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Imbalanced Development and Economic Burden for Urban and Rural Wastewater Treatment in China—Discharge Limit Legislation

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Received: 28 June 2018; Accepted: 18 July 2018; Published: 24 July 2018

Abstract: Water pollution control is a great challenge for China. Compared with urban regions, the wastewater treatment in rural areas is much undeveloped, which is highly related with the much delayed legislation for rural wastewater. Imbalanced urban-rural development and the economic burden of urban and rural wastewater treatment in China was investigated from the perspective of discharge limit legislation. For now, the national discharge limit for rural wastewater is still vacant, although the national discharge limit for urban wastewater had been released for more than ten years. Recently, local rural wastewater discharge limits from several provinces were released, however, based on quite different principles. Some categories emphasized environmental sensitivity with the discharge limit equal and were more strict than urban standards, while some focused on resource recovery for rural regions with loose discharge limits. This study compared the financial burden between rural and urban regions in 31 provinces under different discharge limit legislation conditions. It was revealed that the resources recovery category discharge principle helped to decrease the financial burden imbalance with a reduced Gini coefficient from 0.37 to 0.17. The reduced economic burden from the implementation of a suitably designed rural discharge limit promoted balancing the rural-urban gap and lowering uncertainties and risk of sustainable rural wastewater treatment. This study also revealed the urgency of rural water legislation and proposed development with a balanced financial burden for urban and rural residents under suitable discharge limits, providing a profound insight for environmental management with a focus on balanced urban-rural development for the policy-makers in developing countries.

Keywords: discharge limits for rural and urban areas in China; economic burden; Gini coefficient

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Highlights

- Rural areas lag behind urban areas in legislation for wastewater treatment
- The current discharge limit legislation for rural regions of provinces in China was reviewed
- The Gini coefficient revealed an imbalanced economic burden for urban and rural wastewater treatment
- Discharge limits concerning resource recovery alleviated the imbalance.

1. Introduction

With consideration of the severe water environment burden, tremendous efforts have been directed towards increasing wastewater treatment capacity in China [1]. Based on statistical data from the Ministry of Housing and urban-rural development of China (MOHURD), the number of wastewater treatment plants (WWTPs) has increased from approximately 480 in 2000 to 3700 in 2014, with capacity increasing from 22 million ton/d to 157 million ton/d. Unexpected rapid growth has already made China obtain the largest wastewater treatment capacity around the world. However, most development occurred in cities rather than rural regions. Nearly all the WWTPs were built in urban areas with less development of rural wastewater treatment facilities. In 2016, nearly 93.44% of the municipal wastewater from residents of cities was treated, while the percentage for rural regions was estimated at only about 22%. It was estimated 21–24 million ton/d of wastewater was generated in rural areas and the amount kept increasing due to an improved standard of living. An increasing pollution load and undeveloped wastewater treatment facilities have posed a great threat to the rural environment.

The gap between urban and rural regions (urban-rural gap) was always hot issue for Chinese society [2–4]. Due to weak public infrastructure, less investment, and depopulation without migration, rural regions need greater attention to speed up development. Recently, the NO.1st released pubic document of the Chinese government in 2018 was the statement of rural revitalization strategy, which planed national action to promote rural development including improving the rural environment. The binary urban-rural structure of Chinese society indicated the request of balanced and equal development of urban and rural areas, not only of economic development, but also the right to enjoy a clean environment. Yan reported the close relationship and influence of both the rural-urban income ratio and water environment on rural population wellbeing, indicating the importance to address environment and poverty issues simultaneously [5]. Although inequalities in income of urban-rural residents are relatively well and widely investigated, comparatively little attention has been paid, to date, to the imbalance in environmental infrastructure and its economic burden on local residents [6,7]. This is clearly a shortcoming when it comes to developing environmental policies such as the discharge limit for sustainable environmental management and social justice.

In the past few years, the gap between rural and urban wastewater treatment infrastructures has been remarkably enlarged. Also, the legislation processes, which guided and promoted wastewater treatment development, demonstrated noteworthy differences in urban and rural regions. Specially, discharge standards of all kinds of pollutant discharge limits were one of the crucial legal regulations which decided the engineering process options, and accordingly, the financial cost for wastewater treatment. Legal information about water environment management in rural and urban areas should be reviewed and the relationship between pollution load and legal activities were not clear. The comprehensive review of urban and rural wastewater situations and their discharge limit legislation, including local limits in some provinces of China, was not reported.

Besides, evaluation methods for economic burden analysis were also discussed to provide a profound insight for environmental management. The Gini coefficient, which was originally proposed by the Italian economist Gini in 1912, was primarily designed to measure the inequality of income according to the Lorenz curve with values between 0 and 1 [8,9]. Recently, the concept of the Gini coefficient was enlarged and was proposed to measure inequality and distribution in use of environmental resources, which was named as the environmental Gini coefficient [10,11]. Various environmental issues regarding equality and balance were evaluated by the Gini coefficient method including water use, coal consumption [12], air pollution [13], resource utilization [11], electricity consumption equity [14], carbon emission [15], and even discharge permit allocation [16,17]. However, to our best knowledge, use of the environmental Gini coefficient to evaluate the economic burden for urban and rural wastewater treatment in China was not yet reported in previous literature.

In this study, imbalanced development and economic burden for urban and rural wastewater treatment in China was revealed from the perspective of discharge limit legislation based on the environmental Gini coefficient method. In detail, the objectives of this paper are: (1) Compared with urban development, the wastewater treatment development in rural regions was reviewed and the reason for delayed development from the perspective of discharge limit legislation was discussed; (2) the current discharge limit for rural wastewater treatment in several provinces in China was reviewed and their impacts were analyzed; (3) the financial burden for rural wastewater treatment of different provinces, which was dependent on discharge limits and requirements, was evaluated based on the environmental Gini coefficient under various local discharge limit conditions.

2. Methodology

2.1. Data Sources

The financial burden of wastewater treatment was described by the ratio between yearly treatment expense and total personal life expense. The expense for wastewater treatment ($E_{wastewater}$) was estimated in Equation (1). The yearly personal expenses for rural and urban residents in various provinces were obtained from the most recently released *China Statistical Yearbook 2017*.

$$E_{wastewater} = 365 \cdot P_{wastewater} \cdot C_{electricity} \cdot F_{elecrticity} / p \quad (1)$$

$P_{wastewater}$ is the daily produced wastewater amount in unit of t/(person·d). $C_{electricity}$ is the specific electricity consumption for wastewater treatment (kWh/t). The values of $P_{wastewater}$ and $C_{electricity}$ for urban regions of different provinces were obtained from Yearbook of urban drainage statistics 2016. The values of $P_{wastewater}$ for rural regions of different provinces were obtained from the "National Technical Guideline for Regional Rural Wastewater Treatment". $F_{elecrticity}$ was the fee of electricity with a value of 0.5 yuan RMB/kWh. The ratio of electricity fee and the total cost, p, was estimated as 25% and 90%, respectively, for urban and rural wastewater treatment. There was no statistical data for rural specific electricity consumption for wastewater treatment. It was estimated as 3 kWh/t and 1 kWh/t, respectively, for a discharge limit focusing on environmental sensitivity with strict requirements and a discharge limit focusing on resource recovery with loose requirements, which was discussed in detail in the following section.

Specific energy consumption for oxygen-consuming pollutant removal was calculated by collecting energy consumption data for specific urban wastewater treatment facilities in various provinces and calculating oxygen-consuming pollutants based on local wastewater characteristics. Oxygen-consuming pollutants included COD and NH_3-N with a conversion coefficient of 4.57 kgCOD/kg NH_3-N.

Based on the "Technical Policy for Pollution Control in Rural Regions" launched by the Ministry of Environmental Protection in 2010, provinces of China were divided into six categories including Northeast, North China, Northwest, Southeast, Central South, and Southwest. The rural wastewater characteristics of the six different regions were provided as shown in Table 1.

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

Rural Regions	Northeast [1]	North China [2]	Northwest [3]	Southeast [4]	Central South [5]	Southwest [6]
pH	6.5~8.0	6.5~8.0	6.5~8.5	6.5~8.5	6.5~8.5	6.5~8.0
SS (mg/L)	150~200	100~200	100~200	100~200	100~200	150~200
BOD_5 (mg/L)	200~300	200~300	50~300	70~300	60~150	100~150
COD (mg/L)	200~450	200~450	100~400	150~450	100~300	150~400
NH_3-N (mg/L)	20~90	20~90	3~50	20~50	20~80	20~50
TP (mg/L)	2.0~6.5	2.0~6.5	1.0~6.0	1.5~6.0	2.0~7.0	2.0~6.0

[1] Northeast includes provinces of Hei Longjian, Ji Lin, and Nei Menggu; [2] North China includes provinces of Bei Jing, Tian Jin, Hei Bei, Shan Xi, and Shan Dong; [3] Northwest includes provinces of Shan Xi, Gan Su, Qing Hai, Ning Xia, and Xin Jiang; [4] Southeast includes provinces of Jiang Su, Shang Hai, Zhe Jiang, Fu Jian, Guang Dong, and Han Nan; [5] Central south includes provinces of He Nan, Hu Bei, Hu Nan, An Hui, and Jiang Xi; [6] Southwest includes provinces of Si Chuang, Yun Nan, Gui Zhou, Chong Qing, and Guang Xi.

Average wastewater generation amount was estimated based on data from "Technical Guideline for Regional Rural Wastewater Treatment" launched by MOHURD (Table 2). Generally, more wastewater was generated in the south part of China due to abundant local water resources. With combined consideration of economic level, median values of type II with 65, 90, and

60 L/(person·d) were used for wastewater amount estimation for regional provinces of Northeast, Southeast, and North China, respectively. Meanwhile, median values of type III with 45, 60, and 65 L/(person·d) were used for wastewater amount estimation for regional provinces of Northwest, Southwest, and Central south, respectively.

Table 2. Rural wastewater generation amount in different regions of China.

Village Type	Northeast	Southeast	North China	Northwest	Southwest	Central South
I: Good economic condition with water flush toilet and shower facilities	80~135	90~130	100~145	75~140	80-160	100~180
II: General economic condition with water flush toilet and shower facilities	40~90	80~100	40~80	50~90	60-120	60~120
III: No water flush toilet and general sanitary facilities	40~70	60~90	30~50	30~60	40-80	50~80
IV: No water flush toilet and shower facilities	20~40	40~70	20~40	20~35	20-50	40~60

2.2. The Gini Coefficient Applied to Environmental Burden under Discharge Permit

Figure 1 showed an example of a Lorenz curve. The Gini coefficient is the ratio of the area A to the area (A+B) [18,19], as calculated in Equation (2). The Gini coefficient could be approximated from the curve using the trapezoidal rule in which the area B in Figure 1 was calculated by the sum of all trapezoids.

$$G = 1 - \sum_{i=1}^{m} (X_i - X_{i-1})(Y_i + Y_{i-1}) \quad (2)$$

where X_i was the cumulative proportion of various provinces. Rural and urban regions of 31 provinces was ranked by their burden values from lowest to highest, which were distributed with equal proportion. Y_i was the cumulative proportion of the total financial burden. Accordingly, the higher the value of the Gini coefficient was, the less equality there was. A value of 1 implied absolute inequality while 0 implied absolute equality. Though originated from an economic measurement of income inequality, the Gini coefficient method has been proposed to evaluate inequality and distribution in the use of various environmental resources including water, coal, electricity, and so on. In this study, an environmental Gini coefficient was proposed to evaluate the situation of economic burden for urban and rural wastewater treatment in China, which was not yet reported in previous literature.

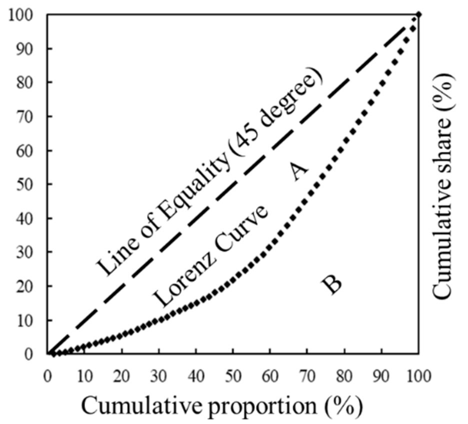

Figure 1. Calculation of Gini coefficient using the Lorenz curve.

3. Results and Discussion

3.1. Delayed Legislation in Rural Area Compared with Urban Regions

Wastewater treatment in China has demonstrated a remarkably unbalanced development between urban and rural regions. As shown in Table 3, urban regions (including both city-level and county-level) have achieved high level treatment in recent years. In 2012, about 87.3% of the wastewater from cities was collected and treated, this number increased to 93.44% in 2016. In county-level urban regions, a wastewater treatment rate as a high as 87.38% was also achieved. Meanwhile, some small scale WWTPs were replaced by larger ones with an optimized design, resulting in a decline in the number of WWTP in years 2015~2016 with capacity rising. In general, the wastewater treatment in urban areas was mature and close to saturation.

In comparison, rural wastewater treatment was much more backward. Before 2012, there were no national statistics since few facilities in rural regions were built. In 2013–2015, the ratio of villages with wastewater treatment facilities grew slowly from 9.1% to 11.4%. Recently, much more attention was paid to rural wastewater treatment. In 2016, 20% of villages had access to a wastewater treatment facility. However, the general rural regions wastewater treatment was still under insufficient development.

Table 3. Comparison between urban and rural wastewater treatment.

Year	Urban Regions (City)			Urban Regions (County)			Rural Regions
	WWTP Amount	Capacity (10^4 t/d)	Treatment Rate (%)	WWTP Amount	Capacity (10^4 t/d)	Treatment Rate (%)	Treatment Rate (%)
2012	1670	11,733	87.3	1416	2623	75.24	/ *
2013	1736	12,454	89.34	1504	2691	78.47	9.1
2014	1807	13,087	90.18	1555	2882	82.12	9.98
2015	1943	14,028	91.9	1599	2999	85.22	11.4
2016	2039	14,910	93.44	1513	3036	87.38	20

* Data about urban (city & county) and rural wastewater treatment was collected for a yearly statistical bulletin on urban and rural construction from 2012 to 2016. The data for rural wastewater treatment in 2012 was not officially reported.

One of the reasons that urban wastewater treatment is developing much faster than rural wastewater treatment was their different legislation processes in water management. Development and legislation comparison between urban and rural wastewater treatment is shown in Figure 2. Dating back to 2000, urban wastewater treatment in China was also quite undeveloped, with only approximately 20 million ton/d treatment capacity in total. It should be noted that China experienced unexpected fast development in urban WWTP construction in the following 15–20 years. The total amount of urban wastewater treatment in 2016 grew to 179 million ton/d with 3552 WWTPs. The fast growth was closely related to, and guaranteed by, timely legal supports. In the years of 2000, 2001, and 2003, three important legal regulations were issued by the Ministry of Environment including the "Technical Policy for Urban Wastewater Treatment", "Technical Guidelines for Urban Wastewater Treatment", and "Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant". The former two provided basic principles for urban WWTP constructions from the perspective of technical process layout design. Discharge standards provided requirements for WWTP management and defined the discharge limits which were dependent on the type of water body for their effluence to flow into.

During the National 11th Five plan (2005–2010), COD was set as restrictive indicator for the first time with a goal of 10% reduction in the national level. The ambitious goals were distributed to more than 30 local provinces in the form of a government task, which strongly simulated WWTP construction. The WWTP number doubled at the end of the 11th Five (2010) than the startup year of 2005, which increased from approximately 950 to 2500. The national 12th Five plan (2011–2015) set both COD and NH_3-N as restrictive indicators with a reduction goal of 8% and 10%, respectively. Accordingly, the requirements of nutrient control were identified legally, which promoted increasing wastewater treatment and enhancing nitrogen/phosphorus removal. Besides, the Ministry of Finance released the "Regulation of Franchise for Public Infrastructure and Utilities", which promoted Public-Private Partnership to solve financial issues by encouraging social capital entering into wastewater treatment. Legislations, together with financial support, stimulated urban China to become one of the largest wastewater treatment markets in the world.

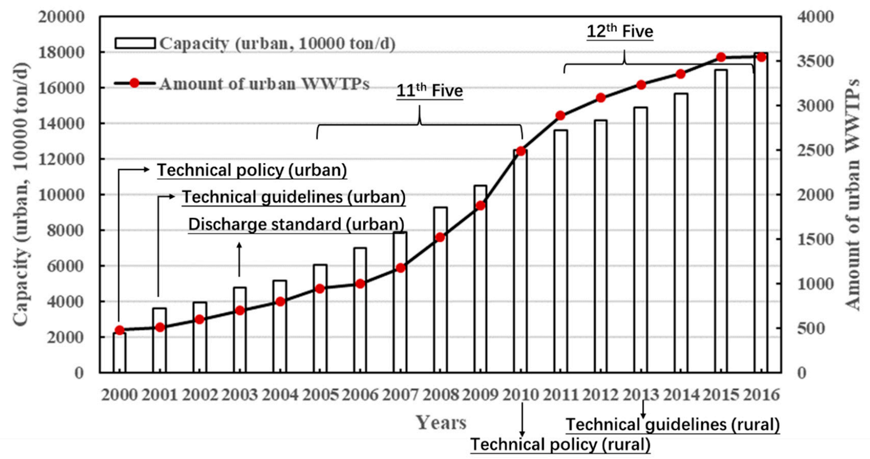

Figure 2. Development and legislation comparisons between urban and rural wastewater treatment.

In comparison, legislation for wastewater treatment in rural area was much delayed. Although the early issued laws including Water Pollution Control Law of China (issued in 1984) and Environment Protection Law of China (issued in 1989) mentioned rural wastewater treatment, specific regulations with detailed requirements were lacking. Until 2010, Technical policy for rural wastewater treatment was issued, 10 years later than that for urban wastewater treatment. In 2013, Guideline on Best Available Technologies of Pollution Prevention and Control for Township-villages was released by the Ministry of Environmental Protection. The release of technology guidelines was also slower than that for urban wastewater, which was probably caused by complicated rural conditions and disputes based on various technology options. Moreover, national discharge limits are not yet announced, and from 2011 on, several provincial discharge requirements were issued, which is discussed in detail in the following section.

3.2. Current Discharge Limit for Rural Wastewater in China

The discharge limit was considered as one of the most crucial statues for regulating wastewater treatment. Urban WWTPs were subject to regulations under National urban WWTP discharge standard (GB 18918-2002) since its release in 2002. In comparison, national discharge standards for rural wastewater are still lacking. In general, urban standards were usually "borrowed" and used as a reference for rural wastewater treatment projects, even though it was clearly stated that the urban standard was not suitable for rural wastewater in its public statement for amendment consultation in 2015. Actually, there was no specific standard designed for rural wastewater in China until 2011.

Some local discharge limits for provinces were issued before the national standard release. As shown in Table 4, the national discharge standards for urban WWTP and the local discharge limit for different provinces were reviewed and compared. For now, provinces including Ning Xia, Fu Jian, Shaan Xi, Beijing, He Bei, Zhe Jiang, Shan Xi, and Chong Qing released local standard for rural wastewater treatment respectively. It should be noted that here only common indicators of discharge limits including COD, NH_3-N, TN, and TP were discussed in this section, since they usually decided the process option. Other indicators such suspended solid and number of fecal coliforms were not discussed, although they would be defined simultaneously by discharge standard.

Table 4. Provincial rural wastewater discharge limits of China.

Year	Province	Discharge Level	COD (mg/L)	NH_3-N (mg/L)	TN (mg/L)	TP (mg/L)	Descriptions
2002	National urban (GB 18918-2002)	Level I-A	50	5	15	0.5	Effluence for reuse or location in sensitive area *.
		Level I-B	60	8	20	1	Discharged into functional type III water body **.
		Level II	100	25	/	3	Discharged into functional type IV and V water body.
		Level III	120	/	/	5	
2011	Ning Xia	Level I	60	8	20	1	Discharged into type III water body **.
		Level II	120	25	/	2	Discharged into type IV and V water body.
		Level III-A	150	/	/	/	For agriculture irrigation (paddy field).
		Level III-B	200	/	/	/	For agriculture irrigation (dry field).
2012	Fu Jian	Level I-A	50	5	15	0.5	Discharged into sensitive regions.
		Level I-B	60	8	20	1	For developed rural area which discharged effluence into type III water body.
		Level II	100	25	/	3	For undeveloped rural area which discharged effluence into type III water body.
		Level III	150	/	/	5	Discharged into type IV and V water body.
2013	Shan Xi	Level I	60	15	20	1	Discharged into functional type III water body **.
		Level II	150	30	/	/	Discharged into type IV and V water body.
		Level III	200	/	/	/	For agriculture irrigation.
2014	Beijing	Level A	30	1.5	15	0.3	Type II and III water body by local definition.
		Level B	40	5	15	0.4	Type IV and V water body by local definition.
2015	He Bei	Level I-A	50	5	15	0.5	Effluence for reuse or location in sensitive area *.
		Level I-B	60	8	20	1	For developed rural area which discharged effluence into type III water body.
		Level II	100	15	/	/	For undeveloped rural area which discharged effluence into type III water body.
		Level III	150	25	/	/	Discharged into type IV and V water body.
2015	Zhe Jiang	Level I	60	15	/	2	Located in environmental sensitive regions or area with less environmental carrying capacity.
		Level II	100	25	/	3	Located in other regions.
2018	Shaan Xi (on trial)	Level I	60	8	20	2	Discharged into functional type III water body **.
		Level II	100	25	/	3	Discharged into type IV and V water body.
2018	Chong Qing	Level I	80	20	/	3	Discharged into river, lake, and water body losing environmental function; or those with capacity 100~500 m^3/d.
		Level II	100	25	/	4	Discharged into other water body and treatment capacity lower than 100 m^3/d.

* Including situations when effluence discharged into a lake, reservoir, and river with poor dilution capacity. ** Including situations: (1) discharged into functional type III water body (excluding drinking resources and swimming area) defined by Environmental quality standard for surface water (GB3838); (2) discharged into functional type II sea area defined by Sea water quality standard (GB3097).

As shown in Table 3, local rural discharge limits varied. The first local rural wastewater discharge limit, which was released by Ning Xia province in 2011 (DB64/T700-2011), canceled Level I-A and used Level I and II for simplification. Also, additional limits designed for situations when effluence was used for irrigation were depicted. Shan Xi province's standard (DB14/726-2013) defined a rural wastewater treatment system by having a capacity lower than 500 m^3/d. The local standards in Fujian province divided rural villages as developed and undeveloped (personal net income lower than 3500 yuan RMB/year) and the requirement for undeveloped rural regions was downshifted one level. Beijing issued local integrated discharge standard of water pollutant (DB11/307-2013) and stated limits for rural wastewater treatment in specific sections, which was the most stringent in China, even more stringent than the urban WWTP standards. The local standard of the Zhe Jiang province (DB33/973-2015) demonstrated remarkable differences with urban standards with no requirement for TN and moderate limit values for NH_3-N and TP. Shaan Xi province's local standard, proposed in 2018, simplified national urban standards with only two levels reflecting the limits for effluent discharged into type III and IV/V water bodies.

In general, although national rural wastewater treatment standards have not yet been released, many provinces have started to propose local discharge limits to support and regulate rural wastewater. However, the various local limits demonstrated remarkable differences, indicating several considerations based on different perspectives. The first consideration was to make use of the successful urban standards, on which the rural standard was based. Provinces including Fu Jian, He Bei, and Shaan Xi followed such perspectives. The second consideration was to reduce pollution load by decreasing discharge amount from rural wastewater. Even more stringent standards than urban regions were used in Beijing. This high discharge limit requirement would lead to more cost and was only suitable for developed regions. The third consideration was to ensure operational availability and economic feasibility of small scale rural wastewater treatment facilities by more flexible limits. The provinces of Zhe Jiang and Chong Qing were examples. No requirement for TN was proposed since TN is not an oxygen consuming substance. The requirements for NH_3-N and TP were not stringent since they were actually nutrients for plant growth. Economic feasibility should also be considered since the cost is much higher for small scale rural wastewater facilities to achieve stable and high efficient N/P removal with limited maintenance. The fourth consideration was to pursue ecological resource recovery, which was applied by Ning Xia and Shan Xi. The needs for irrigation in rural regions were emphasized and wastewater effluent reuse for agriculture was proposed. The limits of both TN and TP were avoided since they were the objectives of resource recovery. Only COD and NH_3-N were considered since they were oxygen-consuming substances, which could cause oxygen deprivation of water bodies and a collapse of the ecosystem.

Based on above considerations, various discharge limits were released by different provinces in China. This is quite different to Europe, whose discharge limits were generally more relaxed in rural insensitive areas and more stringent in congested areas, which was decided by the European water framework directive (EWFD) pollution load approach [20], the main principle for rural wastewater discharge limits in China was not clear and lacked national top-level design. Different considerations led to quite different limits in the provinces. Many factors should be carefully considered, for example, the operational availability and economic feasibility. However, one factor which was usually neglected but important for discharge legislation was the economic burden for local residents, which is discussed in the following section.

3.3. Economic Burden Comparison of Urban and Rural Wastewater Treatment in China

The average national specific energy consumption around China was 0.30 $\pm$ 0.08 kWh/m^3 with average energy consumption for oxygen-consuming pollutants of 0.86 $\pm$ 0.24 kWh/kg. Similar situations were also reported in other countries such as India. It was reported that the energy use in Indian centralized wastewater treatment systems is 0.28 kWh/m^3, which was slightly lower than China, probably caused by local climate and wastewater quality. The specific energy consumption for a decentralized system was much higher than a centralized system. Also, due to ignorance of NH_3-N for the counting of oxygen-consumption, the averaging specific energy of 1.67 kWh/kg BOD was generally lower than China [21].

The local discrepancy between provinces was also demonstrated. Based on experiences from urban regions, it was generally demonstrated that the higher the local resident income was, the lower the specific energy consumption for oxygen-consuming pollutants removal was. As shown in Figure 3, the highest average resident income of Shanghai with nearly 40,000 yuan RMB/year achieved quite low specific energy consumption of 0.53 kWh/kg. In contrast, the highest specific energy consumption of 1.59 kWh/kg was located in Guang Xi province, whose resident income was as low as 17,268 yuan RMB/year. Although exceptions do exist, the general tendency suggested the rural cost exceeds the urban cost when same discharge limits were required. It was probably caused by the higher engineering level in more developed areas. Accordingly, in most rural regions which were undeveloped, the financial burden should be carefully considered.

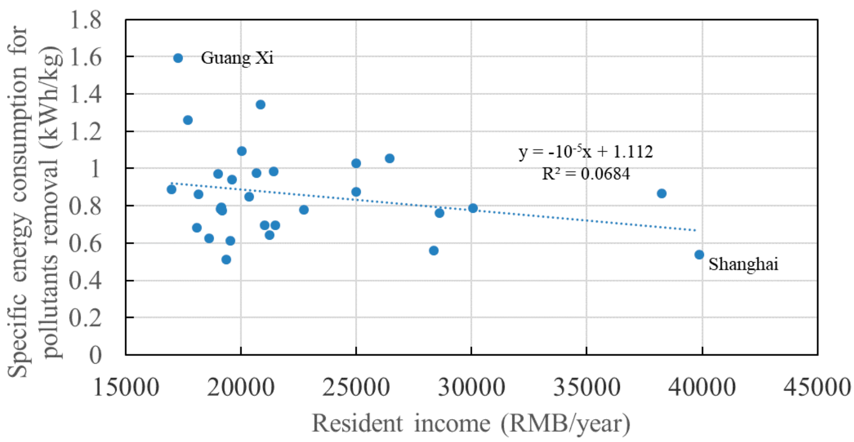

Figure 3. Specific energy consumption for oxygen-consuming pollutants removal (calculated based on urban statistic data of 31 provinces in China excluding Hong Kong, Macao, and Taiwan).

The binary urban-rural structure of Chinese society suggests the implementation of balanced and equal development of urban and rural areas, not only for economic development, but also for the right to enjoy a clean environment. However, the cost for maintaining a clean environment received less attention. The financial cost for rural wastewater treatment of different provinces, which was dependent on discharge limits and requirements, was evaluated based on the Gini coefficient. The ratio between cost for wastewater treatment and total personal expense was used to describe the financial burden.

According to the discussion in Section 3.1, the local rural discharge limit from various provinces could be divided into two categories. The first category focused on the condition of environmental sensitivity and high expectation for pollution load reduction, with a discharge limit equal or even stricter than urban standards such as in Beijing, Fu Jian, He Bei, and Shaan Xi provinces. The second category focused on the condition of resource recovery and technical availability for rural wastewater treatment. Loose discharge limits were released for the available regions and ease of treatment with simple processes were described, together with N&P reuse for agriculture irrigation. Provinces of Ning Xia, Shan Xi, Zhe Jiang, and Chong Qing belong to this category.

These categories clearly indicated two different considerations for discharge limit legislation. Due to the lack of technical and operational ability in rural regions, the first category limits usually required high investment and accordingly high operational cost in wastewater treatment facilities. For example, membrane technology such as MBR (membrane bio-reactor) was widely used in some rural regions due to its ease of operation and high effluent water quality. In contrast, the second category limits generally tend to choose simple biological treatment process such as constructed wetland, biofilter, and stabilized pond, whose investment and maintenance cost was much lower. Accordingly, the economic burden for wastewater treatment varied under different discharge limit conditions.

As shown in Figure 4, The Gini coefficients of economic burden for urban and rural wastewater treatment under different conditions were compared. Considering regional disparity, rural and urban data of 31 provinces in China (excluding Hong Kong, Macao, and Taiwan) was collected for calculation. It should be noted high imbalances existed for condition I. Due to the high cost caused by the strict discharge limit and relative lower income, the burden for rural residents was much higher than those in urban regions. Meanwhile, Gini coefficients were as high as 0.37, indicating the remarkable difference in the economic burden of various provinces. In contrast, if discharge limits of resource recovery categories were widely used for all provinces, the imbalance was lessened, although it still existed. The Gini coefficients decreased to as low as 0.17 under condition II. Discharge limits of resource recovery categories had remarkably reduced financial burdens. It was widely reported in various countries that most wastewater treatment projects required external, usually from central government, funding to proceed. As central funding is unsustainable and likely to become less common in future, a balanced burden would be critical to maintain internal finance with "the polluter-pays" principle [22]. Also, it was proposed to introduce Public private partnerships (PPPs) in rural wastewater treatment, which required private sectors' ability to bare risks [23,24]. In other words, the reduced economic burden by suitably designed rural discharge limits, such as the resource recovery category, ones promoted balancing the rural-urban gap and lowering uncertainties and the risk of sustainable rural wastewater treatment.

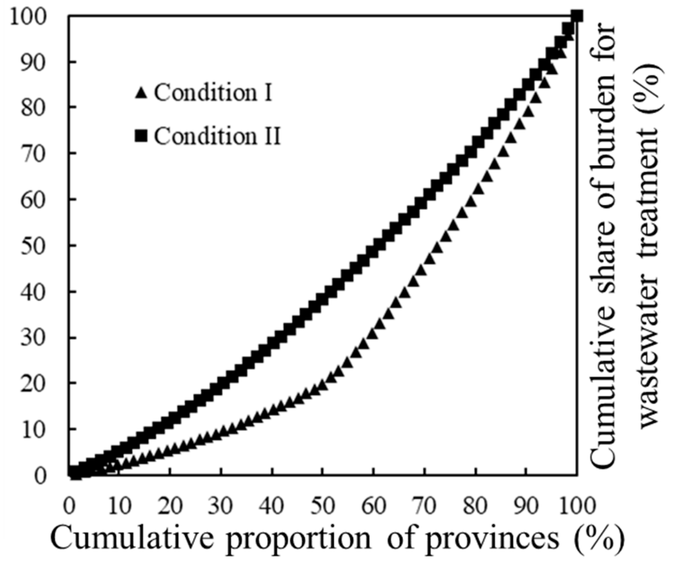

Figure 4. The Gini coefficients of economic burden for urban and rural wastewater treatment under different conditions (Condition I indicates discharge limit of environmental sensitive category; Condition II indicates discharge limit of resource recovery category).

With the imbalanced development and economic burden for urban and rural wastewater treatment in China, discharge limit legislation should take note of the following considerations. Firstly, either the national or local discharge limit specially designed for rural wastewater should be released as soon as possible. For now, urban WWTP discharge standards, or some other wastewater discharge standards, were "borrowed" temporarily for rural wastewater, which limited its development and even brought out disorder in management. Secondly, discharge limit legislation must consider plenty of perspectives including the local ecological capacity and the technical availability for rural areas. One factor which could not be neglected was the balanced economic burden for urban and rural regions discussed in this study. Thirdly, discharge limit legislation should be adjusted according to local circumstances. The environmental and economic characteristics of the rural regions in China varied since its broad geographical distribution. It should also be noted that rural financial burdens in some provinces were even lower than some urban regions. In other words, some developed rural regions obtained higher financial capacity than undeveloped urban regions. Last but not least, to reduce the imbalanced burden, policy-related subsidies were needed to promote rural wastewater treatment. Private funding and public support were also important for the development of rural areas.

4. Conclusions

Wastewater treatment in rural areas of China is much more undeveloped compared to urban regions, which was highly related with the much delayed legislation for rural wastewater. For now, the national rural wastewater discharge limit was still in vacancy, although the national urban wastewater discharge limit had been released for more than ten years. Recently, local rural wastewater discharge limits from several provinces were released, however, based on quite different, even opposite, principles. Some category emphasized environmental sensitivity and high expectations for pollution load reduction with a discharge limit equal or even stricter than the urban standard, while some focused on resource recovery for rural regions with loose discharge limits. Comparison under different discharge limit legislation conditions of the financial burden between rural and urban regions in 31 provinces revealed the resource recovery category discharge principle helped to decrease the financial burden imbalance with a Gini coefficient reducing from 0.37 to 0.17. The reduced economic burden by suitably designed rural discharge limit promoted balancing the rural-urban gap and lowering the uncertainties and risk of sustainable rural wastewater treatment.

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

Funding: Center for Industrial Development and Environmental Governance (CIDEG) and Summer Institute for China's Green Innovators (SICGI).

Acknowledgments: This work is partly financially supported by the Center for Industrial 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 conflicts of interest.

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