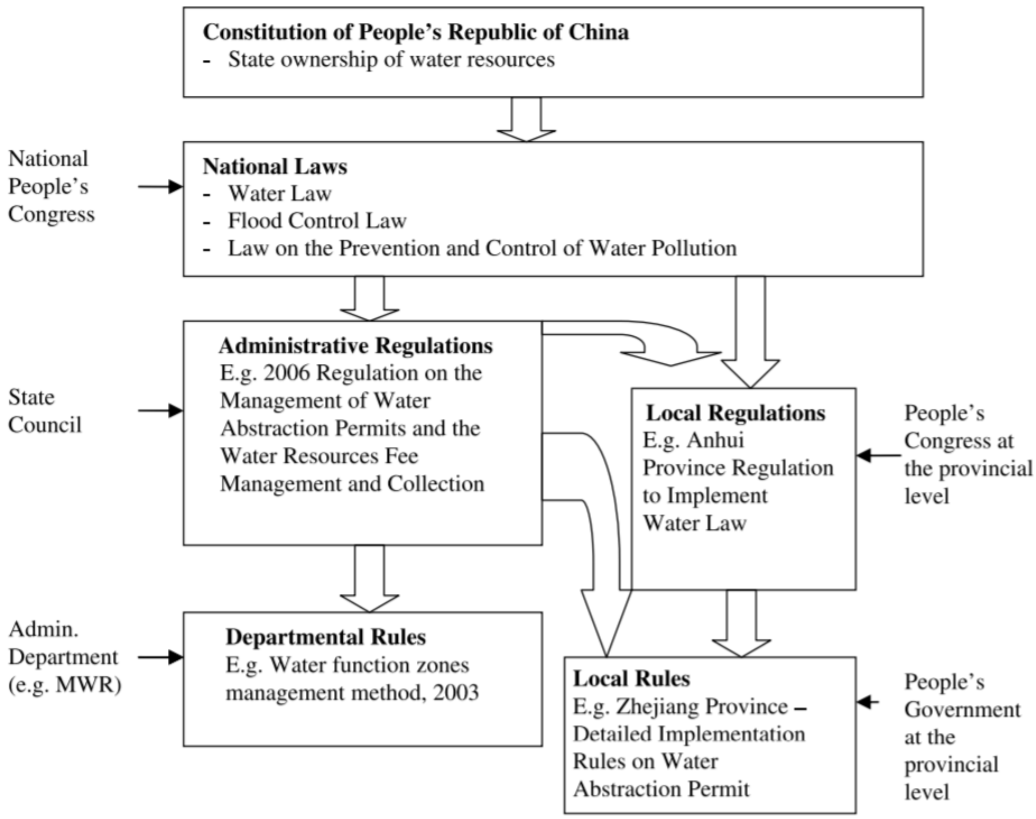
The high-fluorine and high-salt areas along the Xiaofu River and the Xinghua River and high salt area in northwest should use the joint villages centralized water supply. The deficient water area uses single village water supply.

Since the Xiaofu River area and Xinghua River contaminated area and deficient water area are using deep groundwater as water source, there is only few treating steps before send into households. The water in high salt area should be unified treatment by the water supply station.

Due to the difficulty of replenishing deep groundwater, under the principle of sustainable use of water resources, it should be carefully exploited. Therefore, deep groundwater can only be used as a backup resource. In the long-term planning of rural drinking water sources in Zouping County, Handian Reservoir should be used as the main water source to replace the exploitation of deep groundwater (Gao Fenghua, 2007).

Chapter 5. Legal framework and regulatory

Figure 4. China's Legal Framework

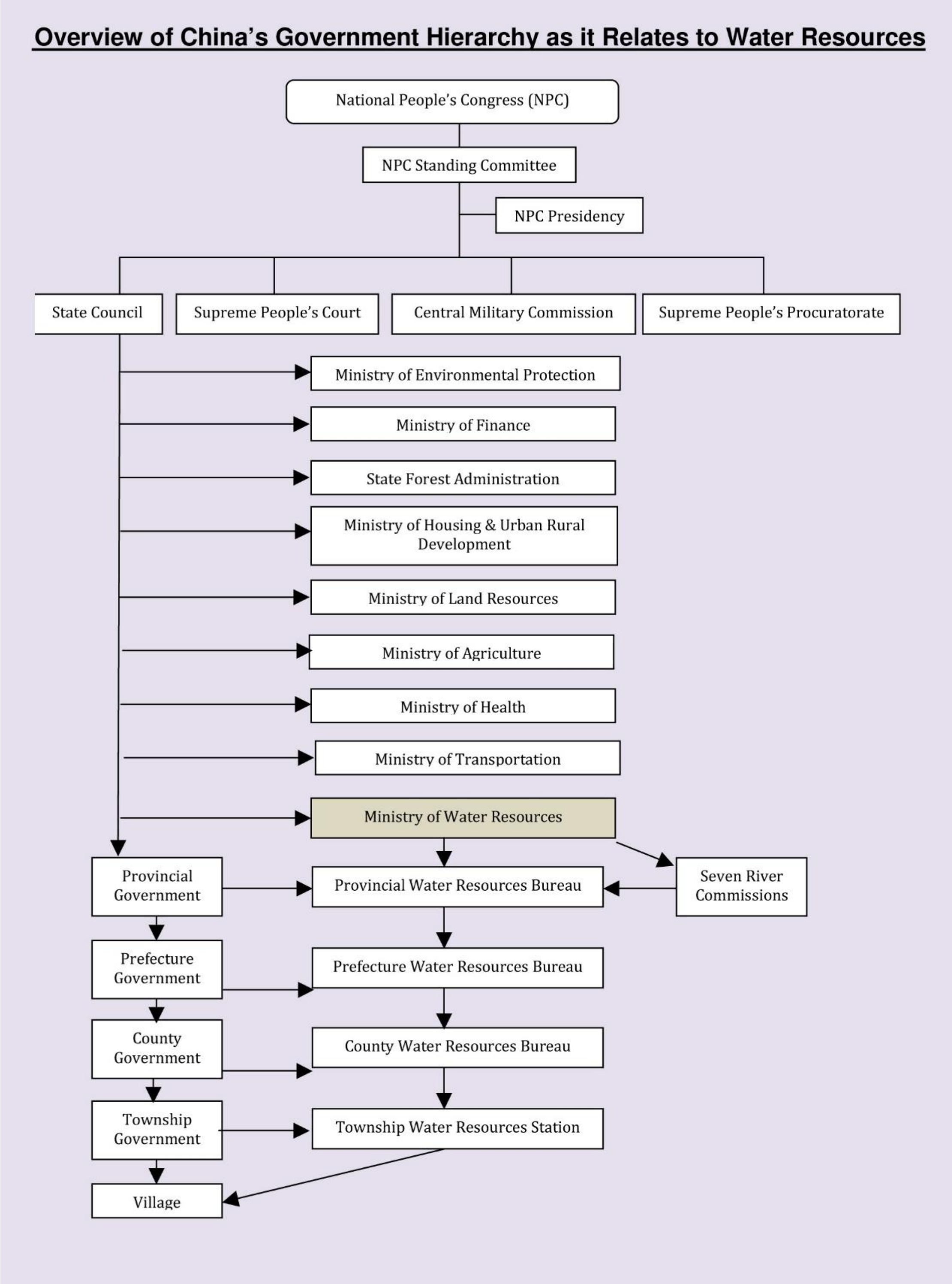


Source: Bin Liu & Robert Speed (2009)

Within the Chinese system, laws are supported by a system of administrative regulations (passed by the country's executive body, the State Council), local laws and regulations (passed by the People's Congress at the provincial level), and both national departmental rules and provincial government rules (made by administrative departments, such as the MWR) (Figure 2)(B. Liu & Speed, 2009). The water sectors work under legislation and standards set by Chinese government and regulators. While national laws and rules set the principles, these requirements are often general in nature and local governments usually have discretion in how these are implemented (Wouters et al., 2004).

China's water management arrangements are primarily set through national laws and policies, for implementation by provincial, prefectural and county governments (Cosier & Shen, 2009).

Figure 5. Overview of China's Government Hierarchy as it Relates to Water Resources



Source: i) Economic Research Services/USDA, "China's Agricultural Water Policy Reforms/AIB-782″ and ii) WEPA website

China faces the problems of flood and waterlogging, drought, water shortage, serious water pollution, soil erosion and other problems that restrict economic and social development. The promulgation of the water law is imperative.

In 1984, the MWR drafted the Water Law of the People's Republic of China. The draft has been discussed and executed at the State Council executive meeting in 1988 (“Overview | China Water Risk,” n.d.).

After decades, the Water Law (1988) can no longer meet the actual needs. Thus, the MWR drafted the Water Law of the People's Republic of China (Revised Draft) and reported it to the State Council in June 2000. The revised draft has been discussed and executed at the State Council executive meeting in 2002 (The Ministry of Water Resource, 2001).

The 2002 Water Law (which revised the 1988 Water Law) is China’s key water legislation and provides a comprehensive framework for integrated water management (National People’s Congress of the People’s Republic of & China, 2002).

With the introduction of the Law on the Prevention and Control of Water Pollution in 1984 and the Water Law in 2002, China established regulatory control for the prevention and control of fresh water pollution and use of its water resources (“Overview | China Water Risk,” n.d.).

Institution arrangements

Even though Zouping County is under the administration of Binzhou City, the Binzhou Water Affairs Bureau does not play a major role in managing the prefecture’s water system. Because the provincial government is responsible for setting policies governing the implementation of the national management framework. County-level administrations in Shandong have a large implementation role (Cosier & Shen, 2009).

Binzhou’s water services are operated by separate companies that fall under the Binzhou Water Affairs Corporation.

The Zouping County Water Affairs Bureau is the water administrative department of the county government, which consists of 19 departments. It is responsible for organizing and implementing the county's long-term water development strategy, flood control and drought relief, water resources management, water conservancy construction and management, urban and rural water supply, and urban drainage. Sewage treatment, ecological water environment construction, water conservation management, soil and water conservation and soil erosion control, farmland water conservancy construction, water administrative law enforcement and fee collection, water conservancy science and technology promotion, water economic development, etc.

The Zouping Yellow River Authority is a subsidiary of the Binzhou Yellow River Authority. The Zouping Yellow River Authority fulfilled the functions of water management in the Zouping reach of the Yellow River Basin, promoted the comprehensive management and development of the Zouping reach of the Yellow River Basin, research and development of watershed policy and water resources, watershed water administrative law enforcement and water administration supervision, planning and implementation of water resources development plans, watershed management

Resource management and protection, river basin flood control plan development, coordination with flood control and drought relief, coordination of water disputes among villages and townships in river basins, and construction and management of important water project organizations in river basins(Lu et al.,2010).

Zouping County Environmental Protection Bureau implements wastewater pollution source control and stabilization projects and livestock and poultry aquaculture pollution control projects and intensifies the construction of urban sewage treatment plants. All towns (sub-districts) in Xiaoqing River watershed have completed sewage treatment plants. Environmental Protection Bureau actively guide the reuse of water resources so that processed water can be reused. The 50,000-ton water reuse project of the county municipal sewage treatment plant is used for water use in the industry and landscape of our county, and effectively resolves the current situation of water shortage in the county's economic development.

Chapter 6. Assess Water Management System in Zouping County

6.1. The Actors and their roles

The Binzhou Water Affairs Bureau is the water administrative department of Binzhou Municipal Government, responsible for the unified management of the city's water conservancy industry and water resources.

The provincial authority and the water authority both contributes to the water planning which includes drinking water as well.

The Zouping County Water Affairs Bureau is a subordinate department of Binzhou Water Conservancy Bureau. The Water Affairs Bureau is the county's water administrative department, responsible for the integrated management of all water-related affairs in the county. The Water Affair Bureau plays an important role in policy implementation.

The drinking water supply is managed by Zouping tap water company and is regulated in the Water Law. The shares of business must be in public ownership. Thus the water company partially act as government institution.

There are also some water companies providing raw water for the Zouping tap water company to ensure water supply is sufficient.

The stakeholders in the process are customers, authorities, governments and enterprises throughout the chain.

6.2. Improve suggestions for water supply management

Zouping's drinking water management structure is clear, but the drinking water safety problem can be seen. The reason behind this phenomenon might be the insufficient execution and supervision.

Although many policies and environmental propaganda often write about zero tolerance for pollution, the actual situation is quite different. Many enterprises still discharge sewage illegally. This increases the difficulty of protecting the water source and directly or indirectly affects the safety of residents' drinking water. Therefore, the environmental department should strengthen supervision and management, improve water source supervision and management, and strengthen the maintenance, repair and transformation of the pipeline network. The administrative law enforcement departments should strengthen the health supervision, make sure water quality sanitation supervision in all processes, and regularly follow up and test the water quality to ensure that the water quality meets the sanitary standards.

In addition, the lack of effective supervision of the use of rural infrastructure funds result in the shrink of funds. The lack of supervision is mainly due to the delay in administrative system reform, information asymmetry, and budget incompleteness. In addition, farmers lack the ability of democratic supervision and lack the ability of democratic supervision to effectively supervise the use of rural infrastructure supply funds. Due to the lack of supervision, the management of rural infrastructure supply funds is chaotic, and the phenomenon of misappropriation and abuse is endless, and the black-box operation is prominent. The limited funds have been “shrinked” in the black-box operation, and the remaining funds have been “filled with water” during the usage process, and many “tofu” projects have appeared (Yunhan Zou, 2017).

Financial investment is an important requirement for efficient drinking water management. Along with behavioral change and awareness awakening, technology promotion for short and long-term changes are required. It is necessary to invest money to construct tap water pipeline in the whole county and reconstruct the existing old pipeline. However, without the behavioral change of industries and villagers’ awareness awakening to change the current situation of water source pollution, it is still hard to achieve safe water drinking.

Chapter 7. Conclusions and Recommendations

Zouping’s long-standing problem of water source is that the original geological brackish water, high fluoride and high iodine groundwater are widespread, while the surface water is less and polluted. It cannot be used as drinking water, and there are many unsafe drinking water populations, which seriously endangers the physical and mental health of the villagers. Therefore, it is very necessary and urgent to solve the problem of rural drinking water insecurity. However, due to the relatively underdeveloped economy in the region, the task is very arduous and quite difficult.

The construction of rural infrastructure in small towns basically rely on state subsidies and local financial funds, and the higher authorities have most of the administrative jurisdiction. With the rapid development of various towns and rural undertakings, the pressure on the shortage of rural infrastructure construction is also increasing. At the same time, most of the infrastructure construction is a public welfare undertaking, which does not produce direct economic benefits and is difficult to obtain credit support. The state's funds for supporting rural infrastructure construction are very limited. Farmers are generally less motivated to projects without state investment, and there is almost no social input. Some townships and villages have heavy liabilities due to historical reasons and are unable to raise funds for rural infrastructure construction. These have directly restricted the rapid development of rural municipal public infrastructure and become a "bottleneck" problem that restricts rural economic and social development (Yunhan Zou, 2017).

Therefore, the state government should continue increase the investment and support rural drinking water safety in underdeveloped areas. Generally speaking, most of the rural areas with unsafe drinking water have poor natural conditions, financial poverty, and relatively backward economic and social development. It is suggested that in matching funds, the matching funds of the state, province and city should be tilted to economically underdeveloped areas, and the proportion of investment should be increased. Increase the proportion of countries investment and reduces the proportion of cost of local and farmers.

Also, the state should expand financing channels. Formulate preferential policies, take various measures to actively promote market-based financing of rural public welfare infrastructure projects, adopt shareholding system, investment funds, transfer of management rights, and fiscal interest subsidies and commitments to attract foreign investment, encourage and guide social funds to invest in large-scale infrastructure. Social welfare projects such as environmental protection, in order to open up diversified financing channels. It is necessary to strengthen the existing fund management, strengthen the interconnection of relevant professional construction plans, prevent waste of resources, and repeat construction.

According to the current situation of rural domestic water use, encouraging farmers using water should be the main policy objective when formulating the water price (Dakai Yang & Ruojun Wang, 2011). At present, the price of tap water in China is generally low, and this situation is particularly serious in rural areas. Water fees account for 0.5% to 1% of farmers' per capita net income, which is a water price that farmers can accept. When water fees account for about 3% of per capita income, water prices are acceptable and can enable people to start saving water. The proportion of water fees in China's disposable income is far below this level. The proportion of water fees in China's disposable income is far below this level.

With the acceleration of rural urbanization, China's water shortage and water pollution problems are becoming more and more serious. Human activities have caused a lot of damage to the environment and threatened groundwater quality, making the use of shallow groundwater not guaranteed. At the same time, human use of groundwater often competes with environmental needs, and excessive mining can lead to serious environmental degradation, sometimes even irreversible. Rural drinking water suffers from serious water quality and reduced water availability. Therefore, we need to balance the human needs and environmental needs to ensure the sustainable exploitation of groundwater, control the exploitation of groundwater to reduce ecological damage and improve public health level.

Therefore, encouraging farmers to use tap water with centralized water supply as the main domestic water is an important task of the current rural water supply system. In the development of water prices, it should be considered that farmers have not been required to pay for water in their own wells for a long time. Therefore, if the price of water is greatly increased, it will affect the farmers' psychological endurance and affordability of water, and the two will affect each other. Each additional penny expenditure will affect the affordability.

Although the current rural water fee income in China cannot compensate for the engineering water price in the full cost pricing, the substantial increase in water price is not conducive to public health and environmental protection. This is because if we increase the price of water significantly, it will reduce the willingness of farmers to use tap water and increase the use of shallow groundwater. Therefore, in order to protect the environment resources, rural water prices should not be greatly increased. Instead, water safety should be considered, the water price should be reduced to encourage farmers using tap water.

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Author
Yu Yan

APPENDIXES

Appendix 1. Research Framework

1. Research objective

The objective of this research is to identify drinking water pollutants in Zouping County, find appropriate drinking water treatment technologies, assess the current drinking water manage system and modify the system based on regulatory framework.

2. Research object

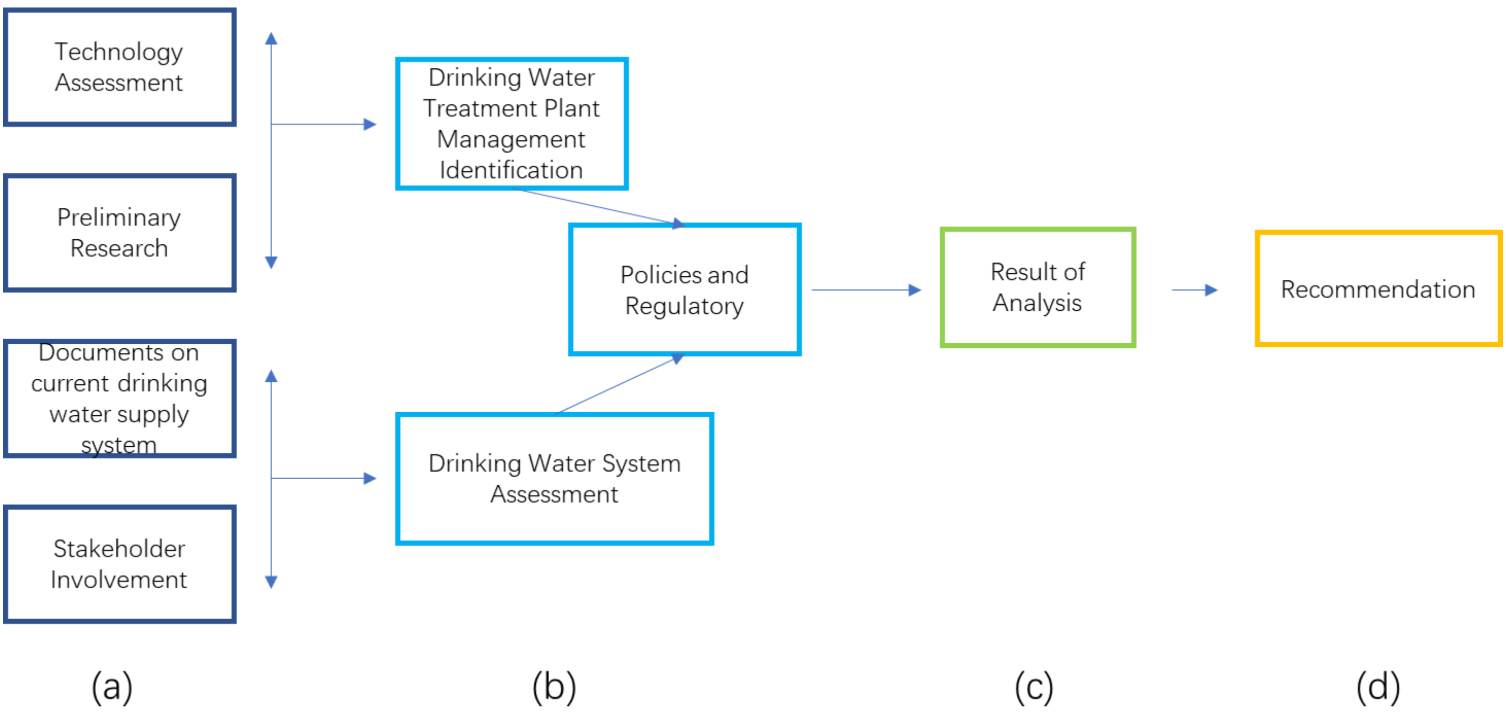
The research object is the drinking water supply system in Zouping County.

3: Research framework

The research framework is described through the following flow charts:

4. Research Questions

Figure 6. A Schematic Presentation of Research Framework



The main research question:

What are the possible options to tackle the plight of drinking water supply and sanitation in Zouping County?

Sub-research questions:

1. What are the water pollutants in this area?

2. What are the possible options of water disinfection for this area?

3. What is the current situation of drinking water supply system?

4. What are the drawbacks in current drinking water supply system?

5. Formulating the research framework

(a) An analysis of the data from drinking water, theories of technology assessment and preliminary research on the drinking water treatment

(b) By means of which the research object will be identified

(c) Confronting the result of the analysis as the basis for recommendation

(d) Recommendation with regard to solve the problem

Appendix 2. Environmental Quality Standards for Surface Water

Grade		Standard Classification	Function
Grade I		Mainly applicable to source water, national nature reserve	Good water quality. The groundwater only needs to be disinfected, and the surface water can be used for living and drinking after simple purification treatment (such as filtration) and disinfection
Grade II		Mainly applicable to centralized drinking water, first-grade protection areas for surface water sources, rare aquatic habitats, fish and shrimp spawning grounds, and feeding grounds for juveniles and young fish	Water quality is slightly polluted. After conventional purification treatment (such as flocculation, sedimentation, filtration, disinfection, etc.), the water quality is available to the consumer
Grade III		Mainly applicable to centralized drinking water, secondary protection areas for surface water sources, wintering of fish and shrimps, migratory passages, aquaculture areas and other fishery waters and swimming areas	Applicable to secondary conservation areas of centralized drinking water sources, general fish conservation areas and swimming areas;
Grade IV		Mainly applicable to general industrial water use areas and recreational water areas where the human body is not in direct contact	Suitable for general industrial protection zones and recreational water zones where the human body is not in direct contact
Grade V		Mainly applicable to agricultural water areas and general landscape waters.	Applicable to agricultural water areas and general landscape waters

Source: National Standards of People's Republic of China

Appendix 3. Drinking Water Quality Classification Requirements

Item	Grade I	Grade II	Grade III
Sensory Traits and General Chemical Indicators			
Chroma	15	20	30
Turbidity	3	10	20
Visible	None	None	None
pH	6.5~8.5	6~9	6~9
Total Hardness (mg/L-$CaCO_3$)	450	550	700
Iron (mg/L)	0.3	0.5	1.0
Manganese (mg/L)	0.1	0.3	0.5
Chloride (mg/L)	250	300	450
Sulfate (mg/L)	250	300	400
Dissolved Solid (mg/L)	1000	1500	2000
Toxicological Indicators			
Fluoride (mg/L)	1.0	1.2	1.5
Arsenic (mg/L)	0.05	0.05	0.05
HG (mg/L)	0.001	0.001	0.001
Cadmium (mg/L)	0.01	0.01	0.01
Chromium (mg/L)	0.05	0.05	0.05
Lead (mg/L)	0.05	0.05	0.05
Nitrate (mg/L-N)	20	20	20
Bacteriology Index			
Total Number of Bacteria (No./ml)	100	200	300
E. coli (No./ml)	3	11	27
Free Residual Chlorine (mg/L)	0.3	0.3	0.3

Annotation: Grade I is the required value; Grade II is the allowed value and Grade III is the relaxation limit when there is no other water source.

Appendix 4. Rural drinking water quantity indicators in different regions

Partition	Domestic water quota standard (L/ capita. d)	
	Safety	Basic Safety
Distinct One	40	20
Distinct Two	45	25
Distinct Three	50	30
Distinct Four	55	35
Distinct Five	60	40

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