

Rural sewage treatment processing in Yongjia County, Zhejiang Province

W H Wang¹ and T H Kuan^{2,3}

¹ Professor, Zhejiang University of Water Resources and Electric Power, Hangzhou, China

² Ph.D., P.E. Retired Engineer, Public Works, City of Los Angeles, Los Angeles, CA, USA

Email: tsunkuan@yahoo.com

Abstract. Issues regarding water pollution in rural areas of China have garnered increased attention over the years. Further discussion on the circumstances and results of existing domestic sewage treatment methods may serve as an appropriate reference in solving these important issues. This article explored the current conditions of water contamination in rural areas of China, introduced the characteristics and effects of applicable sewage treatment technology, and summarized the results of the planning, installation, and operation of rural sewage treatment facilities in Yongjia County in Zhejiang Province. However, relying on a single technical design rule is not adequate for solving the practical problems that these villages face. Instead, methods of planning rural sewage treatment should be adapted to better suit local conditions and different residential forms. It is crucial, ultimately, for any domestic sewage treatment system in a rural area to be commissioned, engineered, and maintained by a market-oriented professional company.

1. General water environment situation in rural areas of China

China's recent rapid economic development has greatly increased quality of life for its population, but it has come with a serious tradeoff. Chinese people bear a double burden of air and water pollution. In studies from the summer of 2011, the Chinese government reported that 43 percent of state-monitored rivers were so polluted that they are unsuitable for human contact, and over half of China's population is threatened by seriously polluted water. Due to the long-standing urban-rural dualistic structure and overemphasis on economic development policies negative results, such as ignoring water scarcity, overextending water resources, misusing unsafe pesticides, polluted drinking water sources, and arbitrary disposal of wastewater from local enterprises and villagers, water crises have arisen throughout rural areas of China. According to the Annual Report of 2011 published by the Chinese Ministry of Environmental Protection, the total discharge of pollutants in rural areas makes up approximately half of the national total. These statistics are ominous. This Chinese saying summarizes well the water environment and sanitary situation in rural China: "Sweeping trash depends on the wind blowing, drying sewage relies on the sun shining even as drinking fresh water is determined by the rain" [1].



However, in 2010, the Chinese People's Congress posted "Three Red Guide Lines" as tough thresholds for water resource management principles in China; all levels of Chinese Government are rigorously carrying out steps to protect water resources nationwide. After struggling for several years, the lessening rural waste is improving ecological and human health conditions in the Chinese countryside. The idyllic scene of clean creeks and green hills in many local areas is gradually returning because the Chinese government has done much to address the high levels of pollution, including raising environmental priorities through the cadre evaluation system, and budgeting RMB 5.1 trillion for key pollution control in 2011-2015 [2]. Many measures for the mitigation of pollution and treatment of domestic sewage have been undertaken in rural regions. Consequently, Yongjia County, Zhejiang is a typical example to demonstrate the green awakening of the water environment in rural China.

2. Introduction of water resource conditions in Yongjia County

Yongjia County is located in Wenzhou District in the southeast of Zhejiang province, which is one of the most developed regions in China and famous for its scenic splendor. Yongjia is 15 kilometers north of Wenzhou city proper, which administers the county. The Nanxi River Scenic Area is located within this county, and the river has been tentatively nominated for the list of UNESCO World Heritage Sites.



Figure 1. Maps of Yongjia County.

Yongjia County had a total population of 886, 300 in 2007. Among this population, 63% (555, 640) were farmers living in 166, 360 separate households. The whole county is divided into 8 sub-districts,

including 10 towns, 650 administrated villages, and 1881 native villages. Yongjia County is situated downstream of the southern Ou River, crossing the Ou River from north to south ending in Wenzhou City, and east of Yueqing City (See Figure 1). The total area of Yongjia County is 2698 square kilometres, of which 2308.5 square kilometres are mountainous, 277 square kilometres are plains, and 112.7 square kilometres consist of rivers and lakes. Yongjia also has 36.16 hectares of cultivated land. The area is known as “Eight Parts Mountain, One Part Water, and One Part Farmland.”

Yongjia generally belongs to a subtropical monsoon climate, with mild seasons of full rainfall, an average annual temperature of 18.2° C, and average annual rainfall of about 1702.2 mm, which creates an average annual total of more than 3.6 billion cubic meters of water resources. All rivers in this region belong to the Ou River system, of which Nanxi, Xixi, Guxi, and Wuniuxi are the four major tributaries. The county has a total of 3377 rivers with a total length of 4302 km, including 3294 km of mountain rivers (including Nanxi River) with 1.57 km/km² density; there are 83 strings of river network totaling about 114 km with a drainage density of 1.76 km/km².

In recent years, with the developments of society and economy, the county's waste water emissions have increased year after year. For example, in 1998, 1999, 2000, the county's waste water emissions were 0.57, 0.59, 0.62 million tons, respectively. Thus, pollution in the inhabited areas along the river plains and inland towns has become more serious, making river water quality below Grade IV or V due to industrial and domestic wastewater discharge. Since 2012, water quality of the county's surface water has improved slightly, but the outlook for overall water quality is not optimistic in Yongjia.

3. Challenges of water resource management for Zhejiang Province and Yongjia County

In 2010, China's Communist Party Central Committee and State Council promulgated a “Three Red Lines” policy intended to establish clear and binding limits on water quantity usage, efficiency, and quality. The development of socialist ecological civilization is necessary in implementing the sustainable development of the diversification of propulsion strategy. Under the progress of promoting the construction of water ecological civilizations, the Government of Zhejiang Province launched a program named “The Government of Five Water” (Five Water Project), means that the Government will try their best to govern polluted water, treat sewage, prevent flooding, supply clean water for citizens, and encourage people to save water.

Zhejiang is famous for water scenery, which makes it beautiful and prosperous. Due to the dramatic growth of urbanization and rapid development of industrialization in past decades, many beautiful rivers and lakes are covered with a layer of black shadow, and many sightseeing destinations have been destroyed. This somber reality has made people understand that water is vital to agriculture and is the lifeblood of the city. Moreover, the polluted water resources have become a hurdle for growing the economy and improving livelihood.

From 2013 to 2014 in Zhejiang Province, the data show that the “Five Water Project,” as a breakthrough point, forced economic transformation and upgrades, and remedied severe environmental pollution. Under the program, 5058 kilometers of black rivers were mitigated; rural sewage treatment facilities were built for more than 3.3 million residents, and a rainwater pipe network of over 2845 km was constructed. Domestic sewage and agricultural contamination are two major sources of rural pollution. Zhejiang comprehensively managed the construction of rural sewage treatment facilities; the Province completed 6.66 million sewage treatment stations and laid 2036 million meters of village pipe, which benefited over 330 million farmers. The program also enhanced source control of agricultural contamination and remediation of farm pollution, which lead to the rehabilitation of infrastructures and standardization of new villages [3, 4].

Meanwhile, the Yongjia county government placed “Five Water Project” at a high priority and started a project for the purpose of sustainability of water resources and mitigation of rural wastewater pollution.

First, they invested RMB 7.137 billion to complement local subjects of the “Five Water Project,” including to resolve black, smelly rivers, build sewage treatment plants, and complete village sewage treatment facilities. Under the project urban sewage pipe networks were constructed and arranged, which raised the sewage treatment rate from 34% to 90% and benefited an additional 60,000 farming households, and resolved and improved 284,800 rural drinking water safety issues. The hard work paid off; Yongjia County was twice named “The Most Attractive County” in Zhejiang Province.

4. Strategy and plan for achievement of domestic wastewater treatment in Yongjia County

From 2014 to 2016, the household sewage treatment coverage rate of Yongjia County nearly tripled from 34.1% to 90%, and construction on 1661 village sewage treatment facilities (covering 88% of the entire county’s villages) was completed. This great achievement did not come easily; it was based on the diligent efforts of those working on an intelligent propulsion strategy and comprehensive development plan.

As in humid areas of southern China, rural areas of Yongjia County historically had a very low sewage treatment rate for domestic wastewater. Most villages lacked a sewage system, and households relied on natural conditions to discharge untreated wastewater. Existing limited rural sewage systems often malfunctioned and were expensive to operate due to poor construction, significant leaks, and lack of management personnel. As such, existing rural sewage treatment facilities do not provide the best example in sanitary control. Most villages in vast rural areas of Yongjia are scattered because the terrain is complex, and the economic conditions of many villages are limited, which makes financing improvements and construction of treatment facilities extremely difficult. Therefore, a suitable and strategic management project is necessary to overcome these difficult conditions.

After actively pursuing “Five Water Project” and broadly congregating opinions and demands from the citizens of Yongjia, a rational project goal was assembled, which is to integrate environmental management and protection of water resources, reform rural villages, and consider eco-tourism development as the primary means to finance the construction of the Domestic Wastewater Facility Project (“Project”). Under this common goal, the Government of Yongjia County can finance RMB 0.74 B from the State subsidy, private investments, and personal donations; and the Zhejiang Design Institute of Water Conservancy & Hydroelectric Power is invited to act as their consultant to prepare a technical development plan in a combination of centralized processing and distributed processing to accomplish the Project. The centralized process will use pipe lines to collect discharged wastewater into nearby big treatment plants suitable for large villages where the households number in the hundreds; the distributed process will build a small facility and treat domestic wastewater in place, as appropriate for dispersed households. The estimated total cost to complete the Project is about RMB 0.92 B for construction and remediation of treatment facilities in 650 administrated villages and 1700 native villages, based on the average cost of 5, 200 RMB/per household. The planning stage is divided into a three-year period. The first year, 2014, was spent consolidating and amending existing treatment facilities and launching a pilot program to accumulate experience. The second year, 2015, was the key period to extensively develop the project, and 2016 was designated to solve complicated areas and finish the project [5].

5. Analysis of process model and summary of results

Most villages in Yongjia County are in areas of rolling hills, and the layout of the villages is dispersed. So, the chosen principle of rural sewage treatment processing adhered to the idea of a “mainly decentralized, but supplemented by centralized system” based on an anaerobic + wetland decentralized processing model. Remote and dispersed rural villages apply the decentralized processing mode, and villages where geographical conditions allow use centralized processing, which is mainly determined by local conditions.

In 2015, thirty-five percent of the villages in Yongjia County adopted the decentralized governance model. This is defined by two or more households' toilet water, wash water, and kitchen water collected into a nearby anaerobic tank (septic tank), which is then treated to discharge into the nearest wetland, farmland, or woodland. The decentralized processing mode has advantages of low investment costs, savings of 20% to 30% compared to the centralized processing model, low operation and maintenance costs, and no need to occupy farmland. Practical experience has proved that determining the approach according to local conditions is not only widely accepted by farmers, but also conforms to the Level One Class B of National Urban Sewage Treatment Standard for use in farm irrigation.

The decentralized processing model of "Anaerobic + Wetland/Ecological Pond" can be demonstrated as follows: (See figure 2)

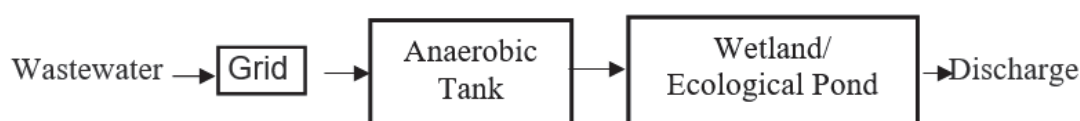


Figure 2. Simple chart of decentralized processing.

Wastewater flows through the grid and solid waste is removed into the unpowered anaerobic tank, which is a masonry or concrete underground tank, for processing. The anaerobic tank is equipped with a multi-grid, correspondingly playing adjustment, sediment, and anaerobic oxidation effects. Anaerobic treatment technology is an effective removal process of organic contaminants, which causes a mineralization effect that transforms organic compounds into methane and carbon dioxide. The effluent runs into wetlands or an eco-system pond for reprocessing. Wetlands and ecological ponds are chosen mainly based on existing idle conditions such as fish ponds, reservoirs, and other low-lying land. When using artificial wetlands or ponds, the type of drift processing is selected as either surface flow or sub-flow, depending on the water quality, site topography, and other geological conditions; subsurface flow is usually constructed in wetlands to avoid clogged pipes. In wetland ponds, various aquatic vegetation is planted to act in aerobic and anaerobic states through absorption and adsorption functions, which combine physical, chemical, and biological functions for further sewage treatment.

According to the official posted data, the recent implementation results from the last three years are summarized in table 1 below.

As the achievements demonstrate in the above table, the coverage rate of the household wastewater treatment eventually reached 90%, which increased rural sewage treatment capacity to 31, 480 t/d (almost double the existing capacity), benefitted 80% of all people living in Yongjia County, effectively improved the source control of surface water and the health of the rural environment, reduced the spread of disease, and made the rivers and streams become beautiful again. Hence, the Yongjia Government not only firmly adheres to the principle "To complete one, to check one, and to operate one," making sure every treatment facility, whether in a centralized or decentralized process, is utilized under the regulation of Zhejiang Rural Sewage Treatment Facilities Management Implementation Plan, but also issues the policy for local administration offices to contract out the maintenance of facilities to dependable private companies to warrant that each facility can be monitored, examined, and kept in regular service.

Certainly, the social and economic consequences of improvements to Yongjia rural sewage treatment are significant. Through specific implementation of the project and the improvement of quality of life, people's environmental awareness awakened in what produced a qualitative leap. Thus, the protection of the environment and conservation of resources became a conscious act of the villagers.

Incidentally, it is hard to analyse and evaluate the exact revenue obtained from rural sewage treatment by reducing the loss or damage to the county's economic development caused by the ecological impacts

of environmental pollution, but indirect profits solely gained through tourism was RMB 4.923 B in 2015, an increase of 25.74% [6, 7].

Table 1. Results of Domestic Wastewater Treatment Project in Yongjia County (Summary of Official Data).

	Decentralized Processing		Centralized Processing			Invest	Benefitted
	A Villages	N Villages	Treat Plant	Pipe Ext	Village	¥x10 ⁸	People Household
Planning Goal	650	1661	12	142 Km	39	9.2	148, 585
2013 Existing	188	435	3 ^a	26 Km			52, 290
2014	178	(505) ^b	8	58 Km	(17) ^b	2.17	31, 300
2015	215	(588) ^b	2	72.7 Km	(6) ^b	2.45	34, 000
2016 (Cont.)	191	(568) ^b	1	100 Km	(16) ^b	(2.0) ^b	20, 000
Subtotal In 3 Years	584	(1661) ^b	11	230.7 Km	(39) ^b	6.62	85, 300

^a Three total treatment plants existed, two already operating and one not fully operating.

^b Figures in () brackets should be further verified.

*A Villages= Administration Villages; N Villages= Native Villages

Incidentally, it is hard to analyze and evaluate the exact revenue obtained from rural sewage treatment by reducing the loss or damage to the county's economic development caused by the ecological impacts of environmental pollution, but indirect profits solely gained through tourism was RMB 4.923 B in 2015, an increase of 25.74% [6, 7].

6. Conclusion

Successfully completing a well-managed rural sewage treatment project in Yongjia County in a short three-year period, while properly addressing the daily demands of around 120, 000 village households, is an illustrious example for China.

Therefore, the assessment of accomplishing a rural sewage treatment in Yongjia County can be concluded as follows:

First, the described Project is one of the sustainable water resources management events successfully completed by the Government of Yongjia County. This Project illustrated that reform against severe rural sewage contamination should be well-planned, strategically managed, and faithfully executed. In addition, the reform system must be supervised by a unified department, and the importance of promoting the market-oriented operation to contract out the project should be appropriately stressed.

Sufficient financial resources are the second most important factor in this project. As described previously, the Yongjia Government amassed about 80% of the estimated cost from Government subsidies, and 10% from private investments for the project budget due to a serious shortage of capital investment. Without ample financial support, it is impossible to complete the project.

Strengthened construction management, long-term maintenance, and reinforced promotion of market-oriented operations are the last factors needed to ensure long-term operation. In order to further develop

the project, the county government promulgated five regulations, one after another, and ultimately opted to contract out the continuing operation and maintenance to private sectors for completion.

In conclusion, the method or strategy successfully applied for treatment of domestic sewage in rural areas of Yongjia County has certain representativeness because not only are the physical and geographical conditions in Yongjia County representative of most rural areas in China, but the economic and social circumstances are comparable to other countryside populations of this nation. However, it is only the dawn of a green awakening, and there is a long way to go to overcome the bitterly opposed change to the environmental pollution in China.

References

- [1] Yu X M, Geng Y, Heck P, and Xue B 2015 *A Review of China's rural water management Sustainability 2015* ISSN 2071-1050
- [2] Zhu J L, Yan Y, He C and Wang C 2015 China's environment: Big issues, accelerating effort, ample opportunities *Goldman Sachs-Asia*
- [3] United States-China Economic and Security Review Commission 2015 *China Ahead of the 13th Five-Year Plan: Competitiveness and Market*
- [4] Chun G 2015 "Five Water Project" Zhejiang Has Drawn a Beautiful Picture *People's Daily*, D797
- [5] Zhejiang environmental protection science design institute and Yongjia County Rural Affairs Office 2014 *Yongjia County Rural Sewage Management Planning (2011-2016)*
- [6] Jiang J F 2016 *The Yongjia County Government Annual Working Report- 2015*
- [7] Jiang J F 2015 *The Yongjia County Government Annual Working Report- 2014*