Research on water supply model, technology, and management mechanism for villages in China

Yanqi Hu*

Department of Environmental Science and Management, Hong Kong University of Science and Technology, Hong Kong, China

*Corresponding author: yhuco@connect.ust.hk

Abstract. China's village drinking water has poor protection of water sources, water purification technology and equipment, water supply pipeline network leakage rate, the high risk of secondary pollution, operation and management mechanism, and other issues. How to enhance China's village drinking water through the whole process of the amount of water and the ability to ensure water quality has become the current problem to be resolved urgently. The study summarizes China's village water supply model selection, conventional and non-conventional water sources of water supply key technologies and applications, as well as long-term management measures, and through the application of China's northwestern Gansu's Huanxian and southeastern Zhejiang's Shangyu District, summarizes the success of the experience of the different regional characteristics, and strengthens the leading demonstration. Relevant countermeasures and suggestions are put forward to realize the long-term operation of rural safe drinking water projects.

Keywords: village drinking water, operation and management mechanism, water supply model, key technologies, regional characteristics.

1. Introduction

"Since the 11th Five-Year Plan“(between 2006 and 2010) in China, with the accelerated pace of construction of new rural areas in China, the focus of rural water supply work has shifted from rural drinking water difficulties to rural drinking water safety, and the level of water supply security for a cumulative total of 270 million people in rural areas has been upgraded, with the proportion of the rural population covered by rural water supply projects reaching 56 percent, and the rate of piped water supply penetration reaching 87 percent [1]. The level of the rural water supply range has been significantly improved. However, with a sharp rise in the number of rural drinking water projects, phenomena such as “heavy construction light management” emerged, coupled with China's rural drinking water projects being small in scale and dispersed, topography and geological conditions are complex, the level of project management cannot keep up with the speed of construction. Issues such as the water sources are not enough to protect; early water supply network, "running, cold, dripping and leaking" phenomenon is severe; the lack of a rural water supply revenue management model; western and coastal areas of exceptional water quality are challenging to use; water purification process and integration of backward equipment; intelligent information technology supervision and management of the low level of technology are appeared [2]. In addition, the more economically developed eastern region of rural drinking water infrastructure construction and maintenance management is relatively perfect. In contrast, China's central and western regions of rural drinking water safety situation is relatively backward, there are still many hidden dangers in the safety of drinking water.

In recent years, scholars have carried out much research and practice around the rural water supply model, technology, and management mechanism. Shi Yuanzhi [3] through the research of Yunnan rural water supply project management in the existence of eight significant models, he proposed that Yunnan should actively explore the farmers' water cooperative management model in the application of small-scale centralized water supply projects to encourage and guide the participation of social capital in the construction and operation of rural water supply; Liu Fuchen [4] pointed out that Juxian City’s development model of self-pressured village water supply in mountainous areas, underground water supply to villages in mountainous areas, village water supply in plain areas, and village water supply around urban areas should be supplemented by innovative water supply, operation, and charging management mechanisms. After analyzing the current situation and existing problems of rural water supply management in Minle City, Zhao Fahua [5] proposed the measure of “using 8-10 households as one control well, implementing one meter per household, and water meters leaving the house” to solve the problem of rural drinking water safety; Liu Kunpeng [6] pointed out that a long-term subsidized loan mechanism should be established to make full use of the existing investment and financing platforms, and to make up for the shortfall in project construction funds; Wang Yueguo [7] proposed supporting the integration of urban and rural water supply projects in the franchise mode and supporting the regional scale rural water supply projects in the “government and social capital cooperation” mode.

Current research on rural drinking water mainly focuses on a specific technology or a regional water supply management model. However, there are relatively few studies involving the development of drinking water sources, the improvement of water quality, as well as the technology of water safety. This study research focuses on improving the technical level and management capacity of village drinking water in China through the whole process. It forms a set of integrated solutions for village water supply mode, technology, and management, providing scientific support for improving water supply security in rural China.

2. Village water supply model selection and implementation

China's natural conditions are complex and diverse, and the level of economic and social development of villages are different, the water supply model mainly includes the following three forms: (1) Urban and rural integration of water supply: By expanding the scale and water supply scope of water plants in cities and central towns, pipe networks are laid to rural areas to form a joint centralized water supply system, and the integration of rural water supply is realized. Rural water supply and urban water supply are on the same network, of the same quality, and under the same management [8]; (2) Centralized water supply in villages and towns: multiple villages as a group to build small and medium-sized water plants, while radiating to the surrounding area [9]; (3) Single-village decentralized water supply: for remote areas, high-altitude and high-cold areas, the use of single-village construction of decentralized water supply facilities, and simultaneous supporting purification and disinfection processes. Under each water supply model, according to the main body of construction and management, ownership and management rights and benefits range distinction are subdivided into various modes and types [10]. Rural water supply project operation and management mode selection should fully consider the local geographic characteristics, water resources, local economic development, village future development planning, and other factors:

(1) The influence of geographic features. For rural water supply project management mode selection, local geographical characteristics should be taken into consideration. Plains, mountains, hills or deserts, and other landscape features determine the residential dispersion of villagers and water supply methods, but also determine the cost of rural water supply projects and the scale of water supply. The residents living in the distribution of altitude terrain, population distribution, and water source characteristics should be considered to choosing the appropriate mode of operation and management.

(2) The impact of water resources conditions. Water quality and water carrying capacity is also essential reference factor in the selection of rural water supply project mode. Water source which mining does not affect the original function or will not cause a sustained decline in groundwater levels, can be used as a large and medium-sized centralized rural water supply project water source. For residential areas where water quality is good but residential areas are to spread out, we can select the high level of the pool of small-scale or single-family water supply; for the water quality which cannot meet the requirements of the need, we can replace the water source or increase the storage project.

(3) The impact of local economic development condition. Rural water supply project capital investment determines the subsequent planning and development, and the local economic development level determines the rural water supply project model selection. Less economically developed areas should also consider the affordability of water prices. Local governments should fully use the original facilities to maximize the benefits of centralized water supply projects. The choice of water supply mode should be diversified, and there is a specific benefit of centralized water supply projects that can be handed over to a professional company management.

(4) The impact of future development planning in villages. Rural water supply project construction should consider the overall planning of local village development, development needs, and the scale and quality of rural water supply requirements. The development and construction of the local water supply business should be a long-term consideration, with planning and implementation step-by-step.

3. The village water supply key technologies and applications

Given the problems of backwardness and frequent maintenance of village water purification equipment, lack of technicians, and low professional level, we need to classify and develop complete sets of equipment that remove conventional pollutants, toxic inorganic ions, trace organic pollutants, and control disinfection by-products based on the water quality characteristics of different village and town water sources, with high efficiency, low chemical consumption, and low maintenance, and create prefabricated water plants and intelligent Operation technology, and to achieve standardization, serial production and engineering application. Water quality improvement technologies for conventional and non-conventional water sources are shown in Tables 1 and 2.

Table 1. Water source protection and water quality improvement technologies for conventional water sources

Technology name	Applicable characteristics	Solving key problems	Main content	Technology utilization
Gas lift deep well-pressurized algae control and decontamination technology	Lakes, reservoirs, and other shallow slow-flowing surface water sources	Addressing the challenges of in situ control of eutrophication and algal pollution in shallow, stagnant, slow-flowing surface water sources	By applying high pressure to the algae-containing water for a short period, the air sacs inside the algal cells rupture, the algal cells lose the buoyancy of the air sacs, their sedimentation is enhanced, and they sink to the bottom of the water to decay in the absence of light conditions	The technology was applied to the “YU Zigou” Reservoir, and after two weeks of operation, the density of algae and VOC content in action were significantly reduced
In situ electrochemical removal of the radioactive element uranium from groundwater sources	Groundwater source areas with excess uranium	Breaking through the technical difficulty of removing uranyl carbonate and calcium uranyl carbonate complexes, realizing efficient, rapid, and selective removal of calcium uranyl carbonate complexes at low concentrations in groundwater.	The technology utilizes components such as penetrating mesh electrodes, intelligent control cabinets, and DC power supplies to achieve in situ electrochemical removal of radioactive uranium from groundwater. By controlling the voltage and reversing the	The technology utilizes components such as penetrating mesh electrodes, intelligent control cabinets, and DC power supplies to achieve in situ electrochemical removal of radioactive uranium from groundwater. By controlling the voltage and reversing the

			inverted pole voltage, groundwater passes through the electrodes. It is reduced and deposited while periodically removing sediments to ensure the stable operation of the equipment.	inverted pole voltage, groundwater passes through the electrodes and is reduced and deposited while periodically removing sediments to ensure the stable operation of the equipment
Intelligent control technology of coagulation and dosing, sedimentation and sludge discharge control technology, and intelligent operation guarantee disinfection technology.	This technology applies to village and township water plants with surface water and groundwater as water sources.	It solves the problems of unstable treatment effect, high dosage, large sludge discharge, and substandard residual chlorine at the end of the pipe network caused by the original control method of coagulation and sedimentation process relying on experience and fixed-time adjustment of critical operating parameters, as well as the problems of substandard residual chlorine at the end of the pipe network caused by non-standard disinfection, long age of the water, and aging of the pipelines in village and township water supply plants.	Through the artificial neural network algorithm model, intelligent control and prediction of coagulant dosage and disinfectant dosage, adjusting the mud discharge cycle and mud discharge time to ensure the stable operation of the equipment.	The technology has been applied to the Qingbo Water Plant in Chang'an District, Xi'an City, Shaanxi Province, where the chlorine residual rate at the customer's faucet has reached more than 97%, and the disinfection operation cost has been reduced by 23%
Adsorption-autocatalytic oxidation depth manganese removal technology research	Applicable to groundwater sources, mainly for manganese ions exceeding the standard problem, can be synchronized with the removal of COD ammonia nitrogen, supporting the core of the process for manganese sand filtration process	Solve the problem of high manganese ion content in village and town drinking water	Developing proprietary manganese removal materials through multi-stage transformation to realize the transformation from high adsorption to high catalytic oxidation, replacing the traditional manganese sand filter media, and shortening the start-up cycle of the filter pool to about ten days	The technology is applied in Suihua City, Heilongjiang Province; during the operation period, the manganese ion content of the effluent is lower than 0.05mg/L, the manganese removal rate is kept above 90%, and the effluent water quality is stable

Table 2. Water source protection and water quality improvement technologies for non-conventional water sources

Technology name	Applicable characteristics	Solving key problems	Main content	Technology utilization
Powerless ultrafiltration-ultraviolet disinfection rainwater purification technology	Applicable to the rainwater collection cellar water in the village and town areas of northwest China, whose water quality has long been turbidity, color, and microbial indicators exceeding the standard	Solve the problems of high energy consumption, frequent maintenance, and microbiological indicators of conventional rainwater ultrafiltration technology and have low energy consumption, low maintenance, and other characteristics	Driven by the trans-membrane pressure generated by the self-weight of water, the nanometer-sized membrane pores distributed on the surface of the ultrafiltration membrane efficiently retain suspended particles, colloids, macromolecules, and pathogenic microorganisms prevalent in rainwater collection cellar water, and form a highly permeable cake layer to ensure the long-term stability of the effluent flux	Technology applied in Huancheng Town, Huan County, Qingyang City, Gansu Province, China
Snowmelt water utilization technology for border guard posts in alpine areas	Snowmelt water in alpine pastoral areas (perennial low temperature and microbial contamination), with short-term turbidity impact, TDS should not be too high	Solve the problems of low level of security of water supply quality and the need for more technology and personnel to maintain and manage facilities or equipment	The technology adopts the multi-stage barrier water supply technology of natural percolation, composite media filtration, ultrafiltration-low-pressure nanofiltration, and composite disinfection, combined with an intelligent remote diagnosis and maintenance system. With low-pressure nanofiltration as the core, different unit modules are flexibly combined according to changes in water quality, and NF270 low-pressure nanofiltration membranes, which are highly resistant to contamination and have lower life cycle costs, are selected to ensure safe water supply quality under temperature changes	It has been successfully assembled and applied at the Wudaoliang pump station outpost in Qinghai Province
Directly supplied drinking water-oriented electrodialysis technology	Suitable for the treatment of low-salt brackish water	It realizes selective and enhanced removal of alkalinity, fluorine, hardness, and other ions while removing dissolved salts at low cost	Electrodialysis technology is a separation method that reduces the salt content in the original liquid by utilizing the selective permeability of the ion exchange membrane with the electric field force as the driving force	It has been popularized and applied in Zhaoling Town, Liquan County, Xianyang City, Shanxi Province, which can remove about 50% of the soluble substances and lower the fluoride concentration in the produced water than 1.0 mg/L

4. Village water supply long-term management initiatives

Village water supply management has a specific public welfare attribute, and the competent authorities should play the primary function in the village water supply management. The government should actively change the “government build and manage” model, precise positioning of government functions, clear corresponding responsibilities, and rights, and exercise the necessary supervision and regulation functions. The government should actively promote the transfer of the right to operate to the enterprise operation, responsible for supervising the operation of various ownership enterprises, as well as water price setting, water fee collection, water quality monitoring, and social services.

The government water management department should clarify the relationship between the various departments, define the behavioral motives of the participants, and establish an effective management mechanism to guarantee the benign operation of the rural drinking water system. The competent authorities and relevant government management departments are responsible for supervising and managing the system, guaranteeing the implementation of funds, sanitary supervision, and water quality testing; the operators are the producers and sellers of drinking water, and they must not only obey government supervision but also provide good water services to water users. As direct beneficiaries, village residents should be responsible for paying for the water supply and participating in maintaining water facilities while enjoying their rights and interests. The government must strengthen publicity and education on water use, gradually correct wrong water use concepts, and actively guide users to form correct water use habits. The participation of non-profit organizations in village and town water supply management will also play a specific role in promoting village and town water supply management.

5. Summary

(1) In recent years, rural water supply security in China has significantly improved. However, there are still problems, such as lagging management levels, noticeable regional differences, and insufficient protection of water sources.

(2) China's water supply model mainly includes integrated urban and rural water supply, centralized water supply in townships, and decentralized water supply in single villages. The selection of rural water supply mode should consider the influence of various aspects, including geographical characteristics, water resources conditions, local economic development, and the future development planning of villages.

(3) When choosing village water supply technology, it is necessary to classify and develop efficient equipment applicable to conventional and non-conventional water sources and realize intelligent operation and standardized production. For water quality improvement technologies, high-efficiency, low chemical consumption, and low maintenance technologies have been developed to remove conventional pollutants, toxic inorganic ions, trace organic pollutants and control disinfection by-products, and have realized engineering applications.

(4) China is a vast country with significant differences in economic and social development levels, natural geographic conditions, and population distribution, especially in rural areas, so it is essential to determine local water supply management mechanisms according to local conditions.

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