Public–Private Partnerships for Wastewater Treatment in Rural Areas: Case Study of Changshu, People’s Republic of China

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Introduction

Environmental Sanitation Requirements in the Context of Rural Modernization in the PRC

The rural society of the People’s Republic of China is undergoing a process of modernization. Although the income level and the quality of life of residents have improved significantly, the environmental rehabilitation is still far from the modern level. The needs of the rural people are very urgent, and central and local governments attach great importance to them. In 2017, President Xi Jinping called on the nation to launch a “rural toilet revolution,” and subsequently introduced action plans such as the State Council’s Rural Habitat Environment Improvement Plan, which elevated rural sanitation a matter of national will.

Domestic wastewater management is one of the most important elements of rural environmental sanitation. It includes various types of wastewater, such as toilet wastewater, kitchen wastewater, and other types generated from washing wastewater in domestic and public life. The main purpose and key task of domestic wastewater management is
to meet the sanitary drainage requirements for modernized living conditions and to control and manage the potential environmental pollution caused by modernized sanitary drainage.

The national circumstances of the PRC require that the restructuring to modernize rural sanitation be fully completed within a relatively short cycle of 20 years, rather than letting it continue for nearly a century (1850–1950) as in European and North American countries—this is a real revolution. The revolution began with a traditional or semi-traditional form of village life and hygiene. A large number of rural households still rely on traditional dry latrines to solve their sanitation problems. Although it is common to install piped water, the sewage or drainage system in homes is extremely inadequate. Almost all villages do not have a sewer system, and in many of them the ground is completely solidified. There is strong rural demand for modern sanitation and wastewater systems, but there are no laws governing how to raise the funds needed for public sewerage and wastewater treatment (Figure 1). While the country has generally established piped systems and wastewater treatment plants in urban areas, it is clear that the village cannot rely on large piped networks and centralized treatment plants as is the case in urban areas. The questions are how to develop village wastewater treatment planning, how to ensure the quality of equipment manufacture and technical installation, and how to effectively monitor the operation and maintenance (O&M) of village wastewater treatment and so on and so forth. These issues need to be addressed in the revolution. So far, no mature system has been developed to solve these problems. This is the biggest challenge that the rural toilet revolution in the PRC, including wastewater treatment, will face.

Figure 1: Rural Area in the Eastern Part of the PRC

These images of rural areas in the PRC were taken during research for this case study. As Chinese society gradually achieves its goal of full modernization, the countryside becomes more beautiful, with smooth roads, beautiful landscapes, and people living and working in peace and contentment, like an ink painting (photos by Ao Li).
Characteristics of Chinese Rural Areas and Challenges in Wastewater Treatment

Sanitary drainage and wastewater treatment systems serve the lives of residents. The manner in which these systems are established must be tailored to the characteristics of the settlement, in order to minimize costs while meeting the sanitation and environmental needs of the residents. From the point of view of drainage engineering, the most important characteristic of the village, which is different from that of the city, is that the settlements are distributed in a large area like spokes in points, with large distances between points, small sizes of individual settlements, and low density of internal housing. This characteristic indicates that rural wastewater treatment cannot be designed like a centralized wastewater collection and treatment system for a large area, otherwise, the cost of establishing pipelines would be unimaginably high. On the other hand, it in turn means that there are abundant agro-ecological resources or other available environmental resources in or around the village settlement, which enhances the pollution absorption capacity for domestic sanitary drainage.

Decentralized wastewater treatment is an appropriate technical system that is more suitable for wastewater disposal in rural areas. It includes two forms: (i) a small pipeline network and treatment system set up on a community basis, and (ii) an onsite treatment system established without the public pipeline network. The latter is the most extreme model of decentralized wastewater treatment. Regardless of the model, whether it is a centralized treatment model in the form of a cluster or an onsite treatment model, onsite wastewater treatment faces different challenges than municipal treatment plants. The main challenge is that the quality of the influent water of decentralized treatment facility varies greatly, and the water temperature changes almost simultaneously with the air temperature. Achieving the same quality of effluent as the city sewage treatment plant will entail greater investment costs and technical difficulties. Because small sewage treatment facilities do not cover a large area, the treatment capacity of each plant is small, and the layout of the plant is scattered, they are often operated remotely or by remote roving maintenance services, which means that wastewater treatment facilities must be designed to meet the demands of long-term unattended operation over a long period of time. All of these characteristics pose serious challenges for wastewater treatment in rural areas. In summary, there are two issues to consider. First, how to set water quality management objectives and select the most appropriate wastewater treatment process adapted to the characteristics of rural settlements and drainage. Second, how to ensure the quality of construction and operation of the system throughout the process, from manufacturing management to installation to operation and maintenance (O&M). The technical difficulties overlap with the difficulties of social management in rural areas of the PRC during the transition period, and represent the major challenges that Chinese wastewater treatment will face in rural areas of the PRC.
Background of the Changshu Model

Since the beginning of the 21st century, a social experiment to test rural wastewater treatment was first conducted in several developed areas of the PRC such as Beijing and Shanghai, but the effect of the experiment was not satisfactory. In 2008, the Ministry of Housing and Urban–Rural Development established the Northern Research Center for Rural Sewage Treatment at the Research Center for Eco-Environment Sciences of the Chinese Academy of Sciences (RCEES – CAS) and assigned Fan Bin to lead the planning research for national rural sewage treatment. With the support of the Ministry, Fan Bin used the limited project funds to conduct the first sample survey on rural wastewater and waste in the country. Based on these survey results, he wrote the Planning Study on Sewage Treatment in National Villages and Towns (Fan et al. 2021).

To further explore the technology and management aspects of establishing wastewater treatment in rural areas, Fan Bin selected Changshu City in Jiangsu Province to establish the first comprehensive demonstration area for county-specific rural wastewater treatment. With the support of the National Science and Technology Support Program and the National Water Environment and Water Pollution Control Major Science and Technology Special Project, Fan Bin worked with the Changshu Municipal Government and introduced Japan’s Kubota Corporation and China Railway Rolling Stock Corporation Limited (CRRC) after 2013. Together, they developed a model for rural wastewater treatment based on the Changshu model from 2009 to 2015. In 2015, the Ministry of Housing and Urban–Rural Development selected 100 counties across the country to replicate the Changshu experience and launched the first nationwide rural wastewater treatment initiative in the PRC.

In the context of the nationwide rural toilet revolution, rural wastewater treatment has cost considerable effort, learning many lessons in the process but also encountering many problems. We hope that the problems and lessons identified in this study will help promote more efficient and cost-effective management of rural sanitation in the PRC, from which other developing countries can learn.

Experiences and Lessons Learned from Pre-Johkasou Wastewater Treatment in Changshu

Geographic, Demographic, and Economic Features of Rural Settlements in Changshu

Changshu is located in the south of Jiangsu Province, PRC. It is a county-level city under the administration of Suzhou City. Changshu consists of eight towns and six subdistricts with a total area of 1,276.32 square kilometers. The area is low and flat, crossed by water networks, located in the temperate zone, and has a subtropical monsoon maritime climate (Changshu Government 2021a). According to the data of the seventh national census, as of 1 November 2020, the urban population of Changshu was 1,230,599, and the rural population was 446,451, accounting for 13.16% of the city of Suzhou (Suzhou Government 2021).
In 2019, the gross regional product of Changshu was CNY226.982 billion. The ratio of the output value of the agricultural, manufacturing, and service industries was 1.7/49.5/48.8. The gross regional product per capita was CNY149,591, and the per capita disposable income of urban and rural residents was CNY57,831, which includes CNY68,962 for urban residents and CNY35,576 for rural residents (Changshu Government 2019a).

The rural area in Changshu is an example of modern rural life in the PRC, depicting a layout of farmland, a dense road network, and convenient transportation. Most residences are located in adjacent villages, and a few residences are scattered on the farmland (Figure 2).

**Figure 2: Satellite Image of Rural Settlements in Changshu**

Clusters in rural areas are characterized by small cluster size, long distances between clusters, and low density within clusters (Adapted by authors from Bai Du. https://map.baidu.com/).

**Background of Rural Domestic Wastewater Treatment in Changshu**

As Changshu is located in the Taihu Lake Basin Protection Area, it is under pressure to manage pollutants and wastewater discharges, making it ready for the development of rural wastewater management.

During 2008–2010, Changshu implemented a 3-year environmental improvement action plan, lifting the constraints of internal administrative division and optimizing the layout of the county's centralized sewage treatment system, while bringing some villages within the scope of centralized treatment. Meanwhile, the city invested CNY200 million to build 180 sets of decentralized wastewater treatment facilities and supporting collection systems in areas selected by the PRC’s Ministry of Housing and Urban–Rural Development as the “county sewage comprehensive treatment demonstration area.” The city encountered the following problems at this stage: (i) the high cost of constructing pipelines to connect some of the villages to the centralized treatment plant; and (ii) the percentage of decentralized sewage treatment facilities in good condition (no broken and missing parts) was less than 40%, and the normal operation rate was less than 15%.
From 2011 to 2014, with the help of RCEES, Changshu began to research and establish a unified system for the operation of decentralized wastewater treatment plants in the county. First, the operating costs of decentralized wastewater treatment plants are fully covered by the city treasury, completely eliminating financial barriers. Changshu citizens, whether they live in the city or in the rural areas, enjoy the same water supply services and have the same wastewater treatment obligations. In practice, the water utility company, on behalf of the Changshu Water Bureau, collects wastewater treatment fees from residents and various legal entities based on the amount of tap water used. The collected wastewater fees are managed in a special account established by the Changshu government and used for the construction and operation of urban and rural wastewater treatment plants in Changshu. Second, professional, intensive O&M and the country’s first remote monitoring system both ensure O&M quality and reduce O&M costs. The County Industry Management Department has also implemented a similar monitoring approach.

As a result of the above measures, the completeness of the city’s decentralized sewage treatment plants increased to 95% and the normal operating rate increased to 92%. During this phase, the following problems emerged: the inferior quality of the plants (average construction cost per household of CNY10,000), the need for frequent maintenance and repair, the cost that resulted in the decentralized wastewater treatment plants built in the early period had high operating costs of CNY3.2 per ton and some plants as high as CNY10 or more. Specifically, the costs of electricity account for only 20% and facility maintenance and repair account for 60%–70% of total operating costs.

To solve the problem of high operating costs caused by the low quality of facilities, Changshu increased its investment and raised the average construction cost per household from CNY10,000 in the previous period to CNY25,000, but the quality of facilities has not improved significantly. On the one hand, it is true that facilities in the market vary and it is difficult to choose. On the other hand, most of the increase in construction investment was still spent on the laying of pipelines, which averaged CNY25,000 for household construction, of which CNY23,000 is invested in the construction of pipelines—due to the village modernization, which brought soil hardening and greening, the cost of laying pipelines reached CNY600 per meter, while the facility itself costs only CNY2,000.

**Technical Demonstration of the Japanese Johkasou System in Dongqing Village**

**Background**

In 2013, to improve the quality of the facilities while reducing construction costs, RCEES worked with Japan’s Kubota Corporation to implement the Johkasou household system, which is the highest level of onsite wastewater treatment. The first demonstration project of the Japanese household Johkasou in the PRC was carried out in Feng Qiangjing Settlement of Dongqing Village in Yushan Town, Changshu City.
The demonstration project installed a total of 54 sets of Johkasou and collected domestic wastewater from 102 households, with a planned treatment capacity of 54 cubic meters per day (m$^3$/d). Construction of the demonstration project began in July 2013 and lasted a total of 45 days. Trial operation began in October 2013 with the distribution of facility points (as shown in Figure 3). The scope of work for the project included the following main tasks: (1) elimination of the original septic tank; (2) connection of the sewer line that was originally connected to the septic tank to the Johkasou; (3) addition of pipes to the sewer line that was not originally connected to the septic tank to connect it to the Johkasou; (4) installation of a grease trap on the kitchen sewer line; and (5) construction, installation, commissioning, and trial operation of the Johkasou.

The introduction of Japan’s Kubota household Johkasou and the acquisition of the demonstration project’s landing helped the PRC bring decentralized wastewater treatment to the world’s most advanced level, while reducing construction costs to CNY18,700 per household. This played a crucial role in the subsequent application and promotion of the Japanese Johkasou household wastewater treatment plant in the PRC.

**Evaluation of the Demonstration Project**

As of 2021, the household Johkasou in Dongqing village has been in operation for 8 years. This section summarizes and evaluates the current operational status of the facilities and offers suggestions to solve the related problems.

The results of the comprehensive onsite inspection and water quality testing showed that although the effluent quality of most of the facilities meets the standards (except for nitrogen), the detailed...
observation revealed that many facilities do not operate normally and are in abnormal condition in various ways. The number of facilities with an abnormal status is 38. The ratio of the number of abnormal facilities to the total number of facilities of 38 units/54 units (hereafter abbreviated as 38/54). The abnormal status of the equipment can be divided into three categories: abnormal supervision, abnormal operation, and abnormal processing effects. The equipment to which none of the above three categories of abnormality applies is considered to be completely normal, with a total of 16 sets and a ratio of 16/54, as shown in Figure 4.

![Figure 4: Results of Onsite Inspection and Water Quality Test](image)

Notes: Analysis is based only on the results of this research. The results given in the figure are only the results of this research. The specific standards in the graph are COD$_c$$\leq$60 mg/L, BOD$_5$$\leq$20 mg/L, SS$\leq$20 mg/L, NH$_3$-N$\leq$(15) mg/L, TN$\leq$20 mg/L.

Source: Authors.

The causes of the three types of anomalies mentioned above fall into two categories, the first due to problems prior to design issues and the second due to problems during maintenance and operation.

**Design Problems**

1. The design did not consider the equipment discharge. The runoff flowed directly into the nearby soil ditch and soil drains, causing clogging and inefficient operation of the equipment.
2. The influence of the drainage habits of the inhabitants. Some of the facilities have the problem of incomplete collection of domestic wastewater, such as only access to toilet wastewater.
O&M Problems

1. The O&M staff is limited by the lack of funds and expertise and therefore can only perform normal cleaning of the facilities, such as cleaning the sediment and floating sludge in the anaerobic tank, cleaning of the residual sludge in the sedimentation tank, and cleaning the biofilm in the reflux tube. But O&M work goes far beyond ensuring a stable operation of the facility, which will affect the effluent water quality.

2. Maintenance and repair personnel are unfamiliar with the plant’s process and have difficulty adjusting the plant’s operating parameters so that the quality of the effluent meets the standard as closely as possible. For example, in the current batch of demonstration equipment, (i) anoxic zone C/N ratio is lower than 2, and dissolved oxygen concentration (DO) is more than 2 milligrams per liter (mg/L), seriously affecting the denitrification effect of the equipment; (ii) the aeration zone DO is greater than 6 mg/L, causing the microorganisms to enter the endogenous respiration phase, and the filler biofilm is consumed, making the equipment difficult to operate. The effects of the above two types of problems on the efficiency of ammonia and total nitrogen removal can be mitigated by adjusting the equipment operating parameters.

3. After receiving the evaluation and water quality testing reports from the third-party supervisor, the O&M team did not respond in time, compounding the equipment-related problems.

After nearly 50 years of developing and improving, such a mature product to solve the problem of rural wastewater treatment in the PRC, there are still some nonapplicable phenomena, which needs to be considered. Based on these findings, we offer the following recommendations for the effective application of Johkasou technology in the PRC:

1. **Accurate and reasonable design.** The design of the equipment prior to installation is critical and determines the functionality of the equipment.

   Accurate research on the amount of sewage discharged from households, rather than estimating data on sewage discharge, is essential to ensure the most efficient load for the equipment. On the other hand, it is important to select a reasonable installation site for the equipment, not only to control construction costs, but also to guarantee the smooth inflow and outflow of sewage.

2. **Strict O&M.** Carrying out the technical and time-sensitive aspects of O&M work is key to the normal operation of the equipment.

   Based on the water quality and dissolved oxygen concentration of the functional area, the reflux and aeration of the equipment can be adjusted more precisely for a more efficient removal of pollutants. This means that O&M staff must have the technical know-how to operate the equipment correctly.
O&M personnel should develop solutions and perform maintenance work in a timely manner or immediately upon learning of the defect in the equipment or upon being notified by third-party supervisors of the abnormal operation, to avoid further damage to the equipment and the environment.

As the household Johkasou demonstration project of Dongqing village is the first household Johkasou construction project in the PRC, there is a lack of practical experience on how to properly and professionally carry out the construction, design, and operation and maintenance of Johkasou. Combined with the differences in the characteristics of domestic wastewater in the PRC and Japan, and the fact that the PRC is still in the scientific exploration stage of setting standards for evaluating the water quality of household wastewater treatment plants, the above-mentioned “abnormal condition” of the plants in the demonstration project of Dongqing Village has emerged. However, with the promotion of the household Johkasou project in the PRC and the accumulation of practical experience, this “abnormal condition” has gradually improved, and the household Johkasou project has become a powerful tool for decentralized wastewater treatment in several areas. From this perspective, the demonstration project of Dongqing village has provided the PRC with a cost-effective technology to solve the problem of sanitary discharge of decentralized wastewater in the PRC’s unsuccessful search for low-cost and high-performance decentralized wastewater treatment technologies.

**County-Level Public–Private Partnership Projects for Rural Wastewater Treatment**

Based on the good results of the household Johkasou demonstration project in Dongqing Village, Changshu in cooperation with RCEES has developed a plan to introduce Japanese Johkasou technology through a public–private partnership (PPP) and operate a county-level decentralized sewage treatment at the same time. It introduced China Railway Rolling Stock Corporation Limited (CRRC) as the enterprise to implement it. This plan raised the PRC’s manufacturing technology for decentralized wastewater treatment plants in line with the world’s advanced standards. It also introduced for the first time, a standardized system for the manufacture, installation, operation, and third-party monitoring of decentralized wastewater treatment plants (Figure 5).
In 2015–2016, under the construction planning for urban–rural integration plans such as the Changshu City Urban Master Plan 2010–2030, the Changshu City Town and Village Sewage Treatment Special Plan, and the Suzhou City Rural Living Sewage Treatment Three-Year Action 2015–2017 Plan, Changshu carried out phase 1 of the County Decentralized Sewage Treatment PPP project, involving 330 natural villages and 12,268 farmer households. With a total investment budget of CNY269 million and the household Johkasou as the technical model, the project planned to collect 4,192.4 tons of sewage per day.

1. Project content: Renovation of farmers’ outdoor wastewater collection system, sewage treatment plants, tailwater discharge system and remote monitoring information system, and construction of green fences and other supporting facilities.

Note the difference between a natural village and an administrative village: (i) difference in composition: a natural village is a village formed naturally by villagers after a long period of settlement. The administrative village is a village administrative unit managed by the township government, and generally consists of a larger or several smaller natural villages; (ii) difference in affiliation: natural villages are subordinate to the administrative village. Natural villages are under the management and leadership of the administrative village committee and the village party branch; and (iii) difference in management: administrative village management is the implementation of the villagers’ independent management (the right lies with the village committee). The natural village does not have a villagers’ committee.
2. **Project financing**: Social capital and state assets jointly financed the project company, i.e., Changshu authorized the Municipal Water Bureau as the project implementation agency and signed a concession agreement with CRRC and the Changshu Water Investment and Development Co. Ltd., founding the project company. The registered capital of the company is 25% of the investment amount, of which 65% is covered by social capital and 35% by state-owned assets. The difference in the investment amount is financed by loans from social capital. The Changshu Branch of the Bank of China has financed a long-term loan with a term of 15 years and a pledge of sewage fees at an interest rate of 4.5%, which is 10% lower than the bank’s benchmark rate for medium- and long-term loans.

3. **Project design**: The project company is responsible for the design, financing, and construction of the facility, as well as for the maintenance and repair and replacement of the equipment after the completion of construction. The first phase of the PPP project has a total duration of 26 years, including a 1-year construction period and a 25-year commercial operation period. During operation, the municipality pays the wastewater treatment fees to the project company based on the results of the performance evaluation. Since it is difficult to calculate the amount of rural wastewater collected, the service fees are paid per family. The payment covers the financial costs of construction and expenses, operating costs, and financial costs and a reasonable profit (set at 7% to encourage competition). The bid for the service fee for phase 1 of the PPP project was set at CNY1,935 per household per year. At the end of the concession period, the project company will hand over the intact facilities to Changshu Water Bureau. The phase 1 PPP project mainly used the household Johkasou technology, which was supplemented by integrated oxidation ditch and vacuum discharge technology, and combined with advanced Internet of Things information technology for efficient operation management.

With the success of phase 1 of the PPP project, Changshu was selected as a demonstration area for comprehensive wastewater management in villages and towns. From 2017 to 2021, Changshu has successively implemented phases 2 to 4 of the PPP project, involving 1,396 natural villages and 37,364 rural households for wastewater collection and treatment. A comparison of the implementation contents of the four phases of the PPP projects (information from the bidding documents of each PPP project) shows that as the PPP projects progressed, the local government’s understanding of rural wastewater management also changed. Of course, there are differences among the four PPP projects in terms of the number of social capital, project content, investment budget, technical model, and discharge standards, as described below:

1. As shown in Table 1, the number of rural households involved is almost the same in each phase of the PPP project, ranging from 10,000 to 13,000 households. Compared with the other phases, two social capitals were introduced in phase 2 (Changshu Government 2019b), an additional incentive for 600 households was introduced (conducting a mid-term evaluation of the project according to the status of construction, and the winner will be awarded the additional project with 600 households and the renewal of the concession contract), which
was to introduce an incentive mechanism to ensure the quality of project implementation. However, the long project cycle of the PPP project and the slow repayment of the funds entailed major financial risks for the company. Combined with the newly introduced social capital in this phase, whose technology had the problem of insufficient treatment effect, the PPP project reverted to a social capital, CRRC, in the later phases.

2. From phase 1 to 3, annual payment per household increased from CNY1,935 to CNY2,180 to CNY3,000, and then dropped again to CNY2,877 in phase 4. From the first to the second phase, there was no significant change in the average household input, which was mainly due to the expansion of wastewater collection from public toilets in the project area, while the technical aspect continued to be dominated by the household Johkasou. Annual payments per household in phase 3 increased by about 38%, from CNY2,180 to CNY3,000 for the following reasons:

a. The priority of wastewater collection in phase 3 was changed from on-site collection to centralized collection, which requires the laying of piping networks and the installation of additional pumping stations midway, resulting in a significant increase in construction investments for collection systems. The reason for changing the collection pattern is as follows: the industry manager believes that the wastewater quality of the centralized treatment system is more stable and convenient for maintenance and servicing, and it can meet the relevant drainage standards.

b. In cases where centralized collection was difficult, on-site treatment was maintained. However, technical practice has shown that in cases where household wastewater is directly connected to the household Johkasou, even the effluent COD and ammonia—two types of easily-removed pollutants—cannot meet the standards for wastewater quality in a stable manner. To try to achieve the standards, the septic tank at the inlet of the household Johkasou was introduced in the third phase to improve the removal rate for COD and ammonia as well as clarity of the wastewater, which increases the construction cost.

c. As the PPP project progressed, service requirements became more stringent, and in phase 3, the contract documents included clear requirements for sludge treatment and disposal at the decentralized facilities and, at the same time, for wastewater quality improvements, which increased the associated operation and maintenance costs.

d. The increased cost of raw materials and labor, as well as the normal annual inflation, also increased average household costs.

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2 The decision on which company will take over the 600-household construction project is based on the quality of the preliminary construction projects of the two companies. The two companies will probably try their best to do a good job in the preliminary construction project in order to obtain the 600 households, which indirectly guarantees the quality of the project.

3 Of the four earlier PPP projects, the government took the initiative in the second PPP project and introduced two companies and a competitive mechanism. At this phase of the PPP, it was also found that the application effect of the products of the newly introduced companies was far from that of the Johkasou, so the later PPP projects did not introduce new products and continued to use the Johkasou.
All the above classifications contributed to the gradual increase in inputs from phase 1 to 3. In phase 4 (Changshu Government 2021b), the annual payment per household decreased from CNY3,000 to CNY2,877, mainly because of (1) the emergence of full market competition in the selection of social capitals; and (2) compared with phase 3, the proportion of households using the centralized wastewater collection model was reduced from 80% to 55% in phase 4, correspondingly reducing the increased cost of the centralized model, which includes pipe laying and wastewater transfer.

3. Having been involved in several phases of the project, the Changshu industry manager has gained more knowledge about the wastewater standard of a decentralized wastewater treatment plant, which also provides a case for the development and implementation of local/industrial wastewater standards.

In the phase 1 PPP project, the wastewater quality assessment standard of household Johkasou was initially set at GB 18918-2002(GB) 1B, according to the design capacity of Johkasou products. However, after the implementation of the project, it was found that the target of achieving a stable GB 1B had been set too carelessly. Therefore, in the design of the phase 2 PPP project, the discharge criteria for the pollutant index had to be discussed, in categorical form. For example, if the concentration of influent COD is greater than 350 mg/L to achieve the removal efficiency of not less than 60% for all indicators evaluated; and if the concentration of influent COD is less than 350 mg/L, the GB 1B standard should be implemented. As for the village sewage treatment system, the concentration of the influent COD could not be less than 120 mg/L. After summarizing the implementation of phase 2 of the PPP project, it was found that it is still difficult to meet the GB 1B standard especially the total nitrogen (total phosphorus not considered) for the effluent indicators for the household wastewater treatment plant, even if the concentration in the influent COD is not higher than 350 mg/L. Coincidentally, local standards for effluent indicators for rural wastewater treatment plants were developed throughout the PRC during phases 2 and 3 of the project. Therefore, for phase 3 of the PPP project, in order to strengthen the protection of the water quality of Taihu Lake and water quality environmentally sensitive areas, in addition to the facilities relative to the assessment section and secondary protection zone of Taihu Lake (greater than 5 m³/d), special discharge limits must be implemented, while the remaining facilities must comply with local standard 1B. For households, local standard 1B does not apply to total nitrogen and total phosphorus.

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4 Main indicators, chemical oxygen demand (COD): COD≤60 milligrams per liter (mg/L); BOD≤20 mg/L; suspended solids (SS)≤20 mg/L; ammonia (NH₃,N)≤8(15) mg/L; total nitrogen (TN)≤20 mg/L; total phosphorus (TP)≤1 mg/L.

5 Main indicators: COD≤50 mg/L; SS≤20 mg/L; NH₃-N≤5(8) mg/L; TN≤20 mg/L; TP≤1 mg/L.

6 Main indicators: COD≤60 mg/L; SS≤20 mg/L; NH₃-N≤8(15) mg/L; TN≤30 mg/L; TP≤3 mg/L.
**Technology Pattern of Operation Management and Supervision**

With the development and promotion of PPP projects, Changshu has also developed a fairly standardized technical pattern in terms of plant operation and supervision. In the PPP project contract, it was agreed that the construction of the project and the maintenance and repair would be integrated. In addition, the administration purchases supervision services from third parties (including construction, operation, and water quality) to monitor the condition of the facility and establish an evaluation and scoring system to link the evaluation results to the amount of payments.

**O&M technology.** The O&M team consists of four groups: water quality inspection, maintenance, cleaning, and commissioning. As the overall supervisor, CRRC is responsible for all work and proposes the task objective to the hired O&M team on a quarterly basis and conducts an evaluation from time to time. The hired O&M team establishes the quarterly O&M plan according to the task workload. The frequency of O&M work is roughly the same as the rule: once a month inspection.
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for small plants with treatment capacity less than 5 m$^3$/d, and once a week for large plants with treatment capacity more than 5 m$^3$/d. Ongoing operating costs are CNY434 ($73) per household per year (CNY159.70 per household per year for utilities, CNY25.50 for pharmaceuticals, CNY117.85 for labor, CNY165.54 for repair and maintenance, and CNY46.85 for administration, accounting for 26.7% of wastewater treatment costs). In addition, there are costs for sludge removal and transportation to the nearest wastewater treatment plant, each amounting to CNY100, including the cost of consumables such as chlorine tablets for disinfection (one tablet per month for a 1 m$^3$/d plant); additional carbon source (sodium acetate once per hour, with the dosage amount determined according to the flow rate); and phosphorus removal agent (PAC, once per hour of polymeric aluminum chloride, with dosage amount determined according to the flow rate).

Since the beginning of phase 1 of the PPP project, the O&M team has established a functional software program for remote monitoring. This platform can collect the operational status and equipment-related data through the company-developed GPRS radio module and send it to the server, which analyzes, processes, and stores the uploaded data. So far, the platform has been developed for small tonnage plants (less than 2 m$^3$/d capacity) and can monitor the positioning of the plant and the current status of the pump, among other things. For testing of large tonnage plants (2–20 m$^3$/d), testing includes plant positioning, logical monitoring of influent, dosage and residual phosphorus remover and carbon source, and real-time uploading of inspection data. The monitoring platform data are automatically updated every 1 hour. The platform can also receive the alarm information of the plant, which is processed by the unified O&M management department of CRRC.

Supervision technology. At present, 12,323 facilities in Changshu wide are on the regulatory list (including the first and second phases of PPP projects and pre-PPP facilities). The supervision team is responsible for monitoring facilities and testing water quality during construction and O&M periods. The monitoring team was divided into four teams with two people each, and the monitoring period includes the construction period and the operation and maintenance period. The plant monitoring team independently developed and deployed a series of intelligent online task monitoring platforms to realize the arrangement of monitoring tasks, real-time uploading of monitoring information, and statistical analysis of monitoring data.

The supervision of the plant is bid separately. The supervision of the construction of the plant and the supervision of the operation of the plant are bid separately. The main content of the monitoring of the construction phase of the plant is the management of the important nodes of the construction phase, where the monitoring group visits the construction site to review the construction process, including the construction drawings, excavation and laying of the pipeline, selection of the site of the plant, and excavation of the pit, and then submits the results directly to the Municipal Water Bureau. The specific procedure for monitoring during the O&M period is on the day before the monitoring day, when the monitoring plan is issued to the members of the online working group of the urban water and wastewater institute (monitoring service purchaser), O&M units (monitored party), and monitoring units (monitoring service provider). Upon arrival at the site on day of monitoring, the monitoring staff observes the appearance,
network, and operation of the facility, and conducts simple tests of water quality indicators on site, then collects water samples, and sends these to the water quality team. Finally, the monitoring information is uploaded to the intelligent monitoring platform using the cell phone. The platform identifies and categorizes the monitoring data and performs statistical analysis to achieve paperless operation, eliminating a lot of manual data entry and post-processing, while sending the day’s monitoring results and conclusions to the City Water and Wastewater Institute. The intelligent monitoring platform costs about CNY700,000 and stores information such as basic plant-related information, monitoring information, and statistical analysis information. External data can be directly imported into the platform, which makes monitoring services more efficient while creating a seamless interface between supervisors and managers, easily providing information to help them make decisions.

Currently, the City Water and Wastewater Drainage Institute evaluates the monitoring unit every 6 months. The monitoring unit is required to complete the semiannual monitoring plan and prepare a monitoring report for each of the five O&M teams, after which it receives a semiannual fee. The current cost of monitoring is CNY2.6 million annually for 23,000 on-site inspections of 12,323 units. Small facilities with a capacity of less than 5 m\(^3\)/d are monitored once a year, and large facilities (with a capacity of more than 5 m\(^3\)/d) are monitored once a quarter. The cost of third-party water quality verification is CNY1.4 million per year for the verification of 35,000 indicators.

**Summary and Proposal**

The Changshu paradigm is an important milestone in the development of rural wastewater governance in the PRC. Its lessons have been summarized in the political language of “unified management, unified planning, unified construction, and unified operation” and incorporated into the national Water Pollution Prevention and Control Action Plan (2015).

The core of the Changshu paradigm is to establish a system suitable for the PRC for rural wastewater treatment technology and industry management with Chinese characteristics. Such a system includes the following points:

1. Establish an efficient management system for rural wastewater treatment from the national governance level. The first point is responsibility management, which focuses on clarifying the investment responsibilities of all members of society for rural wastewater treatment and the responsibilities of governments at all levels for the overall use of funds, the organization and promotion of rural wastewater treatment in their jurisdictions, and the supervision and management of the rural wastewater treatment industry. In the PRC, rural residents are the main responsible parties for rural wastewater management, while urban residents and corporate legal entities share the responsibility for rural wastewater management. The latter should bear a larger proportion to the capital share. The second area is industry management, which includes formulating the rural wastewater treatment plan within the jurisdiction, publishing technical standards, carrying out technical supervision, and organizing support for nonprofit industry.
2. Wastewater treatment is an important technical path of rural wastewater governance. In rural areas, the PRC should focus on decentralized wastewater treatment, complemented by centralized wastewater treatment, to avoid unnecessary pipeline construction costs.

3. The success of decentralized wastewater treatment depends on high-quality technology, including high-quality manufacturing technology, installation technology, and operating technology. Appropriate standardization of the entire process of manufacturing, installation, and operation is an effective means of controlling costs. In this regard, Japan’s household Johkasou technology offers valuable lessons worth learning and promoting.

4. In terms of market organization, taking county-area as the basic unit for organization and implementation, contracting out batch rural wastewater treatment projects in accordance with the general contracting mode of lifelong responsibility management is conducive to reducing the cost of project procurement and industry supervision on the premise of ensuring the quality of engineering and services, and is conducive to the application of innovative technology.

Changshu has taken some detours in organizing the PPP projects in the later stages. The main problem lies in the higher-than-average standards of water quality management in rural wastewater treatment. Therefore, we propose to comprehensively consider the decentralized characteristics of rural decentralized wastewater treatment, the current level of industrial technology, and the investment capacity of the whole society, including rural residents, and then scientifically formulate the water quality standard of rural wastewater treatment according to the 3A principle—appropriate, available, and affordable. On the premise of thoroughly considering the local environmental carrying capacity and environmental protection needs, the requirements for the effluent quality of rural decentralized wastewater treatment facilities shall be appropriately reduced and the effluent quality assessed based on the total amount control of the whole region and whole supervision cycle. In the PRC, rural wastewater treatment projects are fully funded by the government. Therefore, it is suggested that the design of PPP models should focus on managing the efficiency and quality of the project, reduce the constraints on market-based financing, and minimize the costs of financing.
References


Study Questions

1. Which of the solutions presented in this case study can be applied to your country or city?
2. After reading the case study, list 1–2 problems that you think still need to be solved in order to introduce Johkasou in developing countries.
3. Reflecting on the key messages from the case study, what challenges do developing countries face in fulfilling the roles and responsibilities of local government and the private sector to successfully plan, operate, and maintain the wastewater management system in a local community?

Note: In this publication, “$” refers to United States dollars.

The Asian Development Bank refers to “China” as the People’s Republic of China.

Cover photo: A small centralized sewage treatment facility in Changshu (photo by Ao Li).