ENGINEERING APPLICATION AND TREATMENT PERFORMANCE OF DECENTRALIZED CONSTRUCTED WETLANDS FOR RURAL WASTEWATER TREATMENT IN RUIJIN, CHINA

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Abstract. Rural domestic wastewater treatment is an important element in the improvement of rural human settlement and a vital initiative to implement China's rural revitalization strategy. Decentralized constructed wetlands (DCWs) have been widely applied in rural wastewater treatment worldwide due to excellent operation performance. This study discusses the process mechanisms and field application of DCWs, and a case study of rural domestic wastewater treatment facilities using this technology in 10 townships in Ruijin City, China, and comprehensively analyzes and evaluates the operational treatment efficiency. The results showed that the effluent quality of all wastewater treatment facilities was better than the national discharge standard, and the average removal efficiency of chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), ammonia nitrogen (NH_3-N), total phosphorus (TP), and suspended solids (SS) being 85.41%, 91.40%, 87.16%, 81.93%, and 84.02%, respectively. Moreover, the data analysis found that climate temperature has a significant influence on the treatment performance of DCWs, while geographical variation did not exhibit this feature. These findings demonstrated that DCWs have excellent technical, economic, and ecological effectiveness and play a significant role in enhancing rural sewage treatment and water environment repair engineering.
Keywords: *rural area, domestic sewage, treatment technologies, removal efficiency, benefits analysis*

Introduction

As rural urbanization continues to accelerate, the problem of rural domestic sewage discharge is becoming increasingly prominent. Previously, domestic sewage was discharged directly without special treatment, leading to environmental degradation, bacterial growth, and resource waste (Chen et al., 2022). As of the first half of 2024, the data showed that compared to the nearly 100% domestic wastewater treatment rate in cities, the wastewater treatment rate in rural areas is only 45%. Consequently, with the proposal of the rural vitalization strategy, the attention of the Chinese government has turned to improving treatment coverage in rural areas where nearly 500 million people live, which will lead to a significant increase in rural domestic wastewater treatment facilities (Chen et al., 2019).

Most of the villages in southern China are situated between hills and river networks dispersedly, the centralized treatment technology can raise the investment and construction cost of the sewage collection system. Besides, there is a lack of specialized maintenance management personnel in rural areas to ensure the normal operation of enormous and complicated wastewater treatment plants (Li et al., 2021). Therefore, from a technical and economic perspective, centralized rural sewage treatment is not feasible. However, decentralized sewage treatment technology, a self-constructed system

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addressing each pollution source, suits sparsely populated villages and dispersed agricultural homes. Thus, decentralized treatment technology is becoming increasingly popular in rural areas around the world due to its high efficiency, and low energy consumption (Moreira and Dias, 2020).

The conventional rural domestic sewage treatment processes (e.g. septic tank, Soil treatment system, Conventional activated sludge process, etc.) are capable of removing the majority of contaminants from rural wastewater. However, poor removal capacity, low effectiveness, and weak performance suggest that conventional treatment processes could only play a fundamental role in rural wastewater disposal (Ruan et al., 2024). Moreover, most of those conventional treatment processes are difficult for daily management and maintenance and are sensitive to changes in temperature, water quality, humidity, and other changes in the natural environment (Zhang et al., 2023). In contrast, constructed wetlands (CWs) as a sustainable and eco-environmental ecological treatment technology for decentralized treatment of rural domestic wastewater, are reliable wastewater treatment eco-systems consisting of shallow waterways or pools/ponds planted with plenty of aquatic plants (Liu et al., 2024b). The key function of wastewater purification for CWs mainly relies on several nature-based chemical, biological, and ecological reactions such as aerobic/anoxic/anaerobic biodegradation, filtration, adsorption, plant uptake, and photosynthesis. Through the above functions, organic matter, nitrogen, phosphorus, micro-pollutants, and pathogens are removed from wastewater (Zhang et al., 2023). Since CWs require a certain area of land and are suitable for the construction of open spaces in rural areas, they have gradually become one of the most widely adopted decentralized treatment methods for rural wastewater in recent years (Hendy et al., 2023). CWs have attracted increasing attention worldwide and development owing to their remarkable advantages such as low investment and operating cost, low energy consumption, convenient maintenance, high removal efficiency of pollutants, and environmental friendliness (Paruch et al., 2011; Wu et al., 2011; Zhai et al., 2011; Istenic et al., 2023).

In this study, DCWs were adopted to treat rural domestic wastewater in southern China, and the process mechanism and applicable scope of this technology are discussed. In addition, this technology was applied to ten townships in Ruijin City, a city in southern China, where a total of 76 domestic wastewater treatment facilities were constructed. The six wastewater quality indicators including chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), ammonia nitrogen (NH_3-N), total phosphorus (TP), suspended solids (SS), and pH were investigated to evaluate the influent and effluent water quality. Through water quality monitoring and data analysis, this paper evaluated the treatment efficiency comprehensively and analyzed the influence of environmental climate and geographical characteristics on the treatment performance of DCWs wastewater treatment facilities. The findings and discussions in this study systematically analyzed the science and feasibility of DCWs in practical application, which can be used as a reference for other similar wastewater treatment projects.

Materials and methods

Technology description

The project site, Ruijin City, is located in the south of China's Jiangxi Province, with high terrain around the periphery and low in the center, dominated by low hills. Its territory has more land directly used for agricultural production, including arable land,

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forest land, grassland, and aquaculture water surface. The natural climate is characterized by a humid subtropical monsoon climate with abundant rainfall, affluent sunshine, and four distinctive seasons. Rural domestic sewage mainly comes from washing, cooking, toilet flushing, livestock and poultry breeding, and other daily residential activities, of which about 85% of domestic sewage is washing sewage and kitchen sewage (Li et al., 2021). The composition of pollutants in the water quality is relatively simple, mainly containing organic compounds and particulate impurities. Rural domestic sewage is free of poisonous and harmful substances. In general, the ratio of BOD_5 to COD (B/C) is generally used to evaluate the microbial degradability of wastewater under aerobic conditions. Normal domestic wastewater has a large B/C value and good biodegradability (Lu et al., 2016).

Combining the local natural environment characteristics, economic and technological level, and sewage water quality characteristics, this study adopts DCWs for rural domestic wastewater treatment. DCWs have the general characteristics of CWs, but DCWs are more appropriate for small volumes of wastewater with dispersed sources. Thus, DCWs have a smaller footprint and lower investment. In addition, DCWs take full advantage of the natural low-lying terrain, so that wastewater can flow freely into and out of the system, resulting in low-power operation. The main treatment process of DCWs wastewater treatment technology consists of "grating + anaerobic filter + constructed wetland + oxidation pond" (*Figure 1*). This treatment technology has been included in the "Jiangxi Province (air, water, soil) pollution prevention and control of advanced and applicable technology guide catalog" issued by the Jiangxi Provincial Department.

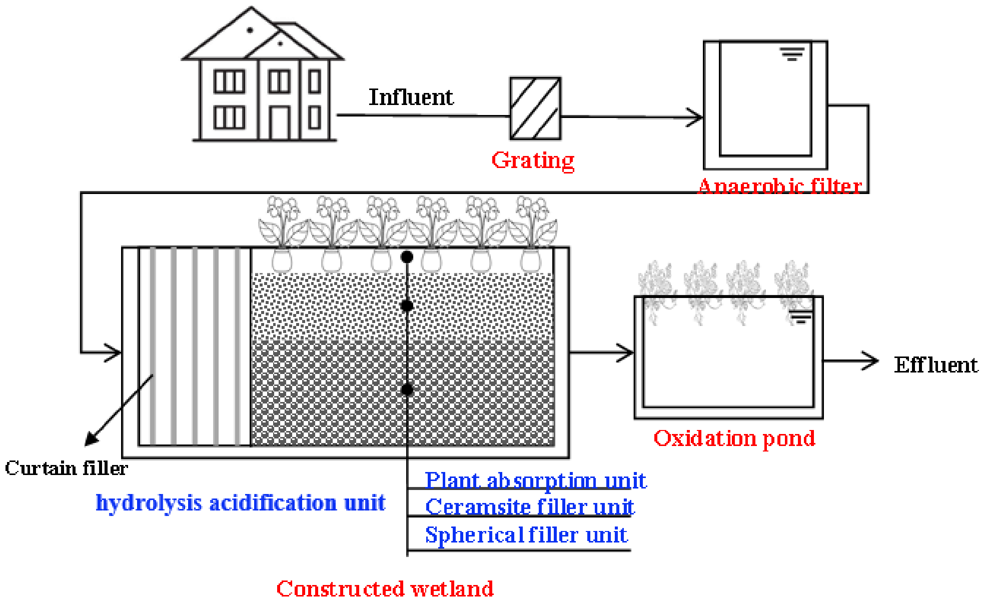

Figure 1. *Constructed wetlands treatment process flow diagram*

The specific sequence of DCWs treatment technology is that the rural domestic wastewater enters the buried anaerobic filter by self-flow after intercepting leaves, domestic garbage, and other large solid wastes through the grating. Subsequently, the wastewater enters the DCWs systems. The wastewater passes through the hydrolysis acidification unit, plant absorption unit, ceramic filler unit, and spherical filler unit

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sequentially. Finally, wastewater is discharged or reused for agricultural irrigation after further degradation of pollutants in the oxidation ponds.

Within the DCWs systems, the hydrolysis acidification unit is filled with soft combined filler, the filling rate of which reaches 75%, and this filler can provide biological beds for microorganisms, thus effectively increasing the microbial concentration in the process area. In the plant absorption unit, the aquatic plants planted include acorus calamus, water iris, and canna indica, and the same plants were planted in the same structure. The pots for planting aquatic plants are fixed 20 to 30 cm below the water surface, and pebbles and coarse sand inside the pots can fix the root system of aquatic plants, to remove the nitrogen and phosphorus pollutants in wastewater by plant root uptake. The ceramic filtration unit, with a particle size of 3 to 5 mm water treatment special ceramic particles, can effectively filter the suspended fine particles in sewage. Enough filtering space between the ceramic particles can effectively solve the problem of traditional sand filter beds that are easy to clog. The spherical packing unit is filled with 50 mm or 76 mm diameter spherical bio-fillers, while these fillers provide a large amount of superficial area for the growth of microorganisms, which further improves the removal efficiency of pollutants in the wastewater.

Technology application

The treatment technologies of DCWs were applied to 10 townships in Ruijin City for rural wastewater treatment, with a total of 76 wastewater treatment facilities (*Figure 2*). The townships are divided into the northern, central, and southern regions according to geographic locations (*Table 1*). The total amount of daily sewage treatment reaches 2,100 tons. The wastewater treatment volume range is 20 t/d to 130 t/d, of which there are 25 facilities with a treatment scale from 5 t/d to 50 t/d and 31 facilities with a treatment scale larger than 50 t/d.

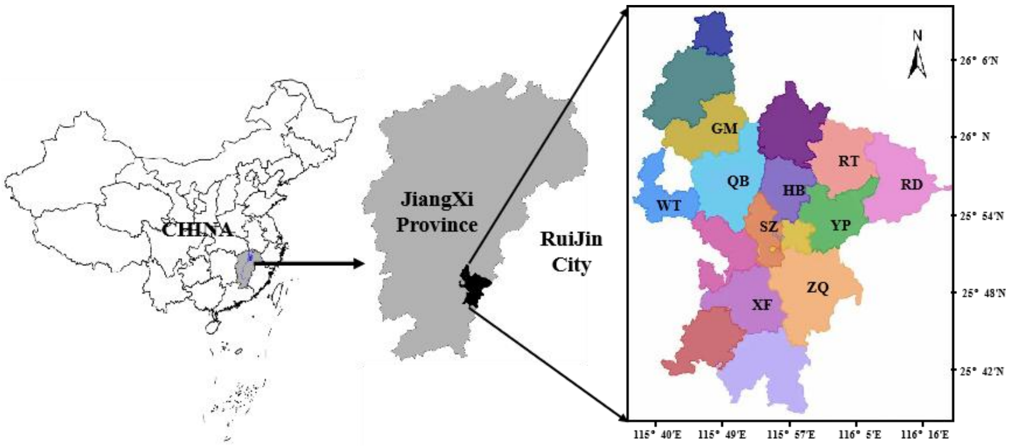

***Figure 2.** Distribution of sewage treatment facilities on the project site*

Monitoring methods and data analysis

In May 2022, November 2022, and August 2023, this study commissioned a qualified third-party monitoring institution to monitor and analyze the influent and effluent quality of 76 wastewater treatment facilities on three occasions. The monitoring items included six indicators: TP, NH_3-N, COD, BOD_5, SS, and pH. According to the requirements of

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the local government, effluent discharge requirements for the implementation of Jiangxi Province's "discharge standards of pollutants for rural domestic sewage treatment Facilities" (DB36/ 1102-2019), and reaching first-degree wastewater discharge standards (*Table 2*). Since at least three wastewater treatment facilities were constructed in each township, the pollutant removal efficiency and effluent water quality concentration were expressed as mean values in this study. The monitoring data were analyzed by one-way ANOVA using SPSS 22 to determine whether different geographic regions and climatic temperatures affect effluent water quality pollutant concentrations.

Table 1. *Relevant information about sewage treatment facilities at the project site*

Region	Name of (acronyms)	Number of sewage facilities	Wastewater treatment volume range (t/d)	Population density (persons/km^2)	Longitudes	Latitude
Northern regions	Ganmian (GM)	3	20-50	149	115°52'42"	26°5'19"
	Jiubao (QB)	3	20-40	311	115°55'1"	25°56'23"
	Rentian (RT)	13	20-130	333	116°7'31"	25°59'23"
Central regions	Huangbai (HB)	8	20-70	395	116°1'11"	25°57'40"
	Ridong (RD)	9	30-80	127	116°16'25"	25°59'25"
	Shazhou (SZ)	3	20-30	331	116°0'32"	25°53'14"
	Yeping (YP)	19	20-100	468	116°4'54"	25°54'35."
Southern regions	Wangtian (WT)	5	20-30	159	115°44'4"	25°56'36"
	Zeqin (ZQ)	8	30-130	89	116°1'46"	25°50'51"
	Xifang (XF)	5	20-40	337	115°52'41"	25°42'42"

Table 2. *Effluent quality discharge standard limits and water quality monitoring methods*

Wastewater Quality Indicator	Emission standards	Monitoring Methods
COD	60mg/L	Water quality determination of the chemical oxygen demand: dichromate
BOD_5	/	Water quality determination of biochemical oxygen demand after 5 days (BOD_5): dichromate for dilution and seed method
NH_3-N	8(15)*mg/L	Water quality determination of ammonia nitrogen: Nessler's reagent spectrophotometry
TP	1mg/L	Water quality determination of the total phosphorus: ammonium
SS	20mg/L	Water quality determination of suspended solids: weight method
pH	6-9	Water quality determination of pH: electrode method

*The value outside parentheses is the control emission for water temperatures greater than 12°C, and the value in parentheses is the control emission for water temperatures less than 12°C

Results and discussions

Treatment effectiveness of water quality indicators

The boxplots of influent and effluent concentrations of contaminants directly reflect the distribution of data. As shown in *Figure 3*, the mean values of the influent concentrations were recorded as follows: COD at 69.47 mg/L, BOD_5 at 27.90 mg/L, NH_3-N at 13.55 mg/L, TP at 2.89 mg/L, SS at 44.97 mg/L. It was to be seen in *Figure 3* that the concentration of COD in influent had several large outliers. This also suggested that there was a high degree of variability in rural concentrations of organic pollutants, which

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is related to the water use habits of human settlements (Yang et al., 2021). After treatment by the facilities, the mean values of effluent concentration were COD at 9.24 mg/L, BOD_5 at 2.26 mg/L, NH_3-N at 1.55 mg/L, TP at 0.45 mg/L, SS at 5.28 mg/L. The results indicated that the effluent quality of the DCWs wastewater treatment facilities is better than the discharge standard requirements. It can be noticed that the pollutant concentration in the effluent was low in this study compared to other studies (Hendy et al., 2023; Liu et al., 2024a). This phenomenon may be related to the low concentration of pollutants in the influent water. Rainwater dilution and large fluctuations in water quality and quantity may lead to low pollutant concentrations in the influent water.

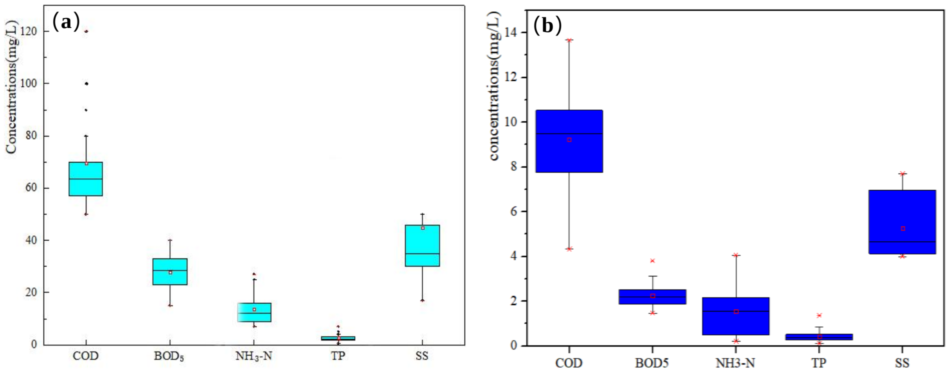

Figure 3. *Boxplot of the influent concentrations (a) and effluent concentrations (b)*

The monitoring and analysis results found that the average removal efficiencies of the five water quality indicators at all sewage treatment facilities shown in *Figure 4* were above 80%, with values of 85.41%, 91.40%, 87.16%, 81.93%, and 84.02% for COD, BOD_5, NH_3-N, TP, and SS, respectively. These results suggested that DCWs wastewater treatment facilities could effectively remove contaminants with superior removal efficiency. COD and BOD_5 removal efficiencies from the different treatment facilities had small floating deviations, while NH_3-N, TP, and SS removals had large deviations. Specifically, the average removal efficiencies from 83.69% to 96.39% for COD, 81.80% to 95.43% for BOD_5, 67.00% to 90.16% for NH_3-N, 66.40% to 89.45% for TP, 65.20% to 95.47% for SS.

Compared to other studies on rural wastewater treatment, the pollutant removal efficiencies in this paper are overall high. For example, Li et al. (2021) investigated a CWs treatment facility located in a village in the lower reaches of the Yangtze River, and the removal efficiency of COD, TN, and TP achieved 61.5%, 68.8%, and 70.5% respectively. Similarly, Yuriy et al. (2015) reported removal efficiencies of 82.6%, 77.3%, and 72.1% for BOD_5, COD, and SS, from the hybrid CWs in the region of Kharkiv Oblast, eastern Ukraine. The high treatment efficiency in this study may be attributed to the physical, chemical, and biological synergies of artificial media, plants, and microorganisms that promote the removal of pollutants (Shuyuan et al., 2024).

Influence of ambient temperature on effluent quality

Several studies have shown that the operational conditions and treatment effectiveness of the CWs treatment facilities are affected by the ambient temperature (Ong et al., 2016). This is because temperature affects microbial activity, aquatic plant growth and

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metabolism, and the amount of dissolved oxygen in wastewater (Pishgar et al., 2021). The project study site is located in southern China, where temperatures vary considerably throughout the year. Therefore, to overcome the adverse effects of temperature on wastewater treatment facilities, it is necessary to analyze the effect of ambient temperature on the treatment effectiveness of the DCWs treatment facility (Fernandez et al., 2019).

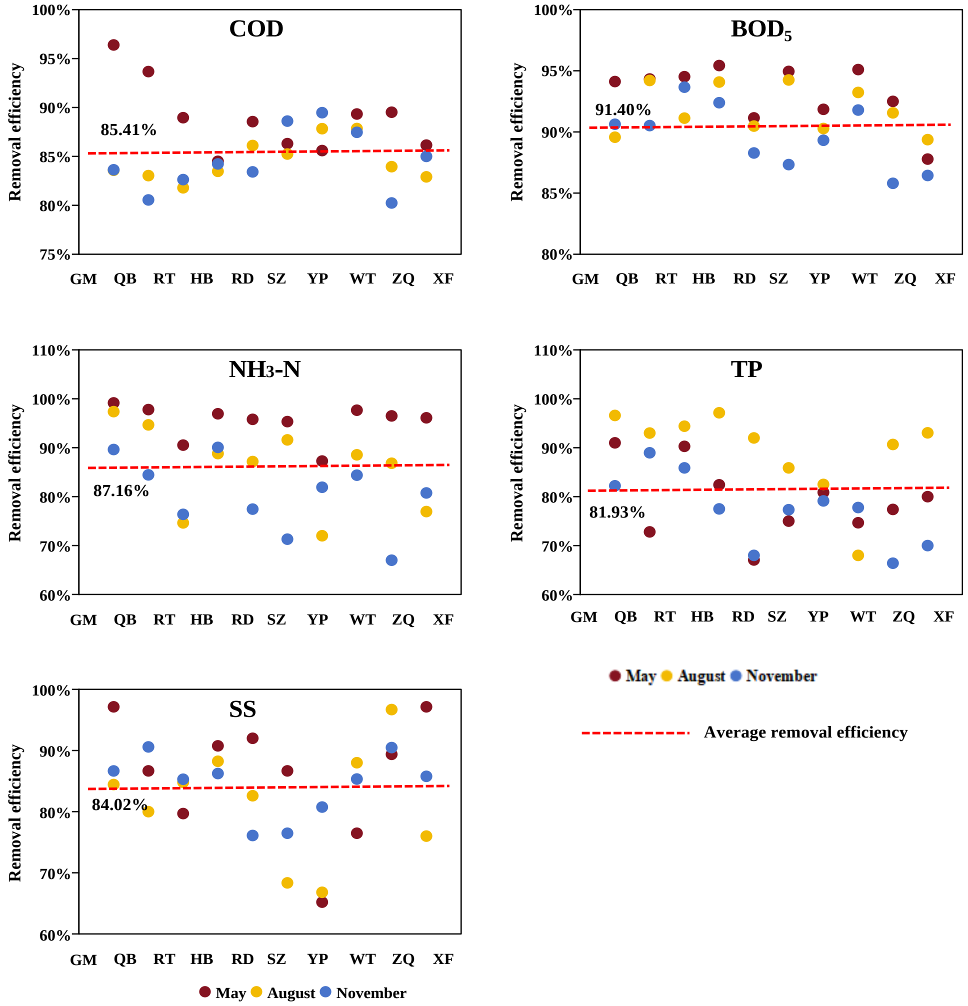

Figure 4. *Average removal efficiency of water quality indicators*

Temperature is an important factor affecting the activity of microorganisms during wastewater treatment. A suitable temperature range for the production and metabolism of microorganisms exists. Too low or too high temperatures can reduce microbial activity, resulting in weak biochemical reaction rates and lower pollutant removal efficiencies. In this study, water quality was monitored in May, August, and November after ambient temperatures remained stable for more than one week. Ambient temperatures were permanently around 29°C, 35°C, and 18°C in May, August and November. The wastewater temperature may be slightly higher than the ambient temperature due to biochemical reactions and aeration in the wastewater treatment facilities.

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As shown in *Figure 5*, the average concentrations of COD, BOD_5, NH_3-N, and SS in the effluent water quality showed the highest value in November and the lowest value in May. The phenomenon indicated that the treatment effectiveness of DCWs and the growth of aquatic plants appeared a correlation pattern. Specifically speaking, May is in the early summer with high temperatures and abundant rainfall. The plants are in a rapid growth phase in May, thus absorbing large quantities of pollutants from the wastewater and converting these contaminants into their nutrients. In contrast, November is in the winter with a low temperature and dry climate. At this time, Plant growth and metabolism slows down, and the absorption and transformation of pollutants in wastewater becomes weaker. Furthermore, the studies indicated that nitrification-denitrification was identified as the primary removal pathway for NH_3-N, and the growth of nitrifying and denitrifying microorganisms was adversely affected by the low-temperature environment, leading to decreased NH_3-N removal (Koutsou et al., 2018). Besides, the activity of nitrite reductase was significantly influenced by low temperatures, while the abundance of nir-type denitrifiers was drastically reduced due to low temperatures, hampering the conversion of NH_3-N within CWs (Yang et al., 2024). Thus, ambient temperature may be an essential factor contributing to higher concentrations of some pollutants in the effluent quality in winter than in summer and autumn.

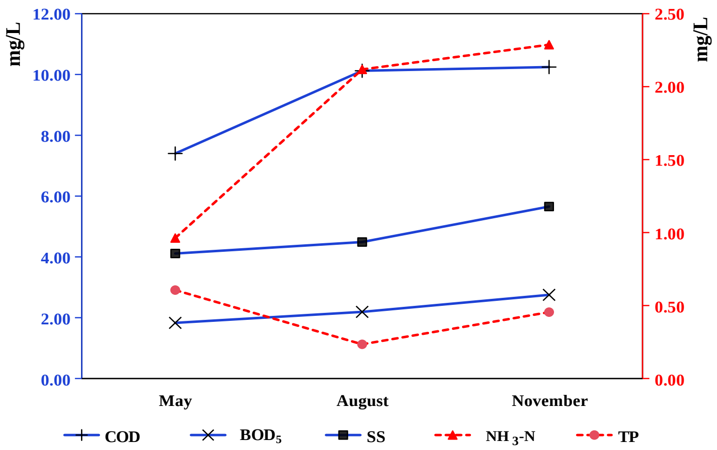

Figure 5. *Average effluent concentrations of pollutants in different months, respectively*

However, TP showed different patterns with COD, BOD_5, NH_3-N, and SS. The highest average concentration of TP (0.61 mg/L) was observed in May, while the lowest average concentration of TP (0.23 mg/L) was observed in August. On the one hand, this phenomenon may be due to the rapid growth of aquatic plants in May, but the lack of timely harvesting of the plants during the management process hindered the uptake of phosphorus-containing substances by the root system of aquatic plants. On the other hand, it is also possible that the high water temperature in May leads to less oxygen solubility in water, resulting in the release adequately of phosphorus by the phosphorus-aggregating bacteria in anaerobic conditions; while the aerobic phosphorus uptake process is limited due to oxygen deficiency.

The results of one-way ANOVA showed that the probability of significance P-value of the mean pollutant removal efficiency in different months was less than 0.01. It is indicated that statistically significant effects of different climatic temperatures on pollutant removal efficiency test results at the 95% confidence intervals (*Table 3*). In

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summary, the analysis showed that different environmental temperatures had a significant influence on the pollutant removal effect of DCWs treatment technology. NH_3-N treatment efficiency was better in the summer period than in the winter period, while TP is the opposite. A similar phenomenon was reported that the average removal efficiency of NH_3-N during the low-temperature period was notably lower at only 28.73% compared to the high-temperature period (83.84%), and a decrease in water temperature contributed to the adsorption of TP (Yang et al., 2024). In addition, considering that the impact of ambient temperatures on wastewater treatment facilities is long-term and continuous, this requires more sustained research and analysis to obtain a more complete picture of data changes. We plan to track changes in ambient and wastewater temperatures throughout the year in the future, and consequently maintain continuous monitoring of water quality and supervision of equipment operation.

Table 3. *One-way analysis of variance (ANOVA) of the results of pollutant removal efficiency at different climatic temperatures in different months*

Items	**COD**	**BOD_5**	**NH_3-N**	**TP**
F	8.470	16.310	30.393	19.327
Between-group mean square	0.027	0.027	0.466	0.413
Levene significance test	0.356	0.071	0.007	<0.01
P value *	<0.01	<0.01	<0.01	<0.01

* The level of significance is 0.05

Many studies showed that CWs can be coupled and combined with other technologies to overcome the adverse effects of ambient temperature on treatment facilities (Lutterbeck et al., 2017; Rahman et al., 2020; Pishgar et al., 2021). For instance, Yang et al. (2024) developed solar photovoltaic power generation-constructed wetland by combining solar power generation technology and CWs and confirmed that this technology effectively increases the dissolved oxygen content in the wastewater and shows superiority in nitrogenous pollutants purification. Zhao et al. (2024) constructed a novel overlapping horizontal subsurface flow CWs, enhancing dissolved oxygen concentration and abundance and diversity of nitrogen-associated microorganisms by utilizing water drops reoxygenation and lightweight fillers, not only enhancing pollutant treatment efficiency but also reducing the required land area.

Characteristics of the spatial distribution of effluent quality

China is a vast country with diverse terrain and climate types. In particular, the project site is located in the southern part of China, where mountains and hills are widely distributed. The characteristics of wastewater quality, residential concentration, and sewage pipe network construction vary greatly in different areas (Wu et al., 2011). Therefore, it is necessary to analyze the impact of the spatial distribution of DCWs wastewater treatment facilities. The project site was divided into the northern, central, and southern regions based on geographic variation, settlement density, and type of human activity. The center of the central region is the municipality area, which has a higher urbanization rate and population density than the north and south. The northern region is covered with large areas of crop cultivation and poultry farming areas. The southern region is more hilly and mountainous, with a smaller and more dispersed population.

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As shown in *Figure 6a* and *Figure 7a*, the average concentrations of COD and BOD_5 monitored at the 10 township sewage treatment facilities were lower than the national emission standards. From *Figure 6b* and *Figure 7b*, it can be observed that the average concentrations of COD and BOD_5 located in the central region were overall higher than in the northern and southern regions. Besides, the townships of SZ located in the central region, had the highest average effluent concentrations of COD (13.67 mg/L) and BOD_5 (3.80 mg/L) in November. It was found that the central region is located around the center of Ruijin City, with intensive human activities and a higher human density (330.25 persons/km^2) than the southern (195 persons/km^2) and northern regions (264.33 persons/km^2). Therefore, it can be estimated that higher influent organic pollutant loads were a contributing factor to higher organic pollutant effluent concentrations in the central region compared to northern and southern regions.

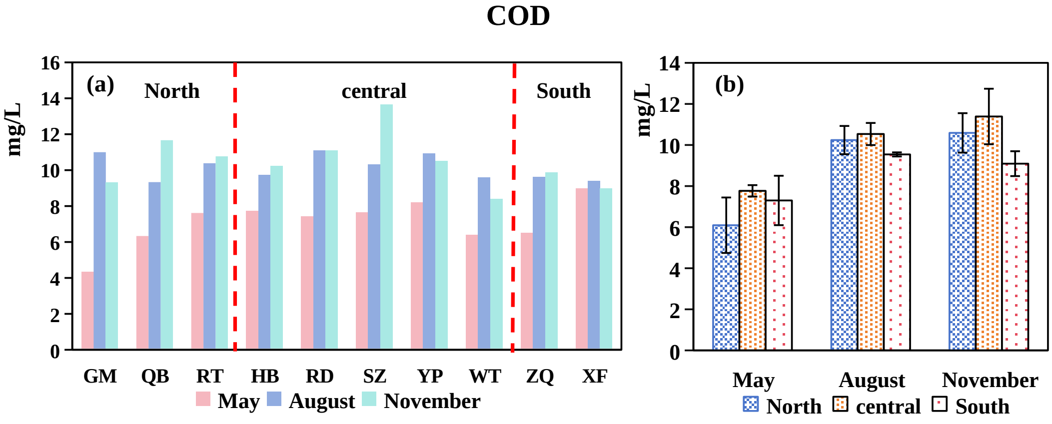

Figure 6. *The average effluent concentration of COD in different townships*

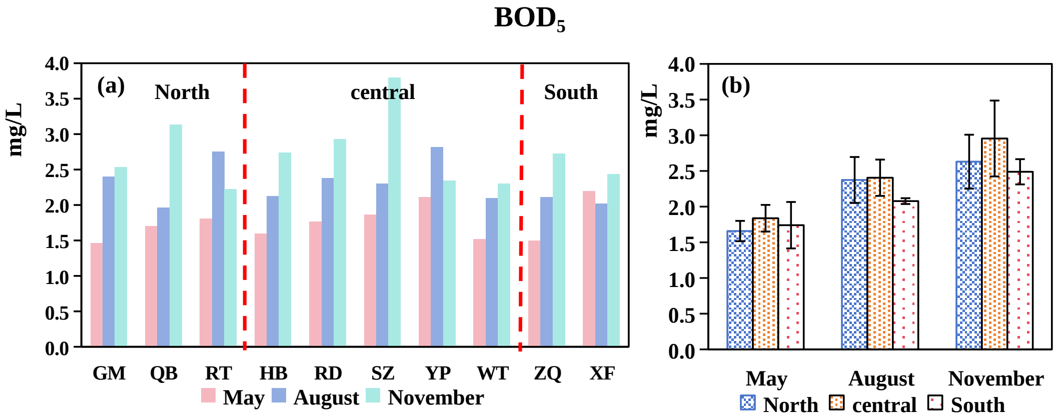

Figure 7. *The average effluent concentration of BOD_5 in different townships*

As shown in *Figure 8a*, similar to COD and BOD_5, the average NH_3-N effluent concentrations were below the national discharge standard. The northern region had the highest average NH_3-N effluent concentrations relative to the central and southern regions (*Figure 8b*). Among them, the RT Township in the northern region had the highest average NH_3-N effluent concentrations of all 10 townships. This may be related to the

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large area of vegetable cultivation and the vigorous development of the farming industry in the northern region. This is because nitrogen fertilizers that are not absorbed and utilized by plants or fixed by microorganisms and soils in the planting industry are the main sources of nitrogen in the aquatic environment. Livestock manure and urine produced by the farming industry decompose a large amount of NH_3N. In addition, most of the southern region is covered by natural forests, and many residents work outside the area all year round resulting in a low population density (Sanjrani et al., 2020). Thus the lower number of NH_3-N pollution sources in the southern region may be a reason for its low average effluent pollutant concentrations.

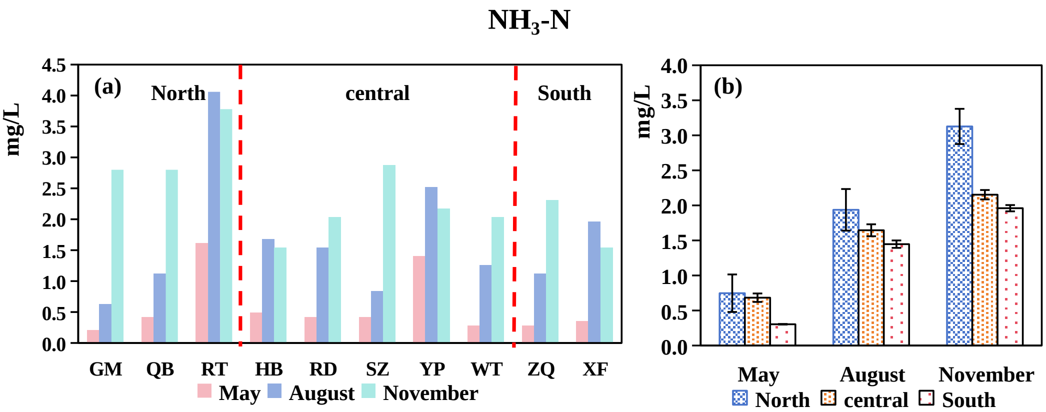

Figure 8. *The average effluent concentration of NH_3-N in different townships facilities*

As shown in *Figure 9a*, the TP effluent average concentration was still well below the national discharge standard. The mean effluent concentrations of TP in the northern, central, and southern regions showed an inconsistent pattern during the three months (*Figure 9b*). Specifically, the mean effluent concentration of TP in the northern region (0.80 mg/L) was higher than that central (0.64 mg/L) and southern regions (0.55 mg/L) in the spring, the mean effluent concentration of TP was close to the same in the three regions in the summer, and it was higher in the southern region (0.57 mg/L) than in the central (0.43 mg/L) and northern regions (0.29 mg/L) in the winter. The above phenomenon may be because the TP effluent concentration is affected by a variety of factors, such as the concentration of TP in influent, the content and stability of dissolved oxygen in the denitrification and phosphorus removal zone, and the state of growth and management of aquatic plants. The specific influencing factors need to be further researched and analyzed.

The results of one-way ANOVA (*Table 4*) showed that the probability of significance p-value of the mean effluent concentrations of the four pollutants (COD, BOD_5, NH_3-N, and TP) was greater than 0.05 for different spatial regions in the north, central, and south. This indicated that there was no statistically significant difference in the effect of geographic spatial variation on pollutants effluent test results at the 95% confidence intervals. In conclusion, the analysis showed that the DCWs wastewater treatment technology can be better adapted to different geographies, environments, and water quality variability, and keeping the system stable operation and high pollutant removal efficiency.

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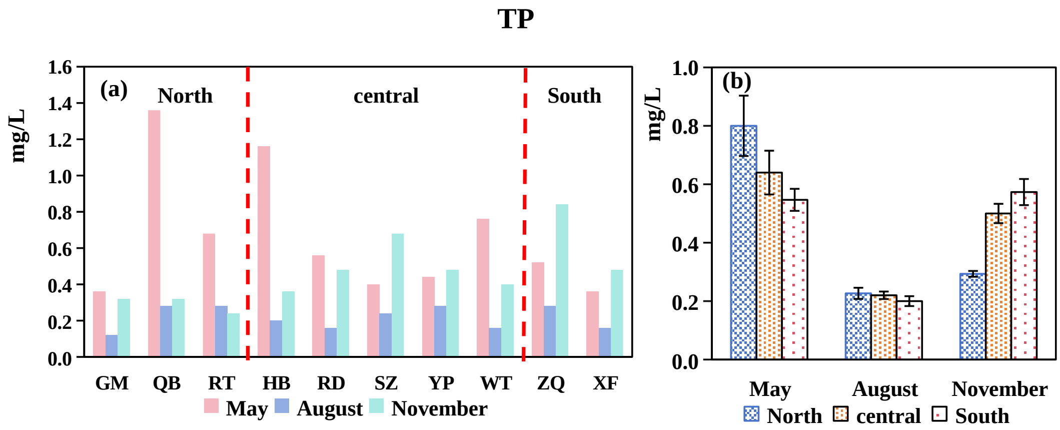

***Figure 9.** The average effluent concentration of TP in different townships*

***Table 4.** One-way analysis of variance (ANOVA) of the results of pollutant effluent concentrations in different spatial geographic areas*

Items	COD	BOD_5	NH_3-N	TP
F	0.962	0.571	3.695	0.613
Between-group mean square	7.534	0.354	0.082	0.01
Levene significance test	0.599	0.867	0.657	0.376
P value *	0.387	0.567	0.0532	0.544

* The level of significance is 0.05

Effectiveness evaluation

CWs wastewater treatment technology is an emerging sustainable environmental protection technology. It has the characteristics of high effectiveness, low-carbon properties, eco-friendliness, and sustainability compared to traditional rural wastewater treatment technologies. It is also suitable for decentralized wastewater treatment in rural areas (Liu et al., 2024b). From the technical feasibility perspective, the water quality monitoring results verified that the DCWs wastewater treatment facilities have a high-efficiency pollutants treatment for rural domestic wastewater. Besides, the effluent quality is superior to the national discharge standard. The facilities also can be adapted to the different geographic environments and water quality variability in rural areas to maintain stable operation and long service life (Zhai et al., 2011). The DCWs wastewater treatment facilities also have low maintenance costs and technical requirements during the operation phase and do not need to be unattended all the time, requiring only regular inspection and maintenance (Li et al., 2024).

In terms of economic feasibility, the DCWs treatment facility is a green, low-carbon, and ecological pollution control technology. Construction of DCWs takes advantage of natural geography with low-lying ponds and wastelands. This type of design allows wastewater to flow into the system and drain smoothly using the principle of hydrodynamic self-flowing. It is achieved that the whole set of systems runs without power and reduces operational energy consumption (Chen et al., 2019). On the other hand, the DCWs treatment facility is a decentralized treatment technology that does not require the construction of a huge sewage collection pipeline network. This is conducive

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to reducing the investment in engineering construction and lowering the cost of sewage treatment, with good economic and technical benefits (Vergeles et al., 2015; Ruan et al., 2024).

In terms of ecological and environmental benefits, the bottom of the anaerobic filter is buried below ground level, and ecological flower beds are installed above its top. Moreover, sidewalks are constructed for recreational breaks, and the sewage treatment facility is planned as a garden green space. DCWs sewage treatment facility operates without secondary pollution, odors, and discharging organic sludge. It is realized that the dual function of treating domestic sewage and beautifying the environment (Pishgar et al., 2021). DCWs wastewater treatment technology can create a good ecological habitat for the residents and a functional and artistic place (Sánchez et al., 2023).

Although the DCWs wastewater treatment technology can realize the purpose of rural sewage treatment and environmental restoration, there are still many aspects that need to be improved in the process of practical application. Firstly, this technology utilizes the natural purification ability of wetland plants and substrates to realize the treatment of rural domestic sewage (Sánchez et al., 2023). However, wetland plants and microorganisms are highly affected by ambient temperature, especially in winter, it is necessary to pay special attention to the impact of significant temperature reduction on plants and microorganisms. Secondly, wetland plants are susceptible to pests and diseases, so plants with high pollution tolerance, good purification effects, and resistance to pests and diseases should be selected (Hendy et al., 2023). The studies reveal that the removal efficiency of CWs can be significantly enhanced by the presence of suitable plant species, such as Paulownia and *Phragmites australis* (Arroyo et al., 2013).

In recent years, with the global rise in awareness regarding carbon neutrality, the treatment wastewater technology in rural areas has become increasingly oriented towards energy conservation, emission reduction, low-carbon output, and resource utilization. The advancement of CWs towards improved removal of organic and inorganic pollutants, sustainability, minimal energy consumption, and low carbon emissions is widely recognized as a viable low-carbon approach for achieving carbon-neutral treatment of rural wastewater (Zhang et al., 2024). In pursuit of carbon neutrality, several studies have shown advanced carbon-neutral bioprocesses are regarded as the prospective trajectory for achieving carbon-neutral treatment of rural wastewater. Some scholars have combined CWs with emerging biotechnologies, such as sulfur-based autotrophic denitrification (SAD), pyrite-based autotrophic denitrification (PAD), and anaerobic ammonia oxidation to enable efficient removal of nitrogen and phosphorus from rural wastewater (Ji et al., 2015; Jiao et al., 2024). These emerging technologies have the advantage of energy conservation, bio-resource recovery, and carbon reduction during the wastewater treatment process, which is in line with the trend of carbon neutrality concepts and development trends.

In addition to the technological innovation of rural wastewater treatment technology, greater efforts are also needed in operation and maintenance management. Due to issues such as sub-standard technical levels, weak supervision, and a lack of operating budget, the operation of some existing facilities has been unsatisfactory, in some cases resulting in stoppages (Liu et al., 2024a). Thus, to maintain the sustainability of rural wastewater treatment facilities, the management strategies should also be scalable and cost-efficient. Increasing investment in the management of wastewater treatment facilities is necessary, and the management strategies should also be site-specific and sustainable (Liu et al., 2023).

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Conclusions

DCWs, a rural wastewater treatment technology with the advantages of minimal investment, low energy consumption, simple operation and maintenance, and efficient removal, have the potential to enhance the rural habitat environment and efficiently treat domestic rural wastewater. This paper discussed the treatment performance of DCWs wastewater treatment technology in actual engineering applications and analyzed the prominent advantages and development prospects. The results showed that the effluent quality of all wastewater treatment facilities was excellent. The average removal efficiency of TP, NH_3-N, COD, BOD_5, and SS was all above 80%. Furthermore, the analyses indicated significant differences in ambient temperatures on the treatment performance of DCWs. In general, the treatment effectiveness in August with a high temperature was better than that of November with a low temperature. Besides, DCWs are well adapted to different geographical environments and maintain stable and efficient operation of the system. Thus, DCWs have significant potential for development and application in rural areas characterized by scattered residences and complex landscapes and can realize technical, economic, and environmental benefits. However, aiming to existing problems such as the effect of temperature, additional technological research and development is desirable to carry out. Furthermore, to maintain the eco-friendliness and sustainability of rural wastewater treatment facilities, combining CWs with emerging biotechnology may be a research priority to achieve carbon-neutral treatment of rural wastewater in the future.

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APPENDIX

Table 1. *Monitoring data on influent and effluent from 76 wastewater treatment facilities in 10 townships in May*

		Influent						Effluent					
townships	**Sewage facilities**	**COD mg/L**	**BOD_5 mg/L**	**NH_3N mg/L**	**TP mg/L**	**SS mg/L**	**pH**	**COD mg/L**	**BOD_5 mg/L**	**NH_3N mg/L**	**TP mg/L**	**SS mg/L**	**pH**
GM	1	134.45	28.55	26.44	3.12	117.67	6.43	6.12	1.51	0.25	0.32	4.13	6.91
	2	106.54	21.41	28.48	4.34	98.56	6.81	3.06	2.32	0.35	0.42	3.87	7.22
	3	119.01	25.03	20.08	4.54	98.77	7.63	4.08	0.60	0.03	0.36	4.34	8.23
QB	1	123.32	39.77	24.41	4.45	24.14	7.46	4.08	0.50	0.25	0.96	4.03	7.68
	2	97.71	21.41	17.29	6.58	36.21	7.12	8.16	1.92	0.68	1.8	4.04	7.68
	3	78.97	28.82	15.30	3.97	24.14	6.81	7.14	2.73	0.33	1.32	4.01	7.35
RT	1	78.34	32.63	15.26	7.54	35.20	6.41	4.08	0.50	1.11	0.67	6.93	6.91
	2	86.45	26.51	18.31	5.78	54.31	6.92	7.14	1.82	3.99	0.64	6.80	6.78
	3	57.54	40.79	15.26	6.23	29.17	6.92	7.14	1.92	0.84	0.44	7.41	6.78
	4	67.65	24.47	16.27	4.23	33.19	7.63	5.10	1.41	0.25	0.43	7.48	7.48
	5	68.68	35.69	21.36	9.43	38.22	7.02	11.21	2.62	1.84	2.76	7.11	6.88
	6	59.16	23.45	14.24	6.75	46.26	7.32	6.12	1.41	2.33	0.36	6.91	7.18
	7	67.13	34.67	19.32	8.22	27.15	7.53	4.08	0.50	0.25	0.68	6.83	7.38
	8	82.54	47.93	13.22	7.76	32.18	6.92	10.20	2.62	0.67	0.44	7.41	6.78
	9	74.45	29.57	21.36	5.63	28.16	6.81	10.20	2.62	1.9	0.36	7.41	6.68
	10	50.43	25.49	19.32	10.89	48.27	6.92	6.12	1.41	1.79	0.44	7.56	6.78
	11	67.81	36.71	17.29	6.32	31.18	9.76	15.29	2.82	4.49	0.68	7.01	8.57
	12	59.43	35.69	16.27	5.34	31.00	7.12	9.18	2.72	0.43	0.46	6.91	6.98
	13	77.39	35.40	13.53	6.88	20.71	6.92	5.10	1.31	1.04	0.72	6.23	6.78
HB	1	49.14	56.08	15.26	7.89	63.36	6.92	6.12	1.21	0.25	0.44	4.54	7.46
	2	45.46	24.47	17.29	6.48	58.33	6.61	13.25	2.72	1.18	2.4	5.36	7.13
	3	53.17	36.71	19.32	8.12	73.42	6.81	11.21	2.82	1.02	2.16	5.31	7.08
	4	49.56	42.83	16.27	5.65	35.20	6.81	8.16	1.21	0.25	0.4	3.56	7.35
	5	54.13	26.51	15.26	6.33	39.22	6.92	7.14	0.60	0.25	0.44	3.78	7.46
	6	51.24	30.59	13.22	5.98	33.19	6.92	4.08	0.71	0.29	0.8	4.32	7.46
	7	57.13	29.57	15.26	6.77	25.14	6.81	6.12	1.61	1.99	2.2	4.19	7.35
	8	40.17	33.23	16.13	5.58	40.14	6.81	7.14	2.02	0.29	0.44	4.27	6.35
RD	1	105.00	22.43	11.19	2.21	38.22	6.92	8.16	1.01	0.31	0.4	4.25	7.46
	2	68.65	21.41	9.15	3.78	28.16	7.22	5.10	1.51	0.84	0.52	4.52	7.79
	3	63.60	20.39	8.14	2.54	49.28	6.94	6.12	1.71	0.61	0.92	4.67	7.46
	4	57.55	18.35	9.15	1.56	58.33	7.12	7.14	1.31	0.26	0.4	4.31	6.68
	5	63.60	15.30	9.15	2.21	85.48	7.22	9.18	2.52	1.76	0.84	3.47	7.79
	6	50.48	25.49	11.19	1.67	48.27	6.41	6.12	1.71	0.25	0.44	3.89	6.91
	7	58.56	21.41	10.17	2.21	32.18	6.61	10.20	2.62	0.25	0.48	4.45	7.13
	8	65.62	16.32	12.20	0.95	57.32	6.51	8.16	2.22	0.29	0.64	2.98	7.02
	9	51.93	18.89	9.66	1.17	52.75	6.36	8.16	1.41	1.01	0.47	4.69	6.80
SZ	1	63.53	49.97	8.14	2.04	37.21	6.71	9.18	2.32	0.64	0.53	4.47	7.24

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		Influent						Effluent					
townships	**Sewage facilities**	**COD mg/L**	**BOD_5 mg/L**	**NH_3N mg/L**	**TP mg/L**	**SS mg/L**	**pH**	**COD mg/L**	**BOD_5 mg/L**	**NH_3N mg/L**	**TP mg/L**	**SS mg/L**	**pH**
	2	50.42	35.69	9.15	1.03	25.14	6.81	10.20	2.82	0.48	0.55	3.59	6.35
	3	54.05	25.35	9.71	3.73	27.65	6.51	4.08	0.50	0.14	0.15	4.15	6.02
YP	1	67.50	23.45	12.20	3.87	30.17	7.02	5.10	1.31	0.48	0.48	7.77	6.57
	2	56.42	33.65	8.14	1.32	19.11	7.63	10.20	2.62	1.26	0.36	7.88	8.23
	3	46.35	20.39	10.17	2.43	27.15	7.02	5.10	1.11	3.49	0.42	7.57	7.57
	4	48.36	32.63	9.15	1.94	18.10	6.81	10.20	2.82	0.25	0.46	6.87	7.35
	5	63.47	23.45	11.19	3.41	14.08	6.81	6.12	1.81	3.84	0.64	6.97	7.35
	6	56.42	29.57	9.15	2.58	17.10	7.53	11.21	2.92	3.64	0.6	7.07	7.12
	7	52.39	23.45	14.24	2.14	13.07	6.92	6.12	1.41	1.99	0.32	6.76	7.46
	8	55.41	22.43	13.22	1.49	22.13	8.24	10.20	2.72	2.21	0.65	6.97	8.89
	9	62.47	24.47	8.14	2.88	23.13	7.02	11.21	2.92	0.25	0.42	6.76	6.57
	10	62.47	26.51	7.12	1.65	15.09	6.92	10.20	2.72	0.29	0.44	7.37	7.46
	11	53.40	28.55	9.15	1.95	21.12	7.83	5.10	1.31	0.25	0.48	6.76	8.45
	12	67.50	23.45	11.19	2.41	18.10	8.75	13.25	2.82	0.43	0.32	6.66	9.43
	13	67.50	24.47	11.19	3.25	15.09	8.44	5.10	1.41	0.46	0.36	7.07	9.11
	14	43.32	31.61	12.20	2.12	16.09	7.83	11.21	2.82	0.31	0.44	7.07	8.45
	15	65.49	20.39	10.17	3.21	19.11	7.42	6.12	1.71	0.25	0.36	6.36	8.01
	16	62.47	29.57	9.15	3.11	23.13	7.73	11.21	2.72	1.96	0.63	6.73	8.34
	17	57.43	20.39	7.12	2.67	26.15	6.92	5.10	1.21	1.93	0.56	6.76	7.46
	18	52.39	35.69	9.15	2.04	27.15	8.03	10.20	2.62	2.11	0.64	6.75	8.67
	19	42.25	19.84	26.96	1.87	19.11	8.03	6.12	1.51	1.28	0.04	7.37	8.67
WT	1	68.51	36.71	12.20	3.21	23.13	8.44	4.08	0.81	0.15	0.32	4.57	9.11
	2	55.41	24.47	13.22	2.57	18.10	7.73	4.08	0.50	0.43	0.32	4.16	8.34
	3	63.47	29.57	16.27	3.22	14.08	8.24	8.16	2.22	0.29	1.92	4.55	8.89
	4	60.45	35.69	11.19	3.86	14.08	8.03	5.10	1.41	0.25	0.46	4.21	8.67
	5	52.16	28.56	7.12	2.14	15.61	6.92	11.21	2.72	0.28	0.84	4.35	7.46
ZQ	1	56.42	17.33	9.15	3.24	56.32	8.75	4.08	0.71	0.15	0.76	4.18	9.43
	2	53.40	22.43	7.12	2.14	32.18	6.81	6.12	1.71	0.25	0.64	4.62	7.35
	3	63.47	20.39	9.15	2.12	63.36	6.81	4.08	0.50	0.21	0.36	3.56	7.35
	4	65.49	21.41	8.14	3.35	28.16	6.92	13.25	2.82	0.27	0.64	3.51	7.46
	5	61.46	20.39	8.14	2.54	47.27	7.93	6.12	1.61	0.43	0.44	4.19	8.56
	6	53.40	24.47	9.15	2.84	33.19	6.81	8.16	2.42	0.25	0.36	4.64	7.35
	7	56.42	18.35	8.14	2.11	28.16	6.41	4.08	0.50	0.25	0.36	3.88	6.91
	8	85.95	15.20	5.01	1.06	31.36	6.92	7.14	1.81	0.43	0.64	4.37	7.46
XF	1	63.47	16.32	9.15	2.15	136.78	7.22	4.08	1.11	0.37	0.4	4.56	7.79
	2	70.53	15.30	8.14	1.76	97.55	6.92	10.20	2.62	0.25	0.48	4.27	7.46
	3	60.45	18.35	9.15	2.39	105.60	7.42	9.18	2.29	0.26	0.32	4.55	8.01
	4	62.47	20.39	10.17	3.59	114.65	7.22	12.23	2.68	0.43	0.36	3.88	7.79
	5	68.09	19.64	8.39	3.11	125.42	6.41	10.20	2.52	0.44	0.24	3.47	6.91

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Table 2. *Monitoring data on influent and effluent from 76 wastewater treatment facilities in 10 townships in August*

		Influent						effluent					
townships	Sewage facilities	COD mg/L	BOD_5 mg/L	NH_3N mg/L	TP mg/L	SS mg/L	pH	COD mg/L	BOD_5 mg/L	NH_3N mg/L	TP mg/L	SS mg/L	pH
GM	1	78.56	25.49	20.34	5.26	5.33	8.14	14.27	3.02	1.51	0.08	37.21	8.22
	2	54.32	20.39	24.41	3.19	4.47	7.93	10.20	2.22	0.03	0.16	29.17	7.93
	3	68.12	23.11	27.25	2.14	4.53	7.63	9.18	2.02	0.36	0.12	23.62	6.95
QB	1	63.45	45.89	23.39	3.67	7.05	7.22	10.20	2.12	1.47	0.44	49.28	7.29
	2	43.17	22.43	19.32	4.32	6.06	7.32	11.21	2.32	1.57	0.24	21.12	7.39
	3	58.38	33.68	20.29	4.01	8.08	7.93	7.14	1.51	0.32	0.16	32.18	8.01
RT	1	57.56	28.55	19.32	6.43	6.87	8.14	14.27	2.22	3.86	0.28	63.36	8.22
	2	54.43	26.51	13.22	3.98	7.17	7.42	7.14	2.52	4.64	0.32	44.25	7.50
	3	63.21	34.67	16.27	5.32	7.22	8.14	10.20	2.62	5.33	0.28	52.30	8.22
	4	78.56	29.57	14.24	4.22	7.17	7.42	7.14	2.72	3.72	0.24	48.27	7.50
	5	54.43	34.67	18.31	6.21	7.07	7.53	12.23	4.14	6.86	0.32	42.24	6.12
	6	60.57	22.43	19.32	5.77	6.94	7.63	12.23	1.21	3.64	0.28	38.22	6.20
	7	43.48	50.99	15.26	4.64	7.43	7.73	8.16	2.12	5.94	0.12	48.27	6.29
	8	60.64	30.59	18.31	3.66	7.07	7.93	13.25	3.73	1.89	0.08	34.19	6.45
	9	52.72	24.47	17.29	4.24	7.15	7.83	10.20	3.83	2.72	0.36	42.24	7.91
	10	62.27	31.61	15.26	5.33	7.17	7.83	11.21	2.93	1.98	0.16	52.30	7.91
	11	45.45	29.57	18.31	5.67	6.84	8.03	12.23	2.42	4.44	0.23	49.28	8.11
	12	53.54	24.47	14.24	3.43	6.97	7.42	7.14	3.83	2.66	0.48	49.00	7.50
	13	54.14	34.89	8.67	6.1	5.33	7.53	12.23	1.82	5.12	0.52	34.08	7.60
HB	1	67.45	44.87	18.31	9.23	4.24	7.12	11.21	2.42	1.89	0.23	54.31	7.19
	2	54.56	46.91	14.24	8.51	4.66	7.73	11.21	2.32	2.92	0.26	43.25	7.81
	3	34.25	30.59	16.27	5.87	6.18	7.63	11.21	2.42	2.55	0.12	38.22	7.70
	4	52.17	28.55	13.22	6.94	5.96	7.93	6.12	1.41	2.89	0.28	63.36	8.01
	5	47.58	21.41	13.22	6.33	7.65	7.02	10.20	2.22	1.35	0.24	57.32	7.09
	6	69.47	36.71	18.31	7.21	7.43	6.92	12.23	2.72	1.28	0.16	39.22	6.98
	7	77.47	29.57	14.24	8.56	4.55	8.85	9.18	1.92	1.63	0.12	52.30	8.93
	8	69.05	49.39	12.20	3.35	6.43	7.73	8.16	1.71	2.03	0.28	52.03	7.81
RD	1	68.65	23.45	15.26	2.34	6.17	7.42	8.16	1.71	2.47	0.16	23.13	7.50
	2	95.91	21.41	9.15	1.98	4.45	7.83	11.21	2.12	4.13	0.08	26.15	7.91
	3	79.76	26.51	11.19	2.11	4.87	7.42	14.27	2.92	1.97	0.08	25.14	7.50
	4	84.81	30.59	10.17	3.42	5.26	7.73	12.23	2.62	0.39	0.16	56.32	7.81
	5	63.60	23.45	12.20	1.09	5.99	7.53	9.18	2.02	1.53	0.16	34.19	7.60
	6	56.54	23.45	13.22	2.45	5.78	8.03	14.27	3.02	1.22	0.24	27.15	8.11
	7	78.75	22.43	8.14	1.95	5.49	8.75	9.18	2.12	1.44	0.08	29.17	8.83
	8	88.84	20.39	10.17	1.21	6.47	8.14	10.20	2.22	1.37	0.23	21.12	8.22
	9	103.13	33.30	18.50	1.45	5.88	7.73	13.25	2.82	3.07	0.28	27.63	7.81
SZ	1	63.53	36.71	11.19	1.98	6.23	8.24	9.18	2.02	1.55	0.27	27.15	8.32

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		Influent						effluent					
townships	Sewage facilities	COD mg/L	BOD_5 mg/L	NH_3N mg/L	TP mg/L	SS mg/L	pH	COD mg/L	BOD_5 mg/L	NH_3N mg/L	TP mg/L	SS mg/L	pH
	2	85.71	41.81	9.15	2.11	6.87	8.03	12.23	2.72	0.96	0.18	18.10	8.11
	3	60.76	41.48	9.66	1.01	6.51	7.42	10.20	2.22	0.12	0.42	14.74	7.50
YP	1	124.93	28.55	8.14	1.32	7.13	7.32	9.18	3.23	1.39	0.16	20.11	7.39
	2	84.63	33.65	9.15	1.25	7.13	7.22	12.23	1.61	2.28	0.24	18.10	7.29
	3	87.65	29.57	9.15	1.85	6.93	7.02	9.18	2.62	2.8	0.28	13.07	7.09
	4	99.74	36.71	6.10	1.33	6.83	7.32	8.16	3.43	1.26	0.12	18.10	7.39
	5	83.62	32.63	8.14	2.02	7.03	6.92	14.27	2.02	2.03	0.16	13.07	6.98
	6	91.68	29.57	10.17	1.89	7.13	7.42	11.21	3.83	2.78	0.24	27.15	7.50
	7	76.57	24.47	9.15	1.67	7.23	7.53	12.23	1.81	1.75	0.24	15.09	7.60
	8	66.50	30.59	12.20	2.34	6.93	7.63	12.23	2.12	1.28	0.32	23.13	7.70
	9	109.82	20.39	10.17	1.89	7.23	7.73	9.18	3.43	3.91	0.22	17.10	7.81
	10	85.64	24.47	8.14	1.47	7.13	7.93	10.20	3.83	4.3	0.36	18.10	8.01
	11	76.57	23.45	9.15	1.59	7.03	7.83	7.14	2.82	1.94	0.24	22.13	7.91
	12	82.62	22.43	8.14	1.33	7.03	7.83	13.25	1.71	2.16	0.16	16.09	7.91
	13	115.86	25.49	7.12	1.43	7.24	8.03	11.21	2.12	2.69	0.36	25.14	8.11
	14	98.74	56.08	8.14	2.21	7.23	7.42	14.27	2.02	3.25	0.36	15.09	7.50
	15	72.54	40.79	9.15	1.56	7.03	7.53	8.16	3.43	3.61	0.32	25.14	7.60
	16	63.47	26.51	10.17	1.01	7.23	7.12	11.21	4.23	3.32	0.24	16.09	7.19
	17	81.61	20.39	11.19	1.21	6.97	7.73	12.23	2.32	1.06	0.76	28.16	7.81
	18	94.71	22.43	12.20	1.41	7.33	7.63	11.21	4.13	4.69	0.24	21.12	7.70
	19	113.11	22.80	5.23	1.62	7.23	7.93	15.29	3.23	1.74	0.36	29.17	8.01
WT	1	94.71	34.67	12.20	1.01	4.29	7.53	7.14	1.51	1.03	0.08	54.31	7.60
	2	83.62	26.51	15.26	0.99	5.24	7.53	7.14	1.61	1.75	0.2	37.21	7.60
	3	85.64	30.59	11.19	0.57	5.88	6.61	9.18	2.02	1.05	0.24	39.22	6.68
	4	63.47	29.57	8.14	1.04	4.29	7.73	11.21	2.52	0.14	0.28	43.25	7.81
	5	67.56	33.66	8.22	0.39	5.18	7.93	14.27	2.92	0.93	0.08	26.01	8.01
ZQ	1	78.59	21.41	5.09	4.18	4.34	8.85	12.23	2.62	1.28	0.12	95.54	8.93
	2	61.46	28.55	9.15	2.44	4.19	7.83	11.21	2.52	1.41	0.18	137.78	7.91
	3	69.52	33.65	8.14	3.56	4.78	8.03	10.20	2.12	1.64	0.33	159.91	8.11
	4	55.41	25.49	10.17	2.61	5.47	6.41	8.16	1.81	0.24	0.24	93.53	6.47
	5	46.35	26.51	9.15	1.88	4.72	7.53	6.12	1.31	1.36	0.39	105.60	7.60
	6	63.47	21.41	6.10	2.06	3.94	7.12	12.23	2.72	1.41	0.18	122.70	7.19
	7	68.51	20.39	8.14	2.34	6.45	7.73	10.20	2.12	1.14	0.24	147.84	7.81
	8	36.70	22.57	12.07	4.93	5.18	7.63	8.16	1.81	1.92	0.56	137.11	7.70
XF	1	45.34	15.30	9.15	1.59	7.18	7.93	7.14	1.51	2.25	0.16	48.27	8.01
	2	53.40	18.35	7.12	3.41	8.65	7.32	12.23	2.52	1.22	0.04	39.22	7.39
	3	62.47	20.39	10.17	2.56	8.15	6.92	6.12	1.31	3.08	0.28	20.11	6.98
	4	63.47	14.28	8.14	1.97	8.46	7.93	9.18	2.02	2.83	0.16	22.13	8.01
	5	50.33	26.68	7.92	1.97	6.88	6.61	13.25	2.82	0.42	0.16	20.26	6.68

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Table 3. *Monitoring data on influent and effluent from 76 wastewater treatment facilities in 10 townships in November*

		Influent						effluent					
townships	**Sewage facilities**	**COD mg/L**	**BOD_5 mg/L**	**NH_3N mg/L**	**TP mg/L**	**SS mg/L**	**pH**	**COD mg/L**	**BOD_5 mg/L**	**NH_3N mg/L**	**TP mg/L**	**SS mg/L**	**pH**
GM	1	59.45	32.63	25.43	3.56	39.22	7.11	9.18	2.22	2.26	0.36	4.26	6.81
	2	63.16	23.45	30.51	1.25	31.18	6.90	11.21	3.13	3.85	0.24	6.35	6.62
	3	48.39	24.92	25.07	0.59	34.60	7.21	8.16	2.18	2.29	0.36	4.11	6.91
QB	1	68.67	39.77	16.27	3.77	58.33	7.35	12.23	3.13	1.21	0.28	5.04	6.74
	2	55.32	27.53	22.37	2.89	48.27	6.31	12.23	3.33	4.51	0.54	4.32	7.01
	3	56.01	31.70	15.35	2.04	116.66	6.98	11.21	3.03	2.68	0.14	4.01	6.93
RT	1	73.45	21.41	16.27	1.44	68.39	7.21	8.16	2.82	3.41	0.16	7.63	6.91
	2	56.45	36.71	18.31	1.15	57.32	7.11	9.18	1.61	5.99	0.24	7.31	6.86
	3	83.56	29.57	14.24	1.42	56.32	7.00	10.20	2.22	5.74	0.08	7.31	6.71
	4	42.54	33.65	15.26	0.98	33.19	7.21	10.20	1.61	4.91	0.16	7.24	6.93
	5	40.34	52.00	14.24	1.03	54.31	6.80	15.29	2.62	4.95	0.2	7.61	6.52
	6	46.12	25.49	16.27	2.54	65.37	7.26	11.21	2.52	2.54	0.16	7.81	6.81
	7	50.54	29.57	19.32	1.14	34.19	7.16	8.16	1.82	3.72	0.12	7.78	6.81
	8	63.12	33.65	14.24	2.59	44.25	7.41	14.27	2.82	1.96	0.12	7.31	7.10
	9	95.18	34.67	17.29	2.18	28.16	7.21	14.27	2.22	1.77	0.28	6.81	6.91
	10	61.87	47.93	13.22	2.88	33.19	6.90	11.21	2.32	3.6	0.24	6.96	6.62
	11	103.41	29.57	14.24	1.99	59.34	7.62	9.18	2.42	2.13	0.16	7.21	6.81
	12	50.27	36.71	19.32	1.52	59.00	7.41	14.27	1.51	4.13	0.6	7.31	7.10
	13	39.15	44.06	15.79	1.24	56.97	7.21	7.14	2.62	4.29	0.6	4.87	6.91
HB	1	45.57	37.73	14.24	0.83	43.25	7.46	11.21	2.82	2.15	0.52	4.36	7.10
	2	58.56	26.51	16.27	2.19	28.16	7.00	12.23	3.02	1.76	0.4	4.79	6.71
	3	68.47	46.91	12.20	1.58	37.21	7.31	12.23	3.43	2.81	0.28	3.67	7.01
	4	74.16	52.00	16.27	1.01	28.16	7.00	8.16	2.22	4.95	0.2	5.16	6.71
	5	63.56	27.53	13.22	2.32	25.14	7.31	12.23	3.23	1.74	0.16	4.43	7.01
	6	52.17	41.81	18.31	1.67	35.20	7.21	11.21	3.02	1.14	0.6	4.19	6.91
	7	77.38	38.75	17.29	2.16	23.13	7.00	9.18	2.52	0.95	0.52	4.27	6.75
	8	80.13	16.76	16.20	1.04	19.75	7.21	7.14	1.81	4.82	0.20	5.46	6.91
RD	1	85.82	26.51	10.17	1.55	17.10	7.00	14.27	3.93	3.11	0.69	3.57	6.71
	2	66.63	25.49	10.17	1.85	21.12	7.51	8.16	2.12	0.7	0.57	5.46	7.20
	3	62.60	32.63	11.19	1.43	18.10	7.21	10.20	2.72	2.7	0.18	6.87	6.91
	4	73.70	23.45	9.15	1.22	19.11	7.31	12.23	3.23	3.66	0.87	6.42	7.01
	5	40.38	24.47	8.14	1.87	15.09	7.00	11.21	2.82	2.02	0.66	4.22	6.71
	6	68.65	26.51	8.14	1.83	28.16	7.41	16.31	4.13	1.54	0.51	4.72	7.10
	7	54.52	21.41	9.15	0.75	25.14	7.11	8.16	2.22	2.21	0.57	4.55	6.81
	8	62.60	20.39	7.12	1.11	21.12	7.41	8.16	2.22	1.56	0.21	4.25	7.10
	9	88.10	24.12	7.78	1.89	15.07	6.90	13.25	3.23	0.81	0.06	3.18	6.62
SZ	1	136.13	38.75	8.14	2.99	19.11	7.31	13.25	3.83	4.47	0.95	4.54	7.01
	2	84.71	30.59	11.19	3.41	18.10	6.90	16.31	4.23	2.55	0.94	3.56	6.62

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		Influent						effluent					
townships	**Sewage facilities**	**COD mg/L**	**BOD_5 mg/L**	**NH_3N mg/L**	**TP mg/L**	**SS mg/L**	**pH**	**COD mg/L**	**BOD_5 mg/L**	**NH_3N mg/L**	**TP mg/L**	**SS mg/L**	**pH**
	3	139.16	20.66	10.68	2.6	13.79	7.41	12.23	3.43	1.59	0.19	4.78	7.10
	1	146.09	20.39	19.32	1.59	17.10	7.21	12.23	2.02	2.62	0.88	7.57	6.91
	2	86.65	21.41	16.27	1.43	46.26	7.21	6.12	2.62	3.06	0.85	7.67	6.91
	3	146.09	23.45	10.17	2.34	58.33	7.11	10.20	1.95	1.25	0.76	7.77	6.81
	4	127.95	26.51	12.20	1.87	45.26	7.11	13.25	1.92	0.44	0.68	8.08	6.81
	5	92.69	24.47	12.20	4.99	32.18	7.00	7.14	2.92	2.40	0.28	7.88	6.71
	6	68.51	19.37	9.15	3.54	57.32	7.41	14.27	2.36	2.18	0.6	7.27	7.10
	7	105.79	22.43	12.20	2.14	64.36	7.51	7.14	2.42	2.59	0.72	7.37	7.20
	8	127.95	19.37	11.19	2.48	21.12	7.61	8.16	2.52	2.73	0.2	7.57	7.30
	9	113.85	18.35	14.24	1.76	48.27	7.71	13.25	2.02	1.84	0.92	7.07	7.39
YP	10	98.74	26.51	9.15	1.88	26.15	7.92	14.27	2.29	5.66	0.52	7.57	7.59
	11	87.65	23.45	10.17	1.43	61.35	7.82	10.20	1.51	1.72	0.2	7.65	7.54
	12	67.50	20.39	9.15	2.34	35.20	7.82	7.14	2.82	2.95	0.28	7.77	7.49
	13	116.87	25.49	15.26	1.67	36.21	8.02	8.16	2.32	1.28	0.68	7.98	7.69
	14	98.74	21.41	10.17	3.45	25.14	7.41	8.16	3.13	2.24	0.24	8.08	7.10
	15	78.59	22.43	12.20	1.38	46.26	7.51	12.23	1.81	2.45	0.32	8.34	7.20
	16	99.74	24.47	9.15	1.49	24.14	7.11	15.29	2.42	1.44	0.16	8.18	6.81
	17	79.59	22.43	11.19	2.43	52.30	7.71	9.18	2.42	0.38	0.64	8.32	7.39
	18	96.72	21.41	12.20	2.88	27.15	7.61	15.29	2.52	1.58	0.12	7.77	7.30
	19	60.30	14.20	12.40	2.61	35.20	7.92	12.23	3.13	2.42	0.12	7.98	7.59
	1	68.51	21.41	19.32	1.44	34.19	7.41	10.20	2.92	4.92	0.28	4.57	7.10
	2	70.53	29.57	16.27	2.02	36.21	7.51	12.23	3.23	1.82	0.4	4.37	7.20
WT	3	64.48	23.45	10.17	1.12	33.19	6.60	6.12	1.81	0.92	0.16	4.52	6.32
	4	69.52	35.69	12.20	1.57	24.14	7.71	8.16	2.22	2.21	0.64	4.88	7.39
	5	61.97	29.87	7.03	2.85	22.28	8.93	6.12	1.41	0.28	0.52	5.61	8.56
	1	47.35	17.33	8.14	3.33	54.31	7.82	12.23	3.13	2.43	0.6	6.47	7.49
	2	49.37	16.32	5.09	3.16	76.43	7.82	9.18	2.52	4.78	0.8	3.81	7.49
	3	55.41	13.26	6.10	1.87	45.26	7.00	9.18	2.52	1.85	0.96	4.19	6.71
ZQ	4	53.40	18.35	8.14	2.56	27.15	7.41	8.16	2.42	2.02	1.04	5.44	7.10
	5	47.35	12.24	7.12	1.84	55.31	7.51	15.29	3.93	2.51	1.28	3.91	7.20
	6	59.44	14.28	6.10	1.99	27.15	7.11	13.25	3.73	1.5	0.68	4.18	6.81
	7	46.35	15.30	7.12	3.66	36.21	7.71	6.12	1.71	1.58	0.6	4.27	7.39
	8	41.33	12.93	8.20	1.59	46.18	7.61	7.14	2.02	1.81	0.76	4.64	7.30
	1	64.48	16.32	10.17	2.03	42.24	7.92	10.20	2.82	1.92	0.28	6.45	7.59
	2	57.43	15.30	9.15	1.45	68.39	6.80	8.16	2.12	2.98	0.2	6.19	6.52
XF	3	63.47	21.41	11.19	1.83	43.25	5.99	6.12	1.71	1.14	0.24	6.52	5.74
	4	61.46	22.43	8.14	1.42	28.16	6.29	8.16	2.22	0.67	0.84	7.15	6.03
	5	53.16	14.54	1.35	1.27	42.97	7.41	13.25	3.43	1.03	0.84	6.59	7.10

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