Exploration and Practice of Decentralized Wastewater Treatment Model

Zhimin Liao; Rongzhong Zhou; Kun Tao; Jialin Zhou; Peiyu Liao (jade.liao@jdlglobalinc.com), JDL Global Environmental Protection Inc, United States of America

Abstract

In China, centralized wastewater treatment has been the conventional approach, yet it faces numerous challenges. In contrast, decentralized wastewater treatment, particularly when equipped with the FMBR (Facultative Membrane Bioreactor) presents a transformative solution. Our first case study showcases a sustainable water infrastructure model for Huichang County's expansion. The study compares the centralized treatment in Phase I with the decentralized approach in Phase II in Huichang County. Our second case study highlights the Wusha River Treatment Project. Overall, the decentralized model has significant potential for effective water management in low-income counties, contributing to the advancement of SDG Goal #6 (Clean Water and Sanitation) as well as other related goals of SDG Goal #2 (hunger), SDG #9 (industry, infrastructure, and innovation), SDG #11 (Cities and Communities), SDG #13 (Climate Change), and SDG17(Partnership).

Adopting a decentralized wastewater treatment model, integrated with the Facultative Membrane Bioreactor (FMBR) process, aligns with the United Nations Sustainable Development Goal 6 (Clean Water and Sanitation) by ensuring sustainable management and access to water and sanitation for all. This innovative approach addresses the challenges posed by the traditional centralized wastewater treatment systems, which require substantial investments in extensive pipe networks, incur high operation and maintenance costs, and suffer from the dilution of influent concentrations in wastewater treatment plants (WWTPs). Decentralized model significantly reduces the need for long-distance conveyance infrastructures, thereby not only lowering carbon emissions associated with the construction of large-scale steel or concrete pipelines but also contributing to SDG 9 (Industry, Innovation, and Infrastructure) by promoting resilient infrastructure and fostering innovation in sanitation technologies.

Furthermore, the decentralized model enhances the sustainability of cities and communities (SDG 11) by reducing urban pollution and improving the quality of local water resources, making cities and human settlements inclusive, safe, resilient, and sustainable. This model also supports efforts to combat climate change (SDG 13), highlighting the interconnection between sustainable urban development, climate action, and the management of water and sanitation services.

In addition, by significantly improving the efficiency of wastewater treatment and increasing the pollutant removal rate, the decentralized model ensures that the water can be safely reused for agricultural irrigation. This contributes to SDG 2 by potentially increasing the availability of water for irrigation, which is crucial for ending hunger and achieving food security.

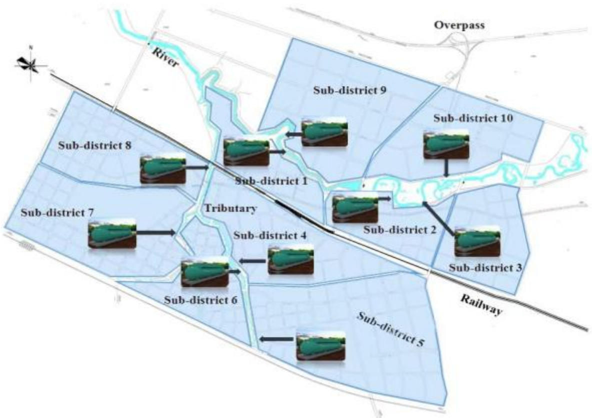
Moreover, the successful implementation of decentralized wastewater treatment systems underscores the importance of partnerships (SDG 17) among governments, the private sector, and civil society to share knowledge, expertise, and financial resources. Such collaborations are crucial for scaling up innovative solutions and achieving the integrated management of water and sanitation services, demonstrating a holistic approach to addressing global water challenges and achieving the Sustainable Development Goals.

Overall, exploring the role of technology in achieving the SDGs is critical for decision-makers and will allow them to overcome any possible trade-offs.

Case study of Huichang County in China

Huichang County, located in Ganzhou City, Jiangxi Province, People's Republic of China, covers a land area of 2,722 square kilometers and encompasses 19 townships and 269 villages. As of the end of 2022, the resident population of Huichang County reached 451,880. With steady economic growth and the development of new urban areas, the treatment capacity of the original sewage treatment plant has become insufficient to meet the increasing demand.

Figure 1. Huichang design diagram of decentralized wastewater treatment mode



Given the significant environmental impact associated with traditional sewage treatment processes, Huichang County opted for a decentralized approach in its Phase II expansion project. The FMBR process was selected as the primary treatment method for the underground sewage treatment plant with a capacity of 5.2 million gallons per day (MGD).

We have created table 1 to compare and analyze Phase I project (centralized treatment mode, 5.2 MGD) and Phase II project (decentralized treatment mode, 5.2 MGD). The total investment decreased by 62.79%. More specifically, the decentralized model in Phase II requires a significantly lower total investment (approximately 0.32 million dollars) compared to the centralized model in Phase I (approximately 0.86 million dollars). Furthermore, the impact of infiltration and leakage of wastewater, infiltration of external water and low influent concentration due to microbial degradation during long-distance conveyance is basically avoided in the process of wastewater conveyance, the influent concentration is greatly improved, such as COD was increased from about 50~150 mg/L in Phase I to about 200~350 mg/L, and the pollutant removal efficiency was increased by more than 2 times. By preventing infiltration and leakage of wastewater, the system supports the health of soil and water resources, which is essential for sustainable agriculture and food security. In addition, The decentralized model in Phase II requires a smaller footprint compared to the centralized model in Phase I.

Figure 2. Huichang FMBR wastewater treatment plant site

The above-mentioned project practice fully demonstrates that the decentralized wastewater treatment model doubles the efficiency in wastewater treatment compared to its centralized counterpart. It also significantly enhances water management and facilitates the recycling and reuse of treated wastewater for irrigation and various indoor applications. It is a new model of low-carbon environmentally friendly, economic, and efficient solution, and is a new idea for future water environment management and a viable climate solution

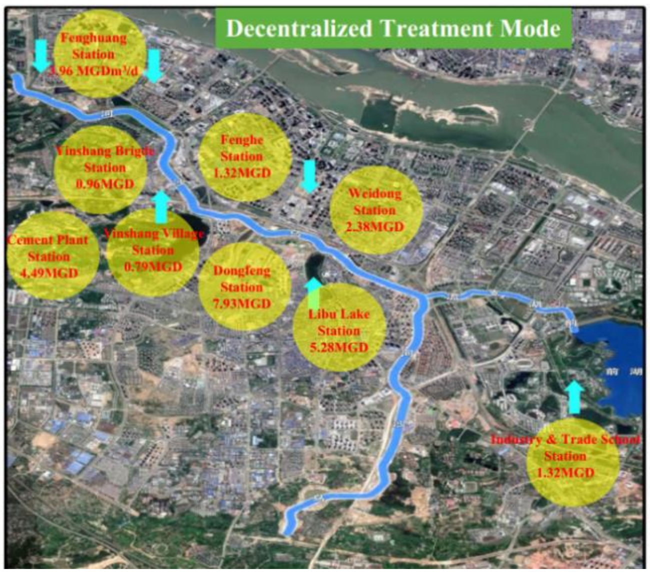
Table 1. Comparison analysis between Phase I and Phase II project model

Item	Phase I (Centralized Wastewater Treatment Model)	Phase II (Decentralized Wastewater Treatment Model)
Treatment Capacity (MGD)	5.2	5.2
Plants or Stations Quantity	1	6
Footprint (m²)	Approximately $3×10^4$	Approximately $1×10^4$
Influent COD (mg/L)	50~150	200~350
Pipeline Scale (km)	98.22 (Mostly DN800)	65.47 (Mostly DN400/DN500)
Total Investment (Million Dollars)	Approximately 0.86	Approximately 0.32

Case study of Wusha River in China

The Wusha River, a left bank tributary of the lower Gan River, spans approximately 40 kilometers with a catchment area of 263.3 square kilometers. It plays a crucial role as a primary water source for Nanchang City, supporting various sectors including agriculture, daily life, and industry. However, the area faced a significant challenge due to the inadequate capacity of the existing wastewater treatment plant, resulting in substantial wastewater discharge into the Wusha River and consequent severe pollution.

Figure 3. Wusha River design diagram decentralized wastewater treatment mode



Initially, the local government considered traditional wastewater treatment methods. However, given the high-density residential nature of the area, the plant would need to be located at a considerable distance, necessitating an extensive and expensive sewer system. To address these issues promptly, the government chose the innovative FMBR technology and embraced a decentralized approach to "Collect, Treat, and Reuse Wastewater On-site." This strategy led to the establishment of nine decentralized wastewater treatment facilities throughout the Wusha River, boasting a total capacity of 26.43 million gallons per day (MGD). The nine station includes Fenghuang Station 0.96 MGD, Yinshang Bridge Station 0.96 MGD, Cement Plant Station 4.49 MGD, Yinshang Village Station - 0.79 MGD, Fenghe Station - 1.32 MGD, Weidong Station - 2.38 MGD, Dongfeng Station - 7.93 MGD, Libu Lake Station - 5.28 MGD and Industry & Trade School Station - 1.32 MGD.

Comparatively, the decentralized FMBR method achieves substantial savings: approximately 90% in sewer, 70% in footprint, and significantly simplifies and accelerates construction work, demonstrating its advantages over traditional centralized treatment models. The project's reduction in the need for extensive sewer networks and its efficient use of resources contribute to lowering carbon emissions associated with traditional wastewater treatment methods.

Figure 4. Libu Lake FMBR wastewater treatment plant site

The project also leveraged a combination of Internet of Things (IoT) and Cloud Platform Central Monitoring System alongside mobile operation and maintenance stations to reduce response times significantly, ensuring the long-term and stable operation of the wastewater facilities, even in unmanned conditions.

By integrating wastewater treatment facilities with the local landscape and reducing the environmental impact on urban areas, the project contributes to making cities and human settlements inclusive, safe, resilient, and sustainable.

Policy recommendations

The policy brief provides two examples of decentralized mode in water infrastructure in rural areas of China. These examples can serve as models for other countries and communities.

We recommend below:

1. Create incentives for innovation and frontier technologies such as FMBR in decentralized mode to maximize the benefits. These incentives can take various forms, including tax breaks, grants, subsidies etc.
2. Promote Public-Private Partnerships (PPPs) and encourage collaboration between governments, technology providers, financial institutions, and local communities through PPPs.

3. Educate the public about the benefits of decentralized wastewater treatment mode to raise community awareness and engagement.
4. Establish mechanisms for the ongoing monitoring and reporting of decentralized wastewater treatment projects to assess their impact on water quality, public health, and local ecosystems.

References

[1] Ganbaatar Khurelbaatar, Bishara Al Marzuqi, Manfred Van Afferden, et al.2021 Data reduced method for cost comparison of wastewater management scenarios–case study for two settlements in Jordan and Oman. Front. Environ. Sci., 9:626634.

[2] Maki Tazawa. 2019 Impact Investment Strategies in Water: Distributed Wastewater Treatment and Water Reuse. Report of the CREO Syndicate. CREO Syndicate, USA.

[3] Ministry of Housing and Urban-Rural Development of PRC.. 2020 Statistical Yearbook of Urban and Rural Construction, China.

[4] Franz Tscheikner-Gratl, Nicolas Caradot, Frédéric Cherqui, et al.2019 Sewer asset management – state of the art and research needs. Urban Water Journal,16:662-675.

[5] Envirosight. 2019 Sewer Exfiltration: The Leaking Enemy. Sewer&water. https://www.msw-mag.com/online_exclusives/2019/04/sewer-exfiltration-the-leaking-enemy_sc_00125.

[6] Fan Lingfeng, Hu Jiazhong, Ou Liang. 2016 Research on low inlet concentration of urban sewage treatment plant and countermeasures. Environmental Science and Management, 220(03):132-135.

[7] Down the drain lies a promising climate and nature solution – UN report. https://www.unep.org/news-and-stories/press-release/down-drain-lies-promising-climate-and-nature-solution-un-report

[8] Obaideen, K., Shehata, N., Sayed, E. T., Abdelkareem, M. A., & Mahmoud, M. S. (2022). The role of wastewater treatment in achieving sustainable development goals (SDGs) and sustainability guideline. Energy Nexus, 7, 100112. https://doi.org/10.1016/j.nexus.2022.100112