Comparison and analysis of discharge standards of rural domestic sewage in different regions

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Abstract. China rural habitat remediation work has made significant progress. As part of this effort, various regions have implemented rural sewage treatment pollutant discharge standards, taking into account their unique economic foundations, management levels, and characteristics of rural sewage discharge. A comparative analysis of the rural domestic sewage discharge standards in the southeastern and northwestern regions of China reveals that these standards primarily consider the water environment quality of the receiving water bodies. However, there are substantial variations in pollutant concentration limits for rural sewage discharged in different regions. This research aims to guide the transition of rural sewage treatment from high-standard discharge to resource utilization. Additionally, it seeks to provide valuable insights for the selection of sewage treatment technologies, models, and governance strategies in different regions of China.

Keywords: rural domestic sewage, discharge standard, control index, resource utilization, different regions.

1. Introduction

Rural domestic sewage treatment plays a crucial role in the rural revitalization strategy and the improvement of rural environments. The untreated sewage from rural areas poses a significant threat, leading to soil and groundwater contamination, which in turn affects crop growth and compromises the safety of drinking water for residents. Therefore, the treatment of rural domestic wastewater not only mitigates environmental pollution but also helps in disease prevention, enhances the rural living environment, and fosters socio-economic development. However, recent data from the Ministry of Housing and Urban-Rural Development (MOHURD) reveals a significant disparity between urban and rural sewage treatment rates. It is projected that the sewage treatment rate in cities will surpass 97% by 2020, while in rural areas, it will only reach 28% by 2021. These statistics highlight a clear deficiency in rural sewage treatment efforts. The main reasons for this disparity include high construction and operation costs, as well as challenges in maintaining sewage treatment facilities due to a lack of mature and stable business models. Given the substantial variation in the level of economic development across different regions of China, it is challenging to establish a single universal discharge standard. Consequently, each province has implemented its own rural sewage treatment standard, tailored to the specific local characteristics and requirements.

China's vast territory encompasses diverse regions with significant variations in village sewage characteristics. Factors such as season, geographic location, living habits, economic conditions, and external influences contribute to a multitude of variables in village sewage emissions. Consequently, the water quality exhibits a wide range and a high coefficient of variation, posing a significant challenge for the implementation of universal village sewage treatment technologies.

Researchers both domestically and internationally have conducted extensive studies on rural wastewater treatment technology and management approaches. For instance, Han et al. developed a rural wastewater treatment equipment based on NISRRBC (Non-Intensified Sequencing Reactor with Recycle Biological Contact), which demonstrated improved pollutant removal efficiency through increased NO3-N concentration and biomass in the NISRRBC system [1]. Nan Ding et al. addressed the degradation challenges of organic matter, nitrogen pollutants, and sulphate by implementing anaerobic treatment methods to enhance the harmlessness of rural wastewater [2]. Ziyun Fan et al. achieved energy-efficient removal of COD, NH3-N, TN, and TP by utilizing a combined biofilter with a solid polymer ferric sulphate phosphate removal layer and alternating aerobic and anaerobic layers [3]. Song et al. tackled the operational and supervisory difficulties of rural wastewater facilities by constructing an integrated biofilter system, thereby enhancing pollutant removal efficiency. They also developed a comprehensive data collection and management system that includes data analysis, standardized process management, and other functions. This system was successfully implemented in Jiaxing City, Zhejiang Province [4].

In recent years, various provinces and cities in China have been implementing rural domestic sewage treatment standards tailored to their specific local conditions. This localized approach aims to better adapt to the local situation and promote effective treatment of rural domestic sewage. However, there has been limited research on comparing treatment standards across different regions and developing treatment technologies that align with these standards. The southeastern region of China is characterized by economic development and abundant rivers and lakes. The conditions for sewage treatment and resource utilization are relatively favorable in this region. However, stricter pollution control measures and discharge standards need to be implemented to address the environmental challenges. On the other hand, the northwestern region of China faces different circumstances, with less developed economic conditions and fewer available resources for sewage treatment. This paper intends to conduct a comprehensive comparison and analysis of rural sewage discharge standards in different regions. The main objective is to provide guidance for the transition of rural sewage treatment from high discharge standards to resourceful utilization. Additionally, the research aims to offer insights and references for the development of rural sewage treatment technologies, models, and governance strategies.

2. Grading of rural domestic wastewater treatment standards in different areas

In this article, the focus is on two provinces in the southeastern region, namely Jiangsu and Anhui. These provinces were chosen due to their relatively higher economic development and similar grading of rural domestic sewage discharge standards. The highest level is Level 1A, followed by Level 1B, and then Level 2. These standards outline the requirements for treating and discharging rural domestic sewage into natural water bodies.For the northwest region, this article focuses on Gansu Province and Inner Mongolia Autonomous Region. These areas are located inland and face challenges related to rural water use and sewage discharge. The classification of rural domestic sewage discharge standards in these regions provides more detailed categories. In the primary standard, rural domestic sewage can be discharged into Class II and Class III waters after treatment. In the secondary A standard, treated rural domestic sewage can be discharged into Class IV and Class V waters. The lower standard allows discharge into unspecified waters (Table 1).

It is worth noting that the rural domestic sewage discharge standards across the seven northwestern provinces (autonomous regions) generally encourage the resource utilization of effluent from rural domestic wastewater treatment facilities. For example, Inner Mongolia stipulates that treated tailwater can be used for irrigation of woodland and grassland, subject to local tertiary standard discharge limits. Gansu, on the other hand, specifies that treated tailwater used for irrigation of woodland and grassland must comply with tertiary A standard limits, while for dry-crop farmland, it must meet tertiary B standard limits.

Table 1. Statistics on the grading results of rural domestic sewage discharge standards

<table>
<tr><th>Areas</th><th>Provinces</th><th>Level 1A standard</th><th>Level 1B standard</th><th>Level 2 standard</th><th>Level 3 standard</th></tr>
<tr><td rowspan="5">Southeast</td><td rowspan="3">Jiangsu</td><td>Drinking Water Resource Protection Zone</td><td>Lake Tai Basin Secondary and Tertiary Protected Areas</td><td rowspan="3">Other areas</td><td rowspan="3"></td></tr>
<tr><td>Taihu Lake Basin First Protection Area</td><td>Tongyu River primary and secondary protected areas</td></tr>
<tr><td>State-level red line for ecological protection</td><td>Provincial ecological protection red line</td></tr>
<tr><td rowspan="2">Anhui</td><td rowspan="2">Scale greater than 100m^3 / d (including) of rural sewage treatment and disposal facilities and the effluent is discharged directly into the GB 3838 in Class III waters (except for designated drinking water source protection zones)</td><td>Scale greater than 100m^3 / d (including) of rural domestic sewage treatment and disposal facilities and directly into the GB 3838 IV, V category of water</td><td>Scale greater than 5m^3 / d (inclusive), less than 100m^3 / d (excluding) of rural sewage treatment and disposal facilities and the effluent is discharged directly into the GB3838 in the IV, V waters and other waters not designated as a functional area of the water environment, ditches, natural wetlands</td><td></td></tr>
<tr><td>Scale greater than 5m^3 / d (inclusive), less than 100m^3 / d (excluding) of rural sewage treatment and disposal facilities and the effluent is discharged directly into the GB3838 in Class III waters (except for the delineation of the drinking water source protection zones)</td><td>Rural domestic wastewater treatment facilities with a size of less than 5 m^3/d (not included)</td><td></td></tr>
<tr><td rowspan="3">Northwest</td><td>Gansu</td><td>Discharge to Class II and III waters</td><td>When discharging to unspecified water bodies, size 55~500m^3/d</td><td>Discharge into IV, V water; flow through natural wetlands, etc. indirectly discharged into II, III water bodies; when discharged into unspecified water bodies, the scale of 5~55 m^3/d.</td><td>When discharging to an unspecified water body, size <5 m^3/d, implement tertiary A standard</td></tr>
<tr><td rowspan="2">Inner Mongolia</td><td colspan="2" rowspan="2">The effluent is directly discharged into the "Environmental Quality Standards for Surface Water" (GB 3838-2002) in the II, III type of water (except for the delineation of drinking water source protection zones), as well as lakes, reservoirs and other closed or semi-enclosed water</td><td rowspan="2">The effluent flows through natural wetlands and other indirect discharges into the "surface water quality standards" (GB3838-2002) IV, V functional waters; discharged into unspecified waters, the size of > 30 m^3/d</td><td>Indirect discharges to Category IV and V waters via natural wetlands</td></tr>
<tr><td>Discharge to unspecified waters, size <30m^3/d</td></tr>
</table>

Note: Class II, III, IV and V water bodies refer to the water bodies stipulated in GB 3838-2002 "Environmental Quality Standards for Surface Water".

3. Analysis of standard control indicators for rural domestic wastewater treatment in different regions

3.1. Selection of different standard control indicators

Table 2. Emission Standards for Pollutants in Rural Domestic Sewage Water in the Southeast and Northwest Provinces

Areas	Level standard	pH	COD_{Cr} mg/L	SS mg/L	NH3-N mg/L	TN mg/L	TP mg/L	LAS mg/L	Animal and vegetable oils mg/L	E. coli count MPN/L
Jiangsu	Level 1A	6~9	50	10	5(8)	20	1	0.5	1	10^4
	Level 1B	6~9	60	20	8(15)	30	3[a]	1	3	10^4
	Level 2	6~9	100	30	25(30)	-	-	2	5	-
Anhui	Level 1A	6~9	50	20	5(8)	20	1	-	3	10^4
	Level 1B	6~9	60	30	8(15)	30	3	-	5	-
	Level 2	6~9	100	50	25(30)	-	-	-	5	-
Gansu	Level 1	6~9	60	20	8(15)	20	2	-	3	-
	Level 2	6~9	100	30	15(25)	-	3	-	5	-
	Level 3A	6~9	120	50	25(30)	-	-	-	15	-
	Level 3B	5.5~8.5	200	100	-	-	-	-	-	-
Inner Mongolia	Level 1	6~9	60	20	8(15)	20	1.5	-	-	-
	Level 2	6~9	100	30	15	-	3	-	-	-
	Level 3	6~9	120	50	25(30)	-	5	-	-	-

Among the discussed provinces/regions, Jiangsu Province distinguishes itself by encompassing a comprehensive set of control items within its local standards. These standards incorporate provisions for both basic control items and selective control items. Notably, the basic control items include crucial parameters such as COD, ammonia nitrogen, total nitrogen, total phosphorus, and animal and vegetable oils. Additionally, the selective control items encompass indicators such as pH, suspended solids, anionic surfactants, and fecal coliforms (Table 2).

In contrast, the remaining provinces/regions exhibit a more limited range of control items in their respective local standards. Inner Mongolia, in particular, has the most constrained set, with only six control items specified. It is worth noting that the local emission standards of these provinces/regions may not explicitly clarify the indicator parameters not indicated in the provided table.

3.2. Analysis of key indicators

Rural domestic sewage treatment involves three main levels: primary, secondary, and tertiary treatment. The primary treatment stage incorporates various components such as septic tanks, biogas tanks, gratings, regulating tanks, and sand sedimentation tanks. This stage effectively addresses suspended solids and COD (Chemical Oxygen Demand) in the sewage. Secondary treatment includes processes like activated sludge, biofilm, or their combination and improvement techniques. These processes are highly effective in treating sewage COD. Tertiary treatment focuses on ecological methods, including artificial wetlands, stabilization ponds, and land treatment technologies. These methods further enhance the quality of the treated water.

Typically, after the secondary treatment, the effluent can meet the local standards for the second and third levels. Further treatment at the tertiary level can achieve the first-level effluent standards. In Table 2, we compare the rural domestic wastewater discharge standards across the four provinces. The pH value and suspended solids concentration indicators in the discharge standards show no significant variations. Therefore, our analysis focuses on COD_{Cr}, ammonia nitrogen, total nitrogen, and total phosphorus indicators across different levels. The specific results of this analysis are as follows:

3.2.1. CODCr

Among the primary standards, both southeastern provinces have the same chemical oxygen demand (COD) limits. The primary A standard sets the limit at 50 mg/L, while the primary B standard allows up to 60 mg/L of COD. Similarly, the two northwestern provinces also share the same primary standard of 60 mg/L for COD. Additionally, the primary B standard in the southeastern provinces aligns with this limit. For the second-level standards, all four provinces have consistent requirements, with a maximum COD limit of less than 100 mg/L. In the two northwestern provinces, there are three levels of standards. The COD pollutant discharge standards specify a limit of less than 120 mg/L. Furthermore, in Gansu Province, there is an additional three-level B discharge standard, where the CODcr effluent indicator requires a limit of less than 200 mg/L.

3.2.2. NH_3-N

The emission standards for ammonia nitrogen vary based on different temperature ranges. In the two southeastern provinces, the ammonia nitrogen emission standards are identical. Under the primary A standard, the limit is set at less than 5 mg/L for temperatures above 12° and less than 8 mg/L for temperatures equal to or below 12°. The primary B standard requires less than 8 mg/L for temperatures equal to or above 12° and less than 15 mg/L for temperatures below or equal to 12°. The secondary standard mandates levels below 25 mg/L for temperatures equal to or above 12° and less than 30 mg/L for temperatures below or equal to 12°. Similarly, the primary standard in the two northwestern provinces aligns with the primary B standard, while the secondary standard requires less than 15 mg/L. Gansu Province maintains the same requirements for ammonia nitrogen across different temperature ranges, with a limit of 30 mg/L. In terms of the third-level standards, temperatures above 12° must meet a limit below 25 mg/L, while temperatures equal to or below 12° must adhere to a limit below 30 mg/L. Except for the third-level B standards in Gansu Province, no specific requirements are outlined for ammonia nitrogen emission indicators.

It is worth noting that Gansu Province does not have specific requirements for the discharge of ammonia nitrogen. Due to the significant impact of ammonia nitrogen on water body eutrophication, the rural wastewater discharge standards set higher limits for ammonia nitrogen in various regions.

3.2.3. TN

Among the four provinces, the Tier 1A standard in the two southeastern provinces and the Tier 1 standard in the two northwestern provinces share a consistent requirement for total nitrogen, which must be below 20 mg/L. In the two southeastern provinces, the Tier 1B standard sets a slightly higher limit of less than 30 mg/L for total nitrogen. However, there is no available data on the requirements for other standard grades in terms of total nitrogen.

It is important to note that rural wastewater treatment facilities are typically small in scale, which often limits the effectiveness of total nitrogen removal. As a result, the local regulations for total nitrogen values in the quality of rural wastewater effluent are not stringent.

3.2.4. TP

Total phosphorus in wastewater is the cumulative amount of organic and inorganic phosphorus, measured in phosphorus units. Elevated levels of total phosphorus can contribute to water body eutrophication, resulting in decreased water quality transparency and a blue-green appearance. Biological methods are commonly employed for treating total phosphorus in rural sewage, with treatment efficiency influenced by factors such as temperature and effective sludge discharge.

The total phosphorus requirements in the treatment standards of the two southeastern provinces are generally similar. The A standard sets a limit of less than 1 mg/L for total phosphorus, while the B standard allows for a limit of less than 3 mg/L. However, in Jiangsu Province, the B standard exempts the assessment of total phosphorus indicators for decentralised village domestic wastewater treatment facilities with a treatment scale of ≤2 tonnes/day. Anhui Province does not have this exemption.

In the two northwestern provinces, the Inner Mongolia Autonomous Region has slightly higher requirements compared to Gansu Province. Under the primary standard, Inner Mongolia sets a limit of 1.5 mg/L for total phosphorus, while Gansu requires 2 mg/L. Both provinces have a secondary standard limit of 3 mg/L for total phosphorus. In terms of the tertiary standard, Inner Mongolia specifies a requirement of less than 5 mg/L for total phosphorus, while Gansu Province does not provide a clear numerical value for this requirement.

4. Summary of the discussion of techniques used in different regions

The different discharge standards for rural domestic wastewater in various regions can be attributed to several factors, including variations in wastewater treatment technologies. Currently, China employs various treatment technologies for rural sewage, such as artificial wetland, activated sludge method, stabilization pond, biofilter, and others. The predominant technologies used in Jiangsu and Anhui, the two southeastern provinces, are the activated sludge method and A^2/O (Anaerobic-Anoxic-Oxic) technology. In contrast, artificial wetland and septic tank technologies are more commonly utilized in Gansu and Inner Mongolia, the two northwestern provinces, for domestic sewage treatment.

The activated sludge method employs microorganisms to absorb, degrade, and oxidize organic pollutants in water. This technology can significantly reduce chemical oxygen demand (COD), total phosphorus, ammonia nitrogen, and suspended solids, thereby achieving high treatment efficiency [5]. A2/O technology adjusts the retention time of wastewater in anaerobic, anoxic, and aerobic zones to effectively remove nitrogen and phosphorus from wastewater [6]. The above-mentioned technologies used in the two southeastern provinces can accelerate sewage treatment efficiency and improve effluent quality, but they come with higher operational costs.

On the other hand, artificial wetland technology utilizes plants, microorganisms, and natural media to treat and purify sewage. It effectively treats organic matter, nitrogen, phosphorus, and other pollutants while improving the ecological environment. Moreover, it has the advantage of low maintenance costs and simple operation [7]. Septic tank technology involves the anaerobic fermentation process of domestic sewage sludge, separating sewage and scum layers to degrade organic matter and reduce pollutant discharge. This technology is characterized by low construction and operating costs [8].

In summary, the technologies predominantly used in the two southeastern provinces have higher treatment efficiency and better effluent quality, but they tend to be more expensive to operate. On the other hand, the technologies employed in the two northwestern provinces have lower effluent water quality but come with lower construction and operating costs.

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