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Expected Rural Wastewater Treatment Promoted by Provincial Local Discharge Limit Legislation in China

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Received: 6 April 2019; Accepted: 28 April 2019; Published: 14 May 2019

Abstract: Wastewater treatment in a rural region in China was undeveloped both in treatment capacity and legislation. The successful fast development of urban wastewater treatment plants (WWTPs) demonstrated the importance of legislation, including discharge limits. However, most provinces, with as high as 79.8% of the rural population in China, released no specific local discharge limits. Newly issued top-designed nationwide policy in September of 2018 by central China government required all provinces to issue their local rural wastewater discharge limits before June 2019. For the first time, this research analyzed the requirements of the newly issued policy and their inconsistence with several existing provincial limits. It proposed flexible principles for determination of discharge limits under various conditions to improve the rural residential environment as a whole. This study also proposed the use of the ratio between wastewater treatment cost and life expense to describe economic burden. Economic burden calculation for wastewater treatment in rural and urban regions was established respectively. Based on three conditions described in the new policy, the average burden for all urban residents was estimated as 0.122 ± 0.038% of the total life expense. In comparison, average nationwide rural burden was 0.087 ± 0.035% and 0.564 ± 0.196% for condition I (Total nitrogen(TN)/total phosphorus(TP) for resource recovery) and condition III (TN/TP for pollutant removal), respectively. It was also revealed that a stringent rural discharge limit lead to a Gini value as high as 0.38, indicting policy-related subsidies for rural residents should be carefully considered to ensure a balanced burden. Local discharge limit legislation and suitable financial policy is expected to promote rural wastewater treatment in China in the near future.

Keywords: Rural wastewater; China; Discharge limit; Gini coefficient

Highlights

- Rural wastewater treatment lags behind urban regions both in treatment capacity and legislation.
- China plans to promote nationwide local rural wastewater discharge limit legislations for the first time.
- Flexible discharge limits help to alleviate the imbalanced economic burden for urban and rural regions.

1. Introduction

Environmental protection and economic development in rural areas is one of the most important social development goals in China [1]. A stringent rural discharge limit lead to a Gini value as high as 0.38, indicting policy-related subsidies for rural residents should be carefully considered to ensure a balanced burden. In comparison, a discharge limit with nutrient recovery achieved a 0.22 Gini value with improved equity [2]. In 2018, the first released document by the Chinese government was a statement about a rural revitalization strategy, which planned to promote comprehensive development in rural regions. However, rural environmental protection, especially for wastewater treatment, was considered as more challenging due to its poor public infrastructure, less investment attractions, and depopulation with out-migration. Recently, in rural regions, most wastewater is discharged into the environment without any treatment. The generation of wastewater in rural regions of China is about 22 to 67 million ton/d, which is roughly estimated by rural population and average personal daily wastewater generation since no official data is available (rural population in 2018 was 0.56 billion based on official statistics of China and average wastewater generation was 0.04–0.12 t/(person d) based on technical policy for pollution control in rural regions launched by Ministry of Environmental Protection). It is expected that the amount will increase in the following years due to improved water supply in rural regions, which accordingly generates a higher pollution load on the rural environment. The development of rural wastewater treatment is unbalanced in China as the economy in China is also unbalanced in different regions. The situation for rural wastewater treatment in the east part of China is better developed than western regions. Even worse, wastewater treatment facilities in rural China are generally in poor condition. Different from urban regions where nearly all cities in China built wastewater treatment plants (WWTPs), China started to pay attention to rural wastewater treatment only in recent years. In 2017, nearly 94.5% municipal wastewater generated by residents in cities was treated while the number for rural regions was estimated at only about 25.1% according to the *China Statistical Yearbook on Urban and Rural Construction*. The success of WWTPs in urban regions has provided abundant engineering skills and administrative experience. However, it cannot be transferred directly into the rural wastewater treatment field [3] due to the characteristics of rural wastewater, including fluctuating quality and quantity [4,5]. An analysis of rural wastewater in China from the perspectives of legislation (e.g. discharge limits) and economic motivation is lacking.

Legislation is the one of the main diving forces which has led to the development of the environment industry [6]. For example, wastewater discharge limits impose direct administrative pressure on local governments to ensure treated wastewater satisfies legal requirements. However, legislation for rural wastewater in China is far behind that for urban wastewater. There is no top-level designed nationwide policy for rural wastewater management. For a long time, some policy and legal requirements initially designed for urban wastewater were borrowed for rural wastewater. Only several regions have issued a local rural wastewater discharge limit. However, it must be emphasized that there are remarkable intrinsic differences between wastewater treatment for urban and rural areas, which suggests specific considerations for urban and rural wastewater are needed. Compared with urban wastewater, rural wastewater generally demonstrates a smaller amount, more flexible water quality fluctuations, and higher pollutant loads. Also, resources for construction investment and skilled labor are also poorly provided in rural areas, all of which indicates the inappropriateness of the lack of specific rural legal regulations. On September 29th 2018, legislation regarding local rural wastewater treatment discharge limits by the Ministry of Ecology and Environment of the People's Republic of China (MEEP) and Ministry of Housing and Urban-Rural Development of China (MoHURD) was announced. It was a very important announcement, which proposed a national plan for rural wastewater treatment of China for the first time. Also, it is the latest national policy promoting legislation with specific requirements, whose impacts should be analyzed. The policy required that all the provinces should issue their own local rural wastewater discharge limit before June 2019. This indicates that a large number of new local rural wastewater discharge regulations will be issued in various provinces in the very near future. Also, principles for discharge limits have varied. In the United States, the pollutant discharge limitation from wastewater was regulated by the National Permit Discharge Elimination System (NPDES), which was technology based or water quality based [7]. In China, the urban wastewater treatment was regulated by the quality of the water body the effluent discharged into and nationwide uniform discharge requirements were issued, which was important to promote WWTPs management within a short time, but also was criticized for its lack of flexibility. In comparison, the principles for rural wastewater were issued for the first time and a "one-size-fits-all" approach was avoided since local limits for every province instead of a uniform national limit were required [8]. Reliable and robust management decision-making under uncertainty with no violation of the mandatory constraints was expected [9]. Some former issued local regulation might be revised according to the principles confirmed by national policy. Thus, both the recent and future expected discharge limits for local provinces around China should be reviewed and evaluated based on its legal consideration.

Economic incentives are another important issue for rural development strategy design, especially considering that China society demonstrates a binary urban–rural structure. The gap between urban and rural regions (urban–rural gap) is remarkable, with more attentions for rural regions required to speed up their development. Although inequalities, such as income and education, of urban–rural residents are widely reported, comparatively little attention has been paid, to date, to infrastructure for public environmental protection and its corresponding economic burden [10,11]. This is clearly a shortcoming when it comes to the development of environmental policies, such as a discharge limit for sustainable environmental management and social justice. Wang and Gong investigated imbalanced development and the economic burden of urban and rural wastewater treatment in China based on old discharge limit legislation [12]. Yu addressed key water crises in rural China for wastewater, with a suggestion of economic instruments [13]. Economic burden is directly impacted by the technology choice for wastewater treatment, which is usually decided by the discharge limit requirements. Various technologies have been developed for decentralized domestic wastewater treatment in rural areas, such as multi-soil-layering (MSL) systems and constructed wetlands, which are eco-friendly, economical, and easy-to-construct [14], and also membrane systems, which guarantee higher water quality despite having a higher cost [15]. The above mentioned newly issued announcement of legislation for rural wastewater discharge has the potential to remarkably change the current situation. Meanwhile, economic burden analysis should be considered for comprehensive environmental management with profound insight. The Gini coefficient, which was first proposed by Gini in 1912, was used in this study to evaluate the balance between the level of economic burden of urban and rural residents under various conditions [16,17]. Previous literature has reported case studies illustrating the measurement of inequality and distribution of environmental resources, such as water use, coal consumption [18], air pollution [19], resource utilization [20], electricity consumption equity [21], and even discharge permit allocation [22,23]. Various economic burdens under different discharge limits required by the new policy announcement were evaluated in this study with an operational cost estimation.

In this study, the delayed rural wastewater treatment in China was investigated and the impacts of newly issued top-level designed nationwide policy for local discharge limits was evaluated from the perspective of its promotion for improving the rural water environment. In detail, the objectives of this paper included: (1) Revealing the current situation of rural wastewater in China, including a comparison with urban wastewater, especially for local rural discharge limits with different considerations; (2) evaluating the requirements of the newly released top-level designed nationwide policy for speeding up the issue of provincial local rural wastewater discharge limits; and (3) analyzing the economic burden for rural and urban wastewater under different discharge limits based on the environmental Gini coefficient method.

2. Methodology

2.1. Data Sources and Economic Burden Calculation for Wastewater Treatment

In this study, the economic burden of wastewater treatment was evaluated via the ratio of expense on wastewater treatment and total life expense. To anticipate the impact of the newly issued top-design policy promoting local rural discharge limits, economic burden under three conditions with its principle were considered in this study for the first time. The burden was calculated by dividing the yearly expense for wastewater treatment by the total personal expense (Equation (1)):

$$\begin{gathered} Economic\ burden = \\ (SE * wastewater\ amount)\,/\,total\ personal\ expense. \end{gathered} \tag{1}$$

The yearly expense for wastewater treatment was obtained by multiplying the specific expense (*SE*) for treating every ton of wastewater with the yearly treated wastewater amount. The methods for the economic burden calculation were established. The data for yearly total personal expenses of rural and urban residents was obtained from the latest release of the *China Statistical Yearbook 2017*. (1) For urban regions, the data about average *SE* and wastewater generation per capital in urban regions of various provinces were collected from the China Urban Drainage Yearbook 2017. The average SE represented the total energy situation of WWTPs in a certain province. It should be noted that some data variation and uncertainty exists within each province for the wastewater generated from people over a life of expenditure, which was neglected in this research. (2) For rural regions, due to the lack of rural wastewater treatment facilities, the SE was estimated based on a theoretical value for pollutant removal with consideration of the economic benefit makeup when resource recovery from wastewater was in use. The rural wastewater characteristics and wastewater generation per capital of different regions (Northeast, North China, Northwest, Southeast, Central south, and Southwest) in China are shown in Table 1. It was assumed all generated wastewater would be collected and treated. Generally, chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP) should be removed during wastewater treatment, especially in urban WWTPs [24]. However, TN and TP are actually nutrient resources for plant growth. In rural regions, where treated wastewater could be reused for agricultural irrigation, another option is to not remove nitrogen(N)/phosphorus(P) and instead reuse it as an alternative to chemical fertilizer [25,26]. In this case, the economic benefits caused by the reduced use of conventional fertilizer were also considered during the calculation of the expense for wastewater treatment. According to the rural discharge requirements, which are discussed in detail in the following section, three conditions were constructed: Condition I: Only COD was treated while N/P was retained and reused; condition II: COD and TN were removed while only P was reused; condition III: COD, TN, and TP were all removed during wastewater treatment. Thus, the specific expense for wastewater treatment (*SE*) of rural regions was estimated as Equations (2)–(4) for the three conditions accordingly:

$$SE_I = E_{COD} \cdot \Delta COD \cdot P_{elecrticity} / p - R_N \cdot P_N - R_P \cdot P_P, \quad (2)$$

$$SE_{II} = (E_{COD} \cdot \Delta COD + E_N \cdot \Delta N) \cdot P_{elecrticity} / p - R_P \cdot P_P, \quad (3)$$

$$SE_{III} = (E_{COD} \cdot \Delta COD + E_N \cdot \Delta N + E_P) \cdot P_{elecrticity} / p, \quad (4)$$

where E_{COD} and E_N are the specific energy consumption amounts with an estimated value of 0.69 kWh/kg COD and 12.8 kWh/kg N from large scale urban WWTPs [27]. ΔCOD and ΔN represent the relative amounts removed during every ton of wastewater treatment. It was assumed that all pollutants were removed for easy calculation. $P_{elecrticity}$ represents the electricity price with a value of 1 Yuan RMB/kWh. The ratio of electricity fee and the total cost, p, was estimated as 40% for both urban and rural wastewater treatment. R_N and R_P represent the recovered amount of N and P. It was assumed all initial N and P would be reused in condition I and II. P_N and P_P are the fertilizer prices of N and P, with 3260 Yuan RMB/t and 5000 Yuan RMB/t [28,29].

According to data from *Technical policy for pollution control in rural regions* (Table 1), the nutritional potential of wastewater can be described by N:P (7.4–12.9) and N:COD (0.10–0.25) with the median value. Northeast and North China achieved the highest N:P and Central south demonstrated the highest N:COD. It should be noted that the nutritional recovery did not mean the direct reuse of rural wastewater. Water quality issues that must be considered in the use of treated wastewater for irrigation include the specific ion toxicity, nitrate content, salinity, heavy metals, and pathogens. Treatment consisting of the removal of parasite contamination and pesticides is necessary to guarantee the safety of wastewater reuse and to avoid secondary contamination of local soil and groundwater.

Table 1. Rural wastewater characteristics of different regions in China.

Rural Regions	COD (mg/L)	NH_4–N (mg/L)	TP (mg/L)	Wastewater Amount [2] (L/(Person·d))	Provinces Included [3]
Northeast	325 [1] (200–450)	55 (20–90)	4.25 (2.0–6.5)	65 (40–90)	Heilongjian, Jilin, Inner Mongolia, Liaoning
North China	325 (200–450)	55 (20–90)	4.25 (2.0–6.5)	60 (40–80)	Beijing, Tianjin, Heibei, Shanxi, Shandong
Northwest	250 (100–400)	26 (3–50)	3.5 (1.0–6.0)	45 (50–90)	Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang
Southeast	300 (150–450)	35 (20–50)	3.75 (1.5–6.0)	90 (80–100)	Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan
Central south	200 (100–300)	50 (20–80)	4.5 (2.0–7.0)	90 (60–120)	Henan, Hubei, Hunan, Anhui, Jiangxi
Southwest	275 (150–400)	35 (20–50)	4 (2.0–6.0)	90 (60–120)	Sichuan, Yunnan, Guizhou, Chongqing, Guangxi, Tibet

[1] Median value was used for wastewater treatment estimation while value in brackets was data from *Technical policy for pollution control in rural regions* launched by the Ministry of Environmental Protection. [2] Median value was estimated based on data from *Technical guideline for regional rural wastewater treatment* launched by MoHURD. [3] Data for Hong Kong, Macao, and Taiwan not available.

2.2. The Gini Coefficient Method

The Gini coefficient method originated from the economic measurement of income inequality. Recently, it was also proposed to evaluate inequality of environmental resources. In this study, the environmental Gini coefficient was used to evaluate the economic burden for urban and rural wastewater treatment in China [30,31]. Rural and urban regions of 31 provinces were ranked according to their burden values from lowest to highest. The Gini coefficient was calculated using Equation (5):

$$G = 1 - \sum_{i=1}^{m} (X_i - X_{i-1})(Y_i + Y_{i-1}), \tag{5}$$

where X_i represents the cumulative proportion of various provinces. Y_i is the cumulative proportion of the total financial burden. A higher Gini coefficient value (0~1) indicates less equality. A detailed calculation was provided in previous literature [12].

3. Results and Discussion

3.1. The Undeveloped Rural Wastewater Treatment in China and Current Regional Discharge Limits

As pollution pressure has increasing due to economic development and population growth, more and more attention has been given to wastewater treatment in China. Initially, most WWTPs were built in urban regions, where wastewater treatment was urgent and more social resources were available. As shown in Table 2, China actually went through an unexpected fast development in urban WWTP construction. The urban WWTP number increased from 427 in 2000 to 2209 in 2017, with the capacity rising from 2157×10^4 t/d to $15{,}743 \times 10^4$ t/d accordingly. Now, as much as 94.54% of urban wastewater is treated and China is now one of the countries with the largest wastewater treatment market in the world. However, this development has been remarkably unbalanced between wastewater treatment plants in urban and rural regions. Before 2012, statistical data for rural wastewater treatment was not available as most rural wastewater was not treated around the country. Recently, rural wastewater treatment has received more attention and the treatment rate has increased to 25.13%. Even so, more efforts are still needed to progress and strengthen rural wastewater treatment.

Table 2. Comparison of urban and rural wastewater treatment in China (2000–2017).

	Urban Regions (City)			Rural Regions
Year	**WWTP Amount**	**Capacity (10^4 t/d)**	**Treatment Rate (%)**	**Treatment Rate (%)**
2000	427	2157.84	34.25	/*
2001	452	3106.25	36.43	/
2002	537	3578	39.97	/
2003	612	4253.6	42.39	/
2004	708	4912	45.67	/
2005	792	5725	51.95	/
2006	815	6366	55.67	/
2007	883	7146	62.87	/
2008	1018	8106	70.16	/
2009	1214	9052	75.25	/
2010	1444	10,436	82.31	/
2011	1588	11,303	83.63	/
2012	1670	11,733	87.3	/
2013	1736	12,454	89.34	9.1
2014	1807	13,087	90.18	9.98
2015	1943	14,028	91.9	11.4
2016	2039	14,910	93.44	20
2017	2209	15,743	94.54	25.13

Data about urban (county region not included) and rural wastewater treatment was collected from *China Statistical Yearbook on Urban and Rural Construction* from 2000 to 2017. The data for rural wastewater treatment from 2000 to 2012 was not officially reported.

Legal regulations issued in the early stage help to promote urban WWTPs' construction. As shown in Figure 1, technical policy for urban wastewater treatment and technical guidelines for urban wastewater treatment were issued by the Ministry of Environment Protection (whose name was changed to the Ministry of Ecology and Environment of the People's Republic of China, MEEP, in 2018) in 2000 and 2001, respectively, which proposed general principles for the development of urban wastewater treatment. In 2002, another important regulation, the discharge standard of pollutants for municipal wastewater treatment plants (GB18918-2002), was published, which provided various discharge limits and requirements for environmental management and supervision. Rapid and efficient development of the water industry indicates the crucial roles of legal regulations.

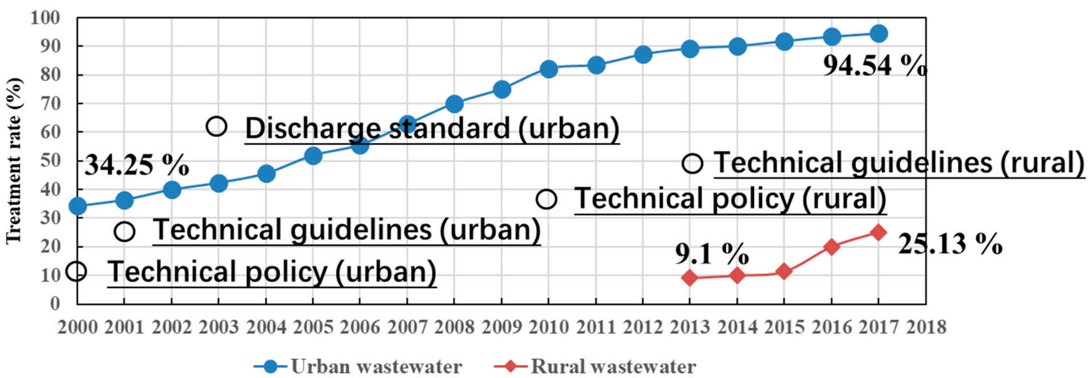

Figure 1. Development of the urban and rural wastewater treatment rate with issued legislation.

The Chinese society demonstrates a long-standing binary urban–rural structure combined with economic-centralized developmental policies, which require institutional reform, regulation revision, economic instruments, technology innovation, and capacity-building to speed up development in rural regions. Wastewater treatment is also one of the examples demonstrating the binary urban–rural structure. As shown in Table 3, rural regions' wastewater treatment is generally insufficiently developed. Meanwhile, legislation for rural wastewater received much less attention in the early stage, with only several very general legal requirements mentioned. For example, the *Water Pollution Control Law of China* and *Environment Protection Law of China* (issued in 1984 and 1989, respectively) stated that rural wastewater treatment should be treated, however, it provided no specific detailed requirements. As late as in the year of 2010, the *Technical policy for rural wastewater treatment* was issued, nearly 10 years later than that issued for urban wastewater treatment. The release of technology guidelines was also late, which was probably caused by complicated rural conditions and disputes based on the various technology options [12].

Table 3. Classification of the current local rural wastewater discharge limit issued before 2018.

Types	Main Characteristics	Provinces	Population Ratio (%)
A	Similar to urban standard	Fujian, Hebei and Shaanxi	11.3
B	More stringent than urban standard	Beijing	0.5
C	More flexible limits than urban standard	Zhejiang and Chongqing	5.1
D	Emphasizing ecological resource recovery	Ningxia and Shanxi	3.3
E	Others (no specific local discharge limits were released while urban limits were borrowed and referred)	All the rest provinces not mentioned above	79.8

The provision of legislation regarding discharge limits was one of most important milestones for water resource management, which placed direct administrative pressure on local government and usually proposed technical options for deciding operational costs. The national urban discharge limits was initially issued in 2003 and experienced revision in 2006. After the revision, the class 1A standard was widely proposed for WWTPs when effluent was discharged into an enclosed or sensitive water body. The main discharge limits included COD (50 mg/L), TN (15 mg/L), and TP (0.5 mg/L). Considering the very huge territorial area of China, a criticism was that all situations applied the same national limits, and only recently has a local urban discharge limit been issued by several provinces, such as Beijing and Tianjin [32].

As for rural wastewater, no national discharge limits exist. For a long time, when needed, the standards initially designed for urban wastewater were borrowed and cited for rural wastewater. Until September 29th of 2018, the nationwide policy for rural wastewater was issued for the first time, which is discussed in detail in the next section. Before the policy announcement, several provinces, including Fujian, Hebei, Shaanxi, Beijing, Zhejiang, Chongqing, Ningxia, and Shanxi, had already issued a local rural wastewater discharge limit. However, due to the lack of top-level designed nationwide policy, inconsistency among these local rural limits existed. In general, while some local provinces emphasized environmental sensitivity with the discharge limit equal or even stricter than the urban standard, some others focused on resource recovery for rural regions with less stringent discharge limits. As shown in Table 3, local rural wastewater discharge limits issued before 2018 can be divided into five types. The first type (Fujian, Hebei, and Shaanxi) generally directly made use of the urban standard. The second type pursued more stringent water quality and used more stringent discharge requirements, which was preferred by economically developed areas, such as Beijing. The third and fourth type proposed more flexible limits considering that the incomes of rural residents were lower and the environmental capacity was higher than urban regions. Meanwhile, the fourth type also emphasized ecological resource recovery from wastewater, such as N/P. The third and the fourth type are more popular and widely accepted due to their sustainable concept. However, only several provinces (Zhejiang, Chongqing, Ningxia, and Shanxi) have applied this idea, and their populations only make up about 8.4% of the total rural population in China. For most rural populations, as high as 79.8% of residents live in areas with no released specific local discharge limits while urban limits were borrowed if needed. This situation will change after the announcement of nationwide policy for rural wastewater, the impacts of which will be discussed later.

3.2. The Top-Level Designed Nationwide Policy for Speeding Up the Issue of Provincial Local Rural Wastewater Discharge Limits

Discharge standards of rural domestic wastewater treatment are one of the most important legal foundations for rural environmental management, which relate to the choice of treatment technology and accordingly to the operation/maintenance cost. In order to fulfill the requirements of the *Three-Year Action Plan for Rural Human Settlement Environmental Renovation*, it is clearly necessary that legislation regarding local discharge limits for rural domestic wastewater treatment is developed rapidly, which is crucial for any improvement of the rural environment to occur. On September 29th 2018, legislation regarding local rural wastewater treatment discharge limits were announced by the Ministry of Ecology and Environment of the People's Republic of China (MEEP) and Ministry of Housing and Urban-Rural Development of China (MoHURD). This is the latest top-level designed national policy-promoting legislation with specific requirements.

According to the new released top-level designed national policy, the main goal for rural wastewater treatment is to improve the rural residential environment, which must consider the actual local situations. The policy proposes that pollutant removal and resource recovery, engineered technology and the ecological method, and the centralized mode and decentralized mode are combined, with the following specific suggestions:

- Extending the urban wastewater network to surrounding rural villages in suburbs.
- Promoting easy-to-maintain, low-cost, and low-energy wastewater treatment technologies, with ecological processes encouraged.
- Encouraging a reduction in sources of wastewater generation and the reuse of treated wastewater.
- Making full use of existing facilities for waste disposal, such as biogas digesters, strengthening the effective connection between toilet improvement and rural domestic sewage treatment, adopting appropriate ways to treat or utilize toilet waste harmlessly, and strictly forbidding the direct discharge of untreated toilet waste into the environment.

Actually, the definition of rural wastewater was not clear before the policy release. To guarantee the successful application of local rural wastewater discharge limits, the scope of local rural wastewater limits was defined for the first time in the announcement. As shown in Figure 2, the applicable scope of local rural wastewater discharge limits was described. If wastewater generated in rural regions is discharged into nearby urban sewerage, the *Water Quality Standard for wastewater Discharged into Urban Sewerage* (GB/T 31962-2015) should be followed. If not, and the rural wastewater scale is <500 m^3/d, the local rural discharge limits are applied. Otherwise, when the scale is higher than 500 m^3/d, the *National Urban WWTP Discharge Standard* (GB 18918-2002) should be considered since the wastewater treatment scale is large. Generally, rural wastewater discharge limits are applicable to treatment facilities whose treatment scale is less than 500 m^3/d. The applicable value of 500 m^3/d could be adjusted according to the actual situation.

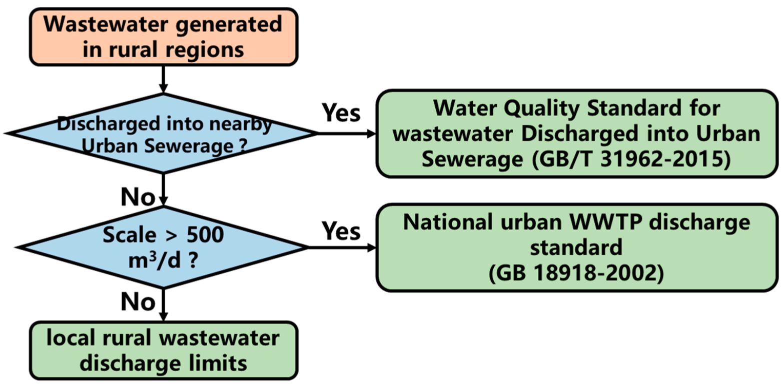

Figure 2. Flow chart describing the scope of local rural wastewater discharge limits.

The formulation of discharge standards for rural domestic wastewater treatment should be based on the local conditions, including population, wastewater scale, water body receiving effluent, and residential environment improvement requirement in rural areas. Based on the policy, the pollutant controlling indexes and discharge limits should be classified and determined accordingly. As shown in Figure 3, if effluent is discharged into a water body directly, the limits should be decided by the water body function. If the water body belongs to the surface water body type II and III according to the *Environmental Quality Standards for Surface Water (GB3838-2002)*, whose environmental requirements are high, pollutant controlling indexes should at least contain COD, SS (suspended solid), and ammonia nitrogen. If the water body belongs to the surface water body type IV and V, pollutant controlling indexes should only focus on COD and SS. It should be noted that if the water body is enclosed or eutrophic, the TN/TP should be added into the pollutant controlling indexes in order to lessen the N/P pollution load. In situations where the water body function is unclear, the general principle for discharge limit determination is to prevent the water body from turning into black and odorous. Besides, if wastewater is discharged into a water body indirectly, e.g., flowing through ditches/wetlands before entering into a water body, more flexible limits could be considered. Meanwhile, if rural wastewater could be reused with a definite purpose, a relative water quality standard should be referred, e.g., irrigation purpose for *GB5084-2005*, fisheries purpose for *GB11607-89*.

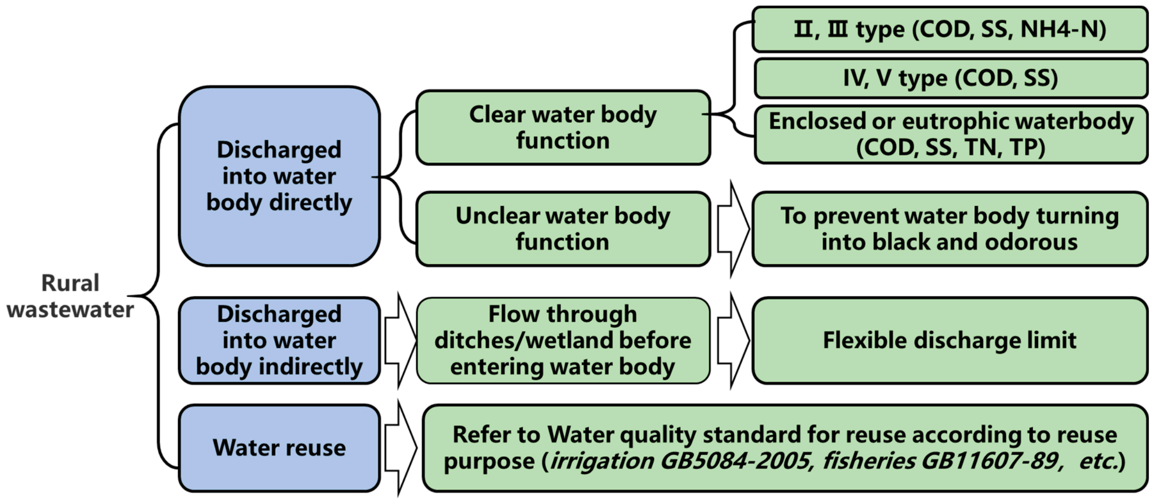

Figure 3. Principles for the determination of discharge limits under various conditions.

Recently, there was a popular, although probably unsuitable, idea in China that rural wastewater should also be treated with the same requirements as urban wastewater. The idea come from the requirement for increasingly more stringent environmental management in China. However, this idea neglected the fact that China is still a developing country with limited financial resources and a huge undeveloped rural population. Local government preferred the idea, which could be considered as proof of their determination to improve the environment and also as a response to national. However, the newly issued policy clearly demonstrates the attitude of central government that the first goal for rural wastewater treatment is to improve the residential environment as a whole rather than just focusing on wastewater quality. Also, the total pollution amount should be reduced with a lesser environmental load, rather than just reducing the effluent pollutant concentration. Meanwhile, the statement about resource recovery could promote rural wastewater reuse under suitable supervision. Shortcomings of the policy also exist. For example, environmental impact assessment is required in the early stages of an engineering project. How to adjust rural wastewater treatment goals to combine local environmental planning based on flexible discharge limits with enough scientific support remains a question. Also, consideration of the financial sustainability of rural wastewater treatment is lacking.

3.3. The Economic Burden for Rural and Urban Wastewater Treatment under Various Discharge Limit Conditions

Discharge limits usually decide the wastewater treatment process choice, which accordingly impacts operational costs and the financial burden on local residents. Generally, the more stringent the discharge limits are, the higher the consumption costs. It is widely accepted that every person had the right to enjoy a clean environment, whether they live in rural or urban regions. Considering the binary urban–rural structure of China and the much lower incomes of rural residents compared with urban residents, a balanced economic burden for all people in rural and urban regions is expected, which is directly influenced by discharge limits. According to the new issued policy, which requires that all provinces of China propose their own local rural discharge limits in the near future (June 2019), three discharge level conditions are described based on the water body function where wastewater directly discharges into. Condition I: Only COD is treated while N/P is retained and reused; condition II: COD and TN are removed while only P is reused; condition III: COD, TN, and TP are all removed during wastewater treatment. The direct operational cost for rural wastewater treatment was estimated based on statistical data in China described in the Methods section. Meanwhile, it should be noted that TN and TP are actually nutrient resources for plant growth. In rural regions, where treated wastewater could be reused for agricultural irrigation, another option is to not remove N/P, and instead reuse it as an alternative to chemical fertilizer. In this case, the economic benefits caused by the reduced use of conventional fertilizer are also considered during the calculation of the expense of wastewater treatment.

The average burden for urban regions and rural regions under three conditions was analyzed for provinces in China (31 provinces excluding Hong Kong, Macao, and Taiwan). As shown in Table 4, the average burden for all urban residents was estimated as 0.122 ± 0.038% of the total life expense. In comparison, under condition I of resource recovery, the average nationwide rural burden was 0.087 ± 0.035%, slightly lower than urban residents. However, under condition II and III with more stringent discharge limits, rural burdens were much higher at 0.490 ± 0.172% and 0.564 ± 0.196%. The results indicate that similar discharge limits for all pollutant indices, including COD, TN, and TP, induce a higher economic burden. The economic burden ranking for rural and urban regions of various provinces under different rural discharge limit conditions was also analyzed (Table 5). Under condition I, all regions demonstrated a lower burden between 0.035% and 0.0219% with urban regions generally higher than rural regions. The situation changed under condition II and III, in that the burden for rural residents increased remarkably. The highest three regions under condition III indicated a burden between 0.665% and 0.701% of rural Shanxi, rural Hainan, and rural Tibet, nearly 10 times higher than those of the lowest three regions.

Table 4. Economic burden for urban regions and rural regions under three conditions.

	Urban	**Rural-Condition I**	**Rural-Condition II**	**Rural-Condition III**
Average economic burden for wastewater treatment	0.122 ± 0.038%	0.087 ± 0.035%	0.490 ± 0.172%	0.564 ± 0.196%

Table 5. Economic burden rank for rural and urban regions of various provinces under different rural discharge limit conditions (the highest and lowest third was listed).

	1st Highest	**2nd Highest**	**3rd Highest**	**1st Lowest**	**2nd Lowest**	**3rd Lowest**
Condition I	Beijing urban 0.219%	Ningxia urban 0.189%	Jiangsu urban 0.164%	Hubei rural 0.035%	Hunan rural 0.036%	Anhui rural 0.037%
Condition II	Shanxi rural 0.627%	Hainan 0.596%	Heilongjian rural 0.579%	Guizhou urban 0.063%	Yunnan urban 0.069%	Jiangxi urban 0.075%
Condition III	Shanxi rural 0.701%	Hainan rural 0.695%	Tibet rural 0.665%	Guizhou urban 0.063%	Yunnan urban 0.069%	Jiangxi urban 0.075%

It should be noted that the technologies used for rural wastewater treatment vary depending on the local situations of different countries. For example, in Brazil, most of the traditional and decentralized processes for rural sewage treatment include use of a septic tank and drain field, and more recently, the combination of a septic tank and anaerobic filter [33]. Membrane bioreactors (MBRs) effectively remove pollutants, but have high capital, operations, and maintenance costs, and thus are more suitable for developed countries rather than developing countries [34]. This study did not pay attention to the specific technology, but the general treatment concept with various considerations.

Gini coefficients for urban and rural wastewater treatment under various conditions were investigated to analyze the economic burden. As shown in Figure 4, condition III proposed the most stringent discharge requirements and meanwhile the most serve imbalance with a high Gini value of 0.38. It was caused by the increased rural wastewater treatment cost with relative lower local incomes. Condition II neglected P removal with a reduced Gini. However, the imbalanced extent was still high (0.36), indicating that P was not the main factor deciding the financial burden balance. In comparison, condition III, which only treated COD and recovered N and P in the wastewater, demonstrated the lowest Gini value of 0.22 with improved equity. Accordingly, condition I was preferred from the perspective of financial equity for rural and urban residents. In other cases, e.g., when condition III with the most stringent discharge limits was required, policy-related subsidies for rural residents should be carefully considered to ensure a balanced burden. Meanwhile, discharge limit legislation should also be considered from all perspectives, including the local ecological capacity and the technical availability for rural areas.

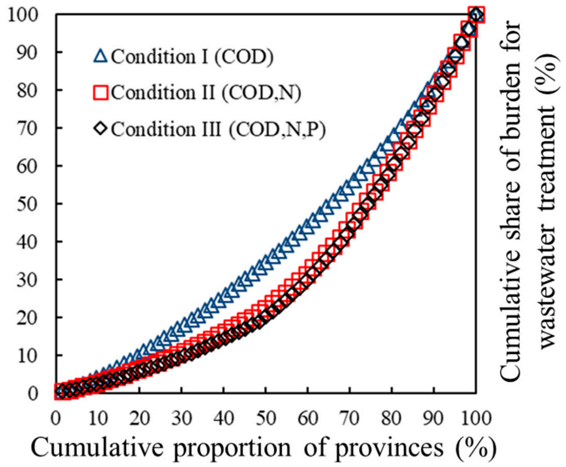

Figure 4. The Gini coefficients of the economic burden for urban and rural wastewater treatment under different conditions (condition I proposed discharge limit for COD; condition II for COD and N in form of ammonia; condition III for COD, N, and P).

4. Conclusions

Newly issued policy in September 2018 by the central Chinese government required all provinces to issue their local rural wastewater discharge limits before June 2019. For the first time, this research analyzed the requirements of the newly issued policy and their inconsistency with several existing provincial limits. This study also proposed the use of the ratio between the wastewater treatment cost and life expense to describe economic burden. The economic burden calculation for wastewater treatment in rural and urban regions was established. Local discharge limit legislation and suitable financial policy is expected to promote rural wastewater treatment in China in the near future. The following conclusions were reached:

- Wastewater treatment in rural regions in China is undeveloped both in treatment capacity and legislation. The successful fast development of urban wastewater treatment plants (*WWTPs*) demonstrates the importance of legislation, including discharge limits. However, most provinces, including as much as 79.8% of the rural population in China, have released no specific local discharge limits.

- Newly issued top-level designed nationwide policy in September 2018 proposed flexible principles for the determination of discharge limits under various conditions to improve the rural residential environment as a whole. The limited existing local rural wastewater discharge limits demonstrate inconsistency due to the lack of top-level designed nationwide policy, with some provinces emphasizing environmental sensitivity with discharge limits equal or even stricter than urban standards while others focus on resource recovery with less stringent discharge limits.
- Based on the three conditions described in the new policy, the average burden for urban residents was estimated as 0.122 ± 0.038% of the total life expense. In comparison, the average nationwide rural burden was 0.087 ± 0.035% and 0.564 ± 0.196% for condition I (TN/TP for resource recovery) and condition III (TN/TP for pollutant removal), respectively.
- Stringent rural discharge limits led to Gini values as high as 0.38, indicating that policy-related subsidies for rural residents should be carefully considered to ensure a balanced burden. In comparison, discharge limits with nutrient recovery achieved a 0.22 Gini value with improved equity.

Author Contributions: Formal analysis, H.G.; Investigation, M.W.; Writing – original draft, M.W. and H.G.; Writing – review & editing, H.G.

Funding: This work is partly financially supported by the Center for Industria Development and Environmental Governance (CIDEG) and Summer Institute for China's Green Innovators (SICGI). We have received the grants in support of our research work. The funds we have received for covering the costs to publish in open access.

Conflicts of Interest: The authors declare no conflict of interest.

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