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Article

A Review of China's Rural Water Management

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Abstract: With less than 6% of total global water resources but one fifth of the global population, China is facing serious challenges for its water resources management, particularly in rural areas due to the long-standing urban-rural dualistic structure and the economic-centralized developmental policies. This paper addresses the key water crises in rural China including potable water supply, wastewater treatment and disposal, water for agricultural purposes, and environmental concerns, and then analyzes the administrative system on water resources from the perspective of characteristics of the current administrative system and regulations; finally, synthetic approaches to solve water problems in rural China are proposed with regard to institutional reform, regulation revision, economic instruments, technology innovation and capacity-building. These recommendations provide valuable insights to water managers in rural China so that they can identify the most appropriate pathways for optimizing their water resources, reducing the total wastewater discharge and improving their water-related ecosystem.

Keywords: integrated water management; water availability; water pollution; rural China

1. Introduction

With less than 6% of total global water resources but one fifth of the global population, China is facing serious challenges to its water resources management, particularly in the rural areas due to the long-standing urban-rural dualistic structure and economically centralized developmental policies [1,2], such as water scarcity [3,4], unsafe drinking water [5], water pollution and arbitrary disposal of wastewater from township enterprises [6,7], incomplete water infrastructure [8,9], corresponding ecological and human health risks [10,11] and imperfect management system [12]. To provide safe drinking water and sufficient water resource supply for rural China has become an important priority in China's 12th 5-year plan [13,14], while water pollution control has become a major concern in policy-making at different levels [15]. However, few studies have been conducted in order to address the water issues in rural China [16,17]. Previous studies indicate that water issues have been a key factor affecting the long-term sustainable development of China [18]. For example, over half of the 1.3 billion people in China drink water that is contaminated with chemical and biological pollutants, such as petroleum, ammonia nitrogen, volatile phenols and mercury [19]. In addition, approximately 88% of sicknesses and 33% of human deaths were directly linked to unsafe domestic water and nearly 700 million and 180 million people have drunk water containing excessive E. coli bacteria and organic pollutant concentrations, respectively [20]. Therefore, it is important to conduct an overview study on water issues in rural China and provide more appropriate recommendations for improving the overall management level.

2. Water Crises in Rural Areas

2.1. Potable Water Supply: Quantity and Quality

More of the rural population could have better drinking water facilities with the great efforts made by the Chinese government. However, until 2010 there was still a rural population of 298 million who cannot receive safe drinking water service. That is because of different characteristics indifferent rural areas (including vast areas, scattered villages, various terrain and climate) make it difficult to use water supply infrastructure, leading to drinking water supplies available [3]. Many rural populations still cannot receive safe drinking water service and have to use surface water, shallow groundwater and rainwater as their 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 [4]. Tap water rates in rural China were only 39.5%, 43.7%, 48.1% and 54.7% from 2007 to 2010, respectively. In 2012 the per capita tap water consumption in urban areas was 171.8 L, while the figure in rural areas was less than 85 L [5].

Lack of effective water quality monitoring is another key issue, making it difficult to manage centralized and decentralized water supply. For instance, due to poor water quality monitoring in Hubei [21], although several centralized waterworks that collect surface water add disinfectants in order to meet national regulations, most waterworks that collect groundwater do not. Such a reality means that the bacteria-related water parameters exceed the national standards, inducing public health concerns. In addition, water quality in some decentralized water supply facilities cannot meet the national standards. Specifically, 37.5% and 50% of the tap water samples from the centralised supply facilities did not reach the national standards for Grade III (National Water Quality Grade III is designed for water sources for drinking purposes (second level water protection areas), fish and shrimp ponds, fish migration channels, aquaculture areas, and swimming areas) [21]. Plus, the lower national water quality standard further complicated this issue. For example, among the non-carcinogenic health risks resulting from drinking water in Ya'an, Sichuan province, the higher concentrations of Pb F, Hg, Cr^{6+} have led to serious public health impacts (in decreasing order). However, the concentrations of these contaminants (with details shown in Table 1) are still within the scope of national water quality standards approved by the Ministry of Environmental Protection, but higher than the maximum acceptable levels established by the International Commission on Radiological Protection [22].

Table 1. Toxicology index of standards for drinking water quality.

Item	Estimated Value	Limit Value	Unit
As	0.01	0.01	mg/L
Cr^{6+}	0.005~0.015	0.05	mg/L
Pb	0.01	0.01	mg/L
Hg	0.001	0.001	mg/L
Fluoride	0.01~1.4	1.0	mg/L

Estimated value abstracted from [22] and limit value abstracted from Standard for drinking water quality (GB5749-2006).

Another key water quality issue is polluted drinking water. Various types of drinking water are associated with different undesirable components, including high fluoride and salt concentrations, making drinking water unsafe. Water with high fluoride concentrations was mainly found in north China, where 70% of the local population drink high-fluoride water. Most of the individuals who drink polluted surface water were found to live in the south of the Huai River basin as well as in the eastern Qinghai and Tibet [23]. From a national point of view, approximately 323 million Chinese citizens drink unsafe potable water. In addition, approximately 53.7 million Chinese citizens drink water that contains excessive arsenic and fluorine, approximately 38.5 million Chinese citizens drink water that contains excessive salt, and approximately 91 million Chinese citizens drink water that contains excessive iron and manganese [24].

2.2. Wastewater Treatment and Disposal

It is a major challenge to treat increasing domestic wastewater in the rural areas. Due to the scattered distribution of Chinese villages, it is difficult to collect and reuse domestic wastewater in rural areas. In particular, the complicated geographical situations in the mountainous areas and highland areas (covering 59% of the national territory) make wastewater collection and treatment extremely difficult [25]. Moreover, though increasing incomes for rural populations mean many outdoor latrines have been converted to indoor toilets, due to a lack of sewage piping systems, most of the sewage from private toilets is discharged into local water bodies directly, posing serious health and environmental risks to the local ecosystem [6].

Wastewater from rural livestock, poultry and fish farms deserves special attention due to its higher pollutant concentration [26]. Without effective monitoring in rural areas and a lack of advanced treatment technologies and facilities, such wastewater poses serious threats to the local water bodies. Typical issues include eutrophication and pathological risks. For example, the notorious algae bloom of Taihu Lake in 2007 was partly due to random wastewater discharge [7]. Plus, wastewater discharge may contaminate local groundwater through its leakage and affect local citizens' drinking water demand, since many rural populations rely on groundwater as their only drinking water source. According to Chen and Sun [8], the ammonia and nitrogen concentrations in the groundwater at some farms were two to three times higher than normal values. The necessary actions should be taken in order to avoid such a problem. Table 2 shows detailed information on amounts and sources of rural TN and TP emissions due to lack of wastewater treatment and disposal in rural China. They contribute around 10%–16% of the whole amounts of TN and TP into the water body [27].

Table 2. Main non-point pollution emission sources in rural China.

Year	TN Emission(Unit: 10^4 ton)		TP Emission(Unit: 10^4 ton)	
	From Rural Domestic Sewage	From Agricultural Process	From Rural Domestic Sewage	From Agricultural Processes
2001	48	199	9	19
2002	48	202	9	20
2003	47	206	9	21
2004	46	210	8	21
2005	45	218	8	23
2006	45	222	8	23
2007	44	217	8	22
2008	43	229	8	25
2009	42	233	7	25
2010	41	242	7	27

Dataestimated by the authors.

In addition, rapid development of village and township enterprises in rural areas results in increasing industrial wastewater discharge. The complicated nature of industrial wastewater discharged directly to the rural areas deserves special attention due to its toxicity and hazardous substances [28,29].

2.3. Water for Agricultural Purposes

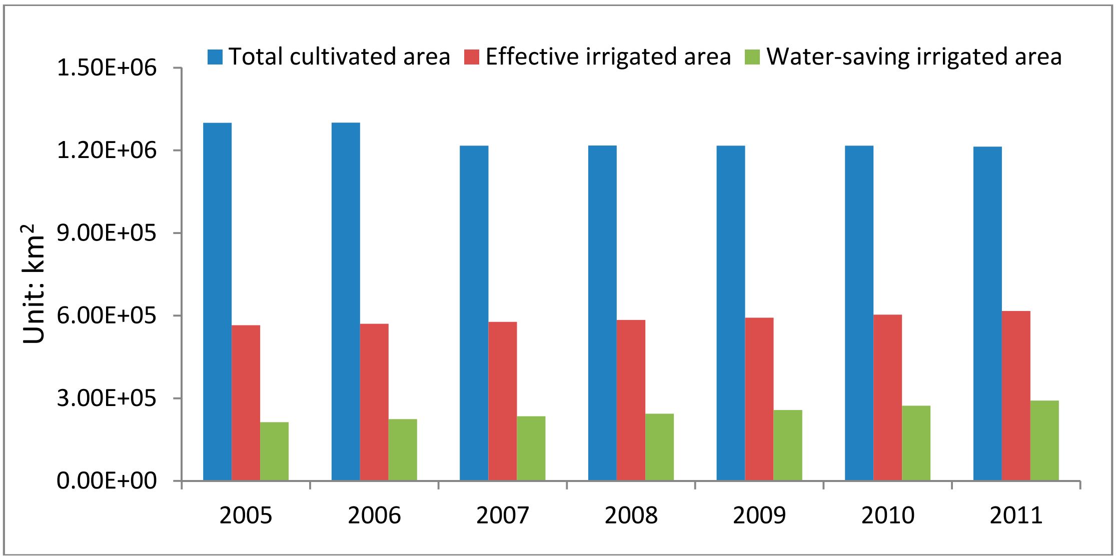
2.3.1. Shortage of Irrigation Water

A large amount of water is used for agricultural purposes in China, accounting for more than 60% of all water usage in China [9]. However, water efficiency is very low due to poor management. In this regard, the utilization coefficient of agricultural irrigation water ranges from 0.50 to 0.53, while such a figure in developed countries is between 0.7 and 0.8 [10].

With the increasing populations and agricultural activities, surface water is decreasing in rural China, leading to more groundwater being used for agricultural irrigation. Currently, about 30% of irrigation water comes from groundwater sources. Moreover, 95% of agricultural wells are located in north China, where only 30% of groundwater resources exist [11]. The over-extraction of groundwater may result in seawater intrusion and land subsidence [30]. For instance, according to Wang (2007), the groundwater table showed little or no decline in 35% of the Chinese villages, but dropped in 57% of the Chinese villages, and even experienced over 1.5 m of decline in 8% of Chinese villages [11].

2.3.2. Inadequate Water Conservancy Facilities

Water conservancy facilities are not up-to-date in rural China and cannot meet with the demand of increasing agricultural production and improving rural living standards. While most public investment on water conservancy facilities is used for industrial and domestic purposes, as well as flood control [31], little investment has been used for agriculture purposes [32]. To date, over half of the arable land is not equipped with water conservancy facilities, meaning that these areas have to rely on natural rainfall for their irrigation [31]. Figure 1 shows detailed data on total arable land, effective irrigation land and water-saving irrigation land for the period of 2005–2011. It is clear that water-saving irrigation facilities were just able to cover 40% of the effective irrigation area, while such a figure in developed countries is about 60% to 80%. Another key issue is that many irrigation facilities are aging and gradually losing their functions due to lack of repair and maintenance. For instance, there are 87,085 reservoirs with a storage capacity of more than 100 km^3 across all of China. However, around 86,000 were built up before 1979, of which over 30,000 medium and small sized reservoirs need complete maintenance. About 42.5% of the total reservoirs have been evaluated as dangerous and need to be repaired immediately [31].



Data were obtained from the China Statistic Yearbook on Environment 2012 [33].

Figure 1. Comparison of total arable area, effective irrigation area and water-saving irrigation area from 2005 to 2011.

2.3.3. Serious Water Pollution

Water pollution has become increasingly serious in rural areas. Figure 2 presents several locations with serious pollution events (described in Sector 2.3.3), while Table 3 presents the poor water quality status in major Chinese rivers, lakes and reservoirs for the year of 2010, where more than 331.6 million rural citizens are being supported. Essentially, surface water pollution includes both point and non-point source pollutions [34]. With increasing industrial and agricultural activities and rural population, the main pollution sources include industrial wastewater, domestic and livestock farm sewage, runoffs, and other non-point source pollutants. Particularly, industrial parks have become the key pollution sources due to their rapid development in rural areas. Sewage discharged from large-scale livestock farms in suburban areas and villages is another major pollution source. Due to the lack of effective enforcement on related environmental regulations in rural areas, much of such sewage is being discharged directly into local water ditches, leading to eutrophication issues in main water bodies [35].

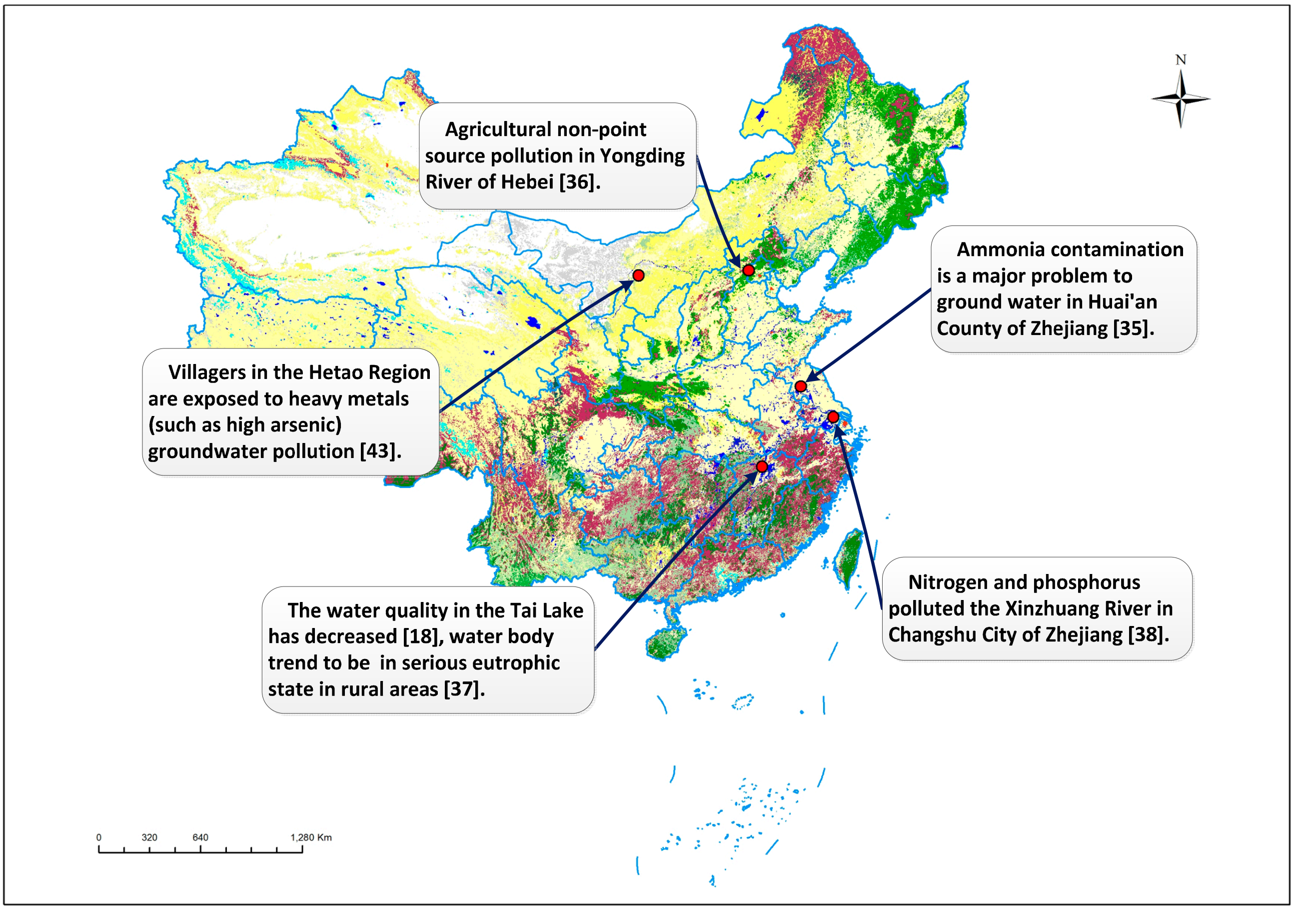


Figure 2. Locations of surface water and ground water pollution events in rural China.

Moreover, agricultural non-point source pollution becomes more serious in some rivers due to overuse of pesticide and fertilizer. For instance, Yongding River, a major river in Hebei, has been polluted by the surrounding agricultural activities [36]. Another case is the notorious algae bloom in the Taihu Lake in 2007, which was mainly induced by the overuse of pesticide, fertilizer and various detergents [18], in which 25.1% of the total nitrogen (TN) and 60% of the total phosphorous (TP) came from domestic sewage [37]. Similar issues also exist for the Xinzhuang River (located in Changshu City, Jiangsu province in east China), where surface water is polluted by nitrogen, phosphorus and inorganic nitrogen. Concentrations of TN, orthophosphate and TP are 2.07, 0.30 and 0.53 mg/L, respectively [38]. These pollution events resulted in many local citizens complaining about the local enforcement of relevant environmental regulations and even suing their local administrative authorities [20].

Table 3. Poor water quality in major Chinese rivers, lakes, reservoirs (2010).

River	Total Length (km)	Classify River Length of Total River Length (%)		Rural Population (Unit:10^4 Persons)
		Grade V	Worse than Grade V	
Liaohe River	5316	17.0	34.0	1887.5
Haihe River	12,680	6.2	48.2	8396
Yellow River (Huanghe River)	14,295	10.3	33.9	7800
Huaihe River	24,072	13.2	22.2	13,600
Lake and reservoir	Region	Categories of overall water quality	Nutritional status	Rural population (Unit:10^4 persons)
Baiyangdian Lake	Hebei	Grade V	Middle Eutropher	-
Taihu Lake	Jiangsu, Zhejiang, Shanghai	Worse than Grade V	Middle Eutropher	1056
Chenghai Lake	Yunnan	Worse than Grade V	Mesotropher	
Dianchi Lake	Yunnan	Worse than Grade V	Middle Eutropher	
Xingyunhu Lake	Yunnan	Worse than Grade V	Middle Eutropher	301
Qiluhu Lake	Yunnan	Worse than Grade V	Middle Eutropher	
Yilonghu Lake	Yunnan	Worse than Grade V	Middle Eutropher	
Namucuo Lake	Tibet	Grade V	Mesotropher	6.9
Yangzhuoyongcuo Lake	Tibet	Grade V	Mesotropher	3.3
Shahu Lake	Ningxia	Worse than Grade V	Light Eutropher	-
Wulungu Lake	Xinjiang	Worse than Grade V	Mesotropher	15
Aibi Lake	Xinjiang	Worse than Grade V	Light Eutropher	6.5
Wujiangdu Lake	Guizhou	Worse than Grade V	Light Eutropher	87.72

Data were obtained from the China Statistic Yearbook on Environment 2011 [39]. "-": no data.

The main groundwater pollutants come from point and non-point residential, industrial and agricultural sources, including N, P, K, organic matter, pathogens, fluorides, heavy metals and salts with higher concentrations (shown in Table 4). For instance, in Huai'an County, Zhejiang province, point source pollution is mainly from the discharge of domestic sewage and industrial wastewater, while non-point source pollution is mainly from the use of fertilisers and pesticides [40]. Fertilisers and pesticides are filtered into the underground water level with runoffs, leading to heavily contaminated groundwater, especially ammonia contamination [41]. Furthermore, wastewater from livestock farms usually contains manure and therefore has higher concentrations of N, P, and K, inducing eutrophication and pathogenic concerns [8]. In this regard, the contamination process and the spatial distribution of nitrate-N concentrations in the groundwater were typical in the high-yielding areas of northern China [42]. Other pollutants, such as arsenic pollution, are also found in rural Chinese water bodies. Such a pollutant mainly comes from mining activities (such as fluorine, iron and manganese shown in Table 4) and posed a serious threat to the local residents. For instance, villagers in the Hetao Region of Inner

Mongolia province in north China are exposed to arsenic pollution due to local mining activities, resulting in many of them suffering from arsenic-related diseases [43–48]. Current technologies cannot easily remove such pollutants from groundwater and remedy the damaged ecosystem; this means a pollution prevention approach should be proposed.

Due to the lack of available water resources, China's famers had to use polluted water or even sewage for irrigation, especially in the North of China. Such behaviours have become an effective measure to alleviate water shortages and make sure that agricultural production can operate normally [49]. However, such an operation introduces contaminants into soils, including persistent organic pollutants, heavy metals, pathogens, high fluorides and salts, *etc.* [50,51], and leads to the reduction of agricultural productivity, lower quality of agricultural products [52,53], soil pollution in farmlands, and potential human health risks [54].

Table 4. Groundwater pollution induced by NO_3^-, TP, arsenic and fluoride in rural China.

Item	Max Value (mg/L)	Specific Location	Region	References
NO_3^-	563.60	Feidong County, Chao County	Anhui Province	[30]
	550.00	Qinggang County, Mingshui County, Zhaodong County	Heilongjiang Province	[55]
	340.00	Jinning County	Yunnan Province	[56]
	184.40	Jiefangzha Irrigation Area	Inner Mongolia Autonomous Region	[57]
	111.30	Tongshan County	Jiangsu Province	[58]
TP	11.22	Nan'an District	Chongqing Province	[59]
	3.21	Feidong County, Chao County	Anhui Province	[30]
	2.49	Jinning County	Yunnan Province	[56,60]
	1.74	Lixin County	Anhui Province	[30,61]
	1.49	Qingyun County	Shandong Province	[62]
As	1.93	Shanyin County, Yingxian County, Shuozhou as part of Datong Basin	Shanxi Province	[44–46]
	1.86	Dengkou County, Linhe County, Hangjinhouqi County	Inner Mongolia Autonomous Region	[47,48]
	1.15	Fuyang County, Dangshan County, Wuhe County, Tianchang County	Anhui Province	[46,63]
	0.83	Kuiteng County,Wusu County	Xinjiang Uygur Autonomous Region	[64]
	0.69	Tengchong County, Gengma County	Yunnan Province	[65]
F	16.00	Xiu County	Liaoning Province	[66]
	13.50	Lanjing county, Fuding County	Fujian Province	[67]
	12.50	Linyi County	Shanxi Province	[68]
	11.80	Dali county	Shaanxi Province	[65]
	10.00	Qianan County	Jilin Province	[69]

2.4. Environmental Concerns

Water issues have also brought up many environmental concerns since polluted water may result in the loss of biodiversity [70]. For instance, industrial wastewater discharge into the Xinanjiang Reservoir of Zhejiang Province led to many large fish being killed [71]. Another case is that the higher

E. coli concentration in Mada Lake of Shandong Province resulted in many fishes, shrimps and crabs becoming extinct [72]. In addition, due to less inflow and increasing industrial wastewater discharge, the Baiyangdian Lake, the biggest freshwater lake in Hebei Province, has experienced significant species losses, particularly for fish and phytoplankton [73].

Another key environmental concern is that due to the use of polluted water or even sewage for irrigation, key pollutants, such as heavy metals, nitrites and organic pollutants, have accumulated in the soil and thus led to human health risks through the food chain, as well as significant impacts on crop production [53,74,75]. For instance, Beijing, the capital of China, is facing limited surface water supply and has to rely on the Guanting Reservoir and Miyun Reservoir. However, the inflow to the two reservoirs has continued to decrease, annually from 3.13 km^3 to less than 1.10 km^3 for the last 50 years. Such a decrease led to much less grain yields, with losses varying from 963,595 tons to 13,287 tons [76]. In recent years, rice with higher cadmium concentrations was found in certain areas in south China, such as Zhejiang Province (1.17 mg/kg), Hunan Province (1.29 mg/kg) and Guangxi Province (0.95 mg/kg) [77–79].

Finally, the polluted water and soil also increased public health risks. In recent years, cancer morbidity and mortality induced by polluted water or soil significantly increased. According to published news, there are more than 400 cancer villages in China [80]. Several investigations revealed that those villages are close to those polluted rivers or soils and the cancer mortality in these villages was correlated with the distances to the polluted sites [81,82].

3. Administrative System for Water Resources

3.1. Characteristics of the Current Administrative System

The existing water resource administrative system in rural China is shown in Figure 3. Water resources are managed by both the central and the local governments. However, fragmented issues exist due to the involvement of several agencies. From a national point of view, the Ministry of Water Resources is in charge of water resource protection, water infrastructure, flood control and drought relief, irrigation and hydrological engineering, and water administrative rules and regulations; the Ministry of Environmental Protection is responsible for pollution prevention and control in key regions and river basins as well as the environmental protection plan for drinking water source 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; and the National Development and Reform Commission (NDRC) is in charge of national water resource allocation plans, water pollution reduction, strategic plans, policies and measures concerning the conservation and comprehensive utilization of water resource, and water prices. Such a fragmented administrative system poses a serious challenge to effective and efficient water management. Particularly, due to a lack of a leading agency, none of them are subordinated to one another, meaning the water-related jurisdictions of these involved agencies are not clear [83]. Such an issue also exists at the local level, making the situation even worse. Consequently, institutional reform is critical so that clear jurisdictions can be established.

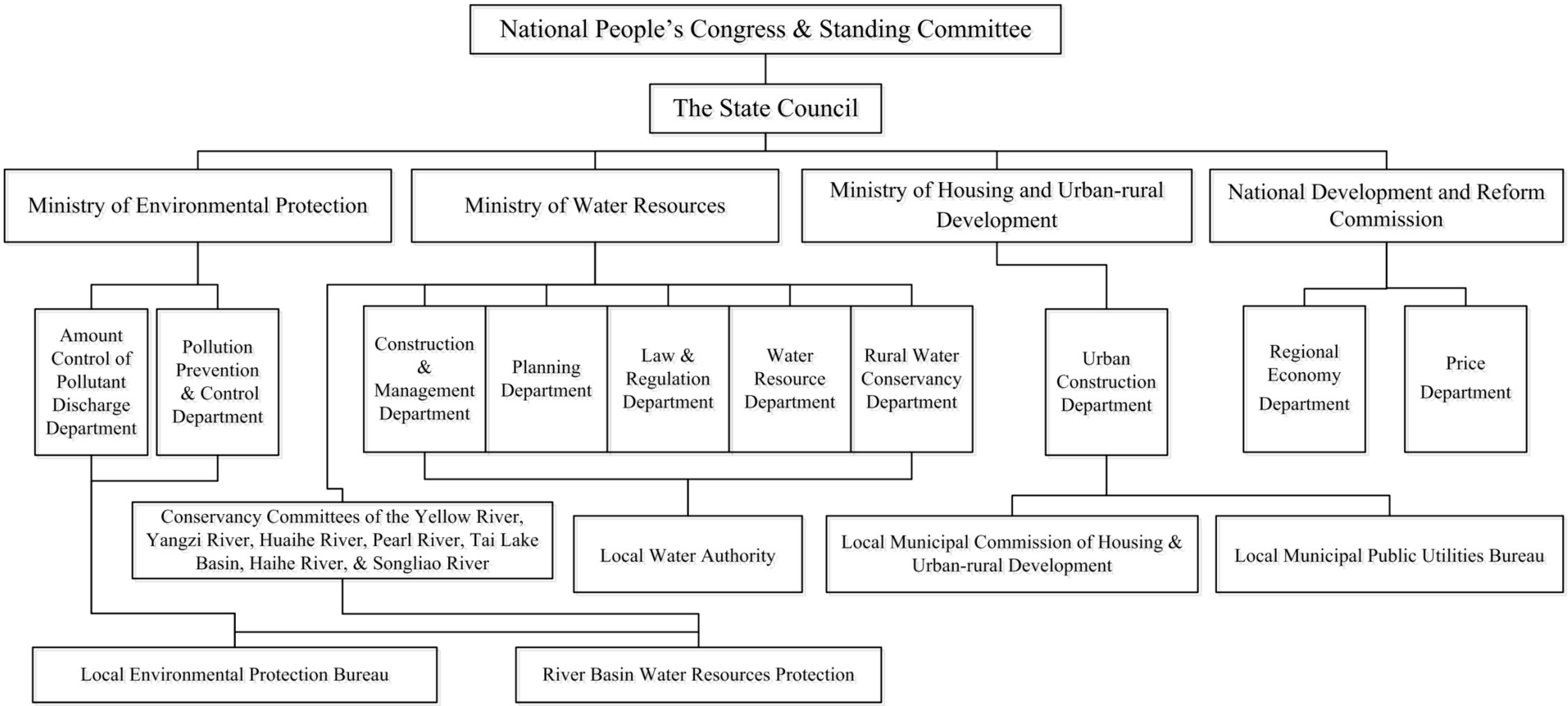


Figure 3. China's Water Administrative Framework.

3.2. Water Management Regulations

Three important laws are related to water management in China, including 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". All of these laws were issued by the Standing Committee of National People's Congress. In order to adapt to rapid development, the "Water Law of the People's Republic of China" was amended in 2002, which also addressed watershed issues [84]. This is because watershed management has become more crucial and received wide attention both from central and regional governments. They began to be aware of the fact that the watershed territories are not consistent with political territories and believe that cross-regional collaboration is necessary. In order to prevent and control water pollution, protect the natural environment, and guarantee the safety of drinking water, the "Law of the People's Republic of China on Prevention Control of Water Pollution" was amended in 2008. The major revision is in the fourth section of the fourth chapter, outlining how to deal with pesticides, fertilisers, wastewater containing livestock manures and aquiculture wastes, as well as how to recover local water-related ecosystems and how to improve irrigation water quality. From an overall point of view, the "Environmental Protection Law of the People's Republic of China" was enacted to protect the whole environment system within China, from which the chapter involving rural China is about the protection of surface water and rational exploitation of groundwater resources, maintaining good water quality, strict management and conservation of agricultural water. Other regulations include the "Resolution of Accelerating Developments of Water Conservancy Reform" proposed by the State Council in 2010 and the "Suggestion of Implementing the Strictest Water Management System" proposed by the State Council 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. In addition, the MEP asked 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. Although these ministry-level regulations are lower than the national regulations, they provide fundamental principles for local governments to enhance their water management capacity.

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 [85]. As the water quality monitoring agency, local environmental protection bureaus are unable to secure active co-operation from other bureaucratic authorities, particularly those associated with polluting industries [86]. This creates a serious barrier for the effective enforcement of water related regulations. Those environmental officials often lack adequate support from outside constituencies to do their jobs effectively. This lack of support takes a serious toll on their commitment to their agency that further erodes their effectiveness. The key to success in water management depends on how field regulators approach polluting problems, hence, how they condition the decision situations. However, the lack of technical support and training seriously reduces field regulators' ability to enforce CP promotion law [85]. The problem is further compounded by a lack of rules, legal support, or funding, and the heavy workload. Under such circumstances, most enforcement officials only focus on enforcing in urban areas, resulting in ineffective and inefficient enforcement in rural China. In addition, those rural enterprises are usually small or medium sized. Most of them have relatively lower environmental awareness and often regard environmental protection a heavy burden. With the reality that most SMEs are currently confronted with difficulties such as obsolete equipment and technologies, untrained and inexperienced labourers, and insufficient financial resources, their production has caused significant negative environmental impacts [87]. As a result, rural farmers are facing similar issues and do not have appropriate knowledge on abiding by the regulations. Consequently, both the provincial and municipal government should consider how to prepare appropriate economic incentive policies, improve lax enforcement and provide necessary financial support to both rural enterprises and farmers.

4. Synthetic Approaches to Solve Water Problems in Rural China

The overview of water management in rural China shows that the successful factors include strong political support from both central and local governments, appropriate policy encouragement, effective technology and information support, continuous capacity building activities and broad international collaboration. Although some progress has been made, our overview shows that there are some common barriers, such as a lack of the establishment of an adequate institutional framework and a basic lack of awareness, technologies and resources. Therefore, an integrated effort that can address all the above issues should be made so that appropriate policy suggestions can be provided.

First of all, institutional reform should be initiated so that different stakeholders can work together and ensure that there is a concerted effort to promote water management in rural China. A possible channel is to establish a round-table so that all aspects from different stakeholders are equally considered and strong support from the central government can be gained. It also creates an opportunity for them to exchange information and feedback, to obtain financial and personnel support, and to negotiate potential conflicts. Particularly, such a channel can facilitate related policy discussions so that emerging issues can be solved. A useful way to keep such a roundtable functional is to host regular conferences to exchange their achievements and experiences.

Second, current water management regulations should be revised in order to fit the new changes. Innovative policies that can provide incentives for water saving, financial assistance and coordination should be raised [88]. For instance, a new safe drinking water act should be established. Such an act should stipulate that water supply in rural China should meet with the national drinking water standards so that rural populations can receive safe drinking water. It requires a systematic improvement of local water infrastructure and the involved stakeholders should carefully monitor the progress of such a project, not only for its design and construction, but also for its operation, so that such a project can be sustainable [29]. Also, due to China's imbalanced development, more region-specific policies should be made by considering the local realities. For instance, in water-shortage areas, more water-saving policies, such as drop irrigation, rainwater collection and reuse, and treated wastewater reuse, should be encouraged, while in water-rich areas, more water quality improvement policies, such as advanced water treatment technologies and more stringent water quality monitoring, should be adopted. Moreover, it is critical to enforce the related regulations more effectively and efficiently. Therefore, policy-makers need to design more useful instruments. For instance, to add one environmental performance indicator on assessing the overall political achievement of the local officials is one effective measure for local politicians to seriously consider the enforcement of these water regulations. Another example is that the recent establishment of reporting system at all governmental levels allows the public to monitor the officials' enforcement performance. Other instruments include increasing the enforcement budget and the field regulators' capacity. Such a budget could come from water resource tax. Finally, training programs should be prepared for those enforcement officials so that they can better understand the values of their job and learn necessary enforcement skills. Plus, continuous commitment from senior management can strengthen the confidence of those regulators and stimulate them to do a better job.

Third, economic instruments should be adopted in order to improve water management in rural China. Unlike the "stick" policy, namely enforcement of environmental regulations, economic instruments can be regarded as a "carrot" policy and can provide better incentives to the practitioners. Normal economic instruments include water pricing, water quotas, and wastewater charge and wastewater emission trade. Water pricing refers to increasing water rates [89]. Currently, water price in China does not include the water resource fee, only covering costs related with water collection, water infrastructure, and water treatment. Without a consideration of water resources, such a pricing system cannot reflect the true cost of water resources and therefore does not provide a driver for those water users to pay enough attention to protect water resources [3]. Consequently, necessary price reform should be made so that money collected can be used to subsidize the protection of water resource. Water quotas are another useful tool [90,91]. Especially in water shortage areas, limited water resources can be equitably allocated to water users based upon their basic needs. The successful implementation of a water quota system is dependent on a planned water use system operated by local water management agencies. Such a system sets up penalty mechanisms for water use that exceeds the given quota. Water users would be required to pay several times the normal rate for water when they exceed the given quota. This measure can encourage water users to apply state-of-the-art water conservation technologies and seek potential water reuse or recycling collaboration opportunities with other users. As such, wastewater charge and wastewater emission trade are useful tools to recover the costs borne by the regulatory authority for its pollution control function, to change the behaviours of the dischargers, and to raise funds for water resource management. For instance, charges can cover the costs related to wastewater treatment, cleaner production and relevant research activities and for subsidizing water conservation equipment for some large water users, as well as covering monitoring costs [7]. Wastewater emission trade can help control the total water consumption through transparent marketing mechanisms. Such a measure will induce water users to seek possible water saving initiatives, while discouraging those users that do not like to take appropriate action. In general, these economic instruments can serve as significant incentives to reduce total water consumption and wastewater discharge and improve economic and financial effectiveness and efficiency.

Fourth, technology innovation is one effective measure to improve water management in rural China. As the largest developing country, demand for environmental monitoring technologies in China is still weak, and both technical capabilities and financial resources are inadequate, especially in rural China. Such a reality means that the levels of pollution and resource consumption are outpacing economic growth. Under such circumstances, both technology-related research and development (R&D) activities and technology transfer should be supported in rural China. In this regard, research institutions and universities should identify research needs through site investigation so that appropriate technological solutions can be obtained. Meanwhile, foreign advanced technologies, equipment and expertise on rural water management, such as hybrid artificial wetland technologies for domestic wastewater treatment, sludge recirculation technology, decentralized purification tanks, advanced environmental restoration and remedial technologies, should be transferred to rural areas through training programs, demonstration projects, technical missions and staff exchange. Also, information is the key to improving water management and it is important to provide quantitative information to decision-makers. In practice, it refers to the establishment of a computer-based system that provides decision makers with the tools needed to monitor, evaluate, protect water resource and treat rural wastewater. In order to provide past, present, and predictive information on water management in rural China, this information system should include software that helps with decision making, data resources such as databases, the hardware resources of a system, human resource management on water management (such as enforcement area of each enforcement official), and computerized processes that enable enforcement officials to predict the potential impacts of illegal wastewater discharge. Such a platform can provide accurate and timely information to decision makers for their strategic planning, and facilitate the effective implementation of water management. In addition, it will be appropriate to develop a public website so that the related information can be publicized.

Finally, capacity-building activities should be initiated so as to improve overall public awareness and enhance their abilities. Such activities include the strengthening of different stakeholders, managerial systems and human resources, developing effective means to facilitate community participation and communication, and promoting the creation of favourable policy environments. Awareness-raising activities, including TV promotions, newsletters and workshops, should be carried out periodically in order to build understanding. These initiatives can provide forums at which experiences from different parts of the world and from different institutions could be objectively reviewed and lessons drawn from these combined experiences. These activities can also create opportunities for stakeholders to strengthen their mutual understandings and friendship. In general, capacity building should directly reflect the needs and overall conditions of rural areas. As such, it should be a long-term process, with clearly enunciated short-, medium- and long-term goals which can be evaluated periodically. The needs at various levels should be specifically considered. Good communication and extensive interactions between different stakeholders and levels are essential requirements for any successful capacity building process. Local water management agencies should take the leadership role in this process so that different voices from different parties can be equally heard.

5. Conclusions

Water management is becoming a significant public concern in rural China. While most people's concerns focus on urban water management, very little attention has been given to broader rural China. This paper aims to fill this gap by employing an overview study approach. Based upon a complete literature review on current water management situations in rural China, including water quantity and quality, water regulations, key challenges are summarized. By considering Chinese realities, several recommendations for improving overall water management in rural China are presented, including appropriate policy reform, the application of economic instruments, the promotion of advanced technologies and initiatives for capacity-building. These recommendations provide valuable insights to water managers in rural China so that they can identify the most appropriate pathways for optimizing their water resources, reducing the total wastewater discharge and improving their water-related ecosystem.

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Author Contributions

Xiaoman Yu, Yong Geng, Peter Heck and Bing Xue conducted the research, designed and wrote the paper; all authors have read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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