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Original article

Distributed treatment of rural environmental wastewater by artificial ecological geographic information system

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ABSTRACT

The existing extensive domestic sewage discharge methods and simple sewage pipe network collection modes in rural China not only cannot guarantee high sewage collection efficiency, but also fail to achieve rain and sewage diversion, resulting in the deterioration of living environment, the serious pollution of surface water and groundwater in rural areas, and even directly threatening the quality of the water environment. Therefore, accelerating the researches on rural domestic sewage treatment technologies and the scientific and effective treatment of rural domestic sewage as much as possible is a very important task at present, which is of great significance to the overall improvement of China's rural environment. Therefore, on the basis of summarizing and analyzing previous research works, taking a town in Xuzhou City, Jiangsu Province, China as an example, this paper expounds the research status of rural domestic sewage treatment and its significance in improving rural environment, elaborates the development background, current status and future challenges of rural domestic sewage treatment technologies, introduces the related works of other scholars and the research area of this paper, analyzes the systematic mode of ecological treatment of rural domestic sewage, proposes the systematic mode of biological treatment of rural domestic sewage, conducts technological mode analysis of rural domestic sewage treatment, implements the effect evaluation of rural domestic sewage treatment, describes the impact of domestic sewage treatment on rural environment indicators, explores the improvement of the rural environment by domestic sewage treatment, discusses the applicability evaluation of different rural domestic sewage treatment technologies, and finally performs the quantitative description of the effect of domestic sewage treatment on the improvement of rural environment. The study results show that In the town of Xuzhou City, part of the mixed sewage is absorbed by the remediation plants, and part of the pollutants in the process of infiltrating the subsoil are intercepted by the soil medium, or absorbed, utilized or fixed by the roots of the remediation plants, or transformed by the microorganisms in the soil, and degraded into non-toxic or low-toxic components. The integrated technology refers to the small and medium-sized sewage treatment device developed by combining the pretreatment, secondary and advanced treatment technologies of rural domestic sewage, which is an important development direction of rural domestic sewage decentralized treatment technology. The study results in this paper provide a reference for further researches on treatment and technology of domestic sewage for improvement of rural environment in China.

1. Introduction

Environmental pollution caused by rural domestic sewage is not only a potential safety hazard for rural water sources, but also aggravates the crisis of freshwater resources, making farmland irrigation ineffective and endangering the survival and development of farmers (Cheng et al., 2020). Therefore, the establishment of rural sewage collection, treatment and reuse methods according to local conditions, implementation of corresponding operating

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and management costs, ensuring the normal operation of sewage treatment facilities, and avoiding rural water soil and agricultural product pollution caused by direct discharge of sewage are urgent problems that rural areas need to solve (Lu et al., 2016). The composition of rural domestic sewage is relatively complex, which contains a large amount of organic matter, inorganic matter, microorganisms, pathogens and other substances, which also contains abundant phosphorus and nitrogen, but basically does not contain refractory organic matter and heavy metals. The characteristics of rural domestic sewage include a wide range of sites, unstable water quality, large changes in water volume, low treatment efficiency, and a trend toward urbanization (Cheng et al., 2017). Rural domestic sewage treatment methods should be comprehensively considered in combination with rural local geographical conditions, economic conditions, environmental conditions, and management levels. Domestic sewage treatment methods must comply with the principles of economy, efficiency and simplicity and rural domestic sewage is one of the causes of rural water environment pollution. It has become a potential safety hazard in rural water sources and aggravated the crisis of freshwater resources; therefore, researches on rural domestic sewage treatment technology are of great significance (Hong et al., 2019).

Due to economic reasons, there are no specialized personnel in rural areas to manage and maintain domestic sewage treatment. Rural domestic sewage treatment needs to be combined with the local economic situation and meet the actual needs of rural agriculture (Wałęga et al., 2018). It has the characteristics of low investment and operation cost, simple management and operation, low energy consumption, and high efficiency. For agricultural production, the land treatment system mainly purifies pollutants through the microorganisms and plant roots in the land and the land (Han et al., 2019). The management of sewage treatment increases the actual operating pressure of the terminal, reduces the residence time of domestic sewage in the terminal, causes problems such as unsatisfactory treatment effects, and indirectly wastes treatment investment. This process includes direct treatment of sewage, reprocessing or advanced treatment of sewage after artificial or other processes, using sewage to create wetland nature reserves, and providing valuable ecological habitats for wild communities. Integrated technology refers to a small and medium-sized sewage treatment device developed by combining pretreatment technology, secondary treatment technology and advanced treatment technology (Gu et al., 2016). Therefore, to develop a set of low-cost, high-efficiency domestic sewage treatment technologies suitable for new communities based on actual conditions is the only way to build a resource-saving and environment-friendly society (Wang et al., 2019) (see Table 1).

On the basis of summarizing and analyzing previous research works, taking a town in Xuzhou City, Jiangsu Province, China as an example, this paper expounds the research status of rural domestic sewage treatment and its significance in improving rural environment, elaborates the development background, current status and future challenges of rural domestic sewage treatment technologies, introduces the related works of other scholars and the research area of this paper, analyzes the systematic mode of ecological treatment of rural domestic sewage, proposes the systematic mode of biological treatment of rural domestic sewage, conducts technological mode analysis of rural domestic sewage treatment, implements the effect evaluation of rural domestic sewage treatment, describes the impact of domestic sewage treatment on rural environment indicators, explores the improvement of the rural environment by domestic sewage treatment, discusses the applicability evaluation of different rural domestic sewage treatment technologies, and finally performs the quantitative description of the effect of domestic sewage treatment on the improvement of rural environment. The detailed chapter arrangement is as follows: Section 2 introduces the related works of other scholars and the research area of this paper; Section 3 conducts technological mode analysis of rural domestic sewage treatment; Section 4 explores the improvement of the rural environment by domestic sewage treatment; Section 5 discusses the applicability evaluation of different rural domestic sewage treatment technologies; Section 6 is conclusion.

Table 1
Key index parameters.

Influencing Factors	Controllability	Percentage
Rust layer	Controllable	8.12
Cracking	Controllable	2.05
Corrosion	Controllable	5.70
Water Leakage	Controllable	5.19
Thermal expansion	Uncontrollable	4.37
Cold shrinkage	Uncontrollable	4.65
puncture	Uncontrollable	4.24

2. Related works and study area overview

2.1. Related works

Ecological treatment technology is the effective use of artificial wetland technology and efficient purification and treatment of wastewater. Through the creation of an ecological circle, the ecological system is used to degrade pollutants and finally obtain a good treatment effect (Li et al., 2020; Song et al., 2018; Han et al., 2018). Constructed wetlands are artificially designed and constructed by simulating natural wetlands, using the physical, chemical and biological effects of the matrix, plants, and microorganisms in a composite ecosystem, through filtration, adsorption, co-precipitation, ion exchange, plant adsorption, and microbial decomposition. Constructed wetlands have low capital requirements and strong purification effects, making them a very good technical choice for rural domestic sewage treatment. Physical and chemical treatment technology is also an effective means for rural domestic sewage treatment, and it is widely used (Chen et al., 2019; Lutterbeck et al., 2017; Song et al., 2020; Chofreh et al., 2019). For example, the commonly heard methods such as adsorption and reverse osmosis are all physical and chemical treatment technologies. The feasibility of rural domestic sewage treatment through coagulation technology is very high and the specific treatment methods are more abundant. On the one hand, the operation process is simple and convenient, and the operator knows the reasonable addition of flocculants; the efficiency of rural domestic sewage treatment by coagulation technology is high can effectively shorten the cycle of sewage purification (Han et al., 2019; Wang et al., 2016).

This kind of constructed wetland absorbs and transforms various pollutants in sewage through soil and plants, and reduces the content of organic pollutants in the water body. Moreover, this method can effectively remove some pathogenic microorganisms in domestic sewage, and the treated water can also be used to irrigate farmland, so that the sewage can be further purified (Blum et al., 2017). The wetland sewage treatment system has the advantages of simple construction, low basic investment, no power, no personnel management, and low maintenance costs. The biological contact oxidation process has the advantages of small land occupation, less infrastructure, strong load-bearing capacity, simple maintenance, and low cost (Zha et al., 2018; Latrach et al., 2018). It is currently one of the common domestic sewage treatment processes in rural areas and these different types of methods can be roughly divided into two categories. The disadvantage is that the wetland needs to occupy a lot of land, and the growth of various plants is affected by the seasons, and the plant species of the wet-

land need to be reasonably matched. One is the method of bio-film treatment and the other is plankton treatment, which uses the oxidation of plankton in the water body to purify the water. The treated water can also be used to irrigate farmland to realize the recycling of water quality, and the concentrated sludge can also be returned to farmland (Gao et al., 2017; Jucherski et al., 2019).

2.2. Study area overview

This paper selects a town in Xuzhou City, Jiangsu Province, China as the research object, and analyzes its domestic sewage status and its impact on the improvement of the rural environment. The town has a total area of 49.8 square kilometers, governs 32 administrative villages, and has a total rural population of 33,000. A small amount of land in the town is hilly areas, mostly rivers flooding the plains and it has a typical warm temperate semi-humid continental monsoon climate. The four seasons are distinct throughout the year; the rainfall is mainly concentrated in the three months of July, August and September; high-pressure cold air control, dry climate with little rain and snow. In addition, the multi-year average temperature in the area is 12.5 ℃, the frost-free period is 188 days, and the maximum frozen soil thickness is 0.76 m. In recent years, the town has done a lot of work in economic development and infrastructure construction, and the economic level and quality of life of the villagers have been greatly improved. The town has successively carried out the renovation of rural toilets. Up to now, the renovation of most of the rural dry toilets has been completed. Open discharge problems such as sewage and feces have basically been eliminated, and the rural odor pollution has been effectively treated. Therefore, the main sources of domestic sewage in the area are analyzed, including toilet urine, bathing sewage, washing sewage, and kitchen sewage. Among them, the high-concentration domestic sewage from toilet flushing feces is called black water, and gray water mainly refers to the concentration of pollutants is relatively low in kitchen drainage, washing drainage, bathing drainage, and the clarification of black water after treatment in septic tanks or biogas tanks.

According to the survey of villagers' living habits, the analysis of the ways in which various sewages are discharged into the environment mainly includes the following three ways: washing drainage is mostly directly sprayed on the ground; kitchen and bathing drainage is discharged into the river through the sewer. In short, improper collection and treatment of rural domestic sewage has caused serious harm to the town's rural human settlements and ecological environment. It mainly contains organic substances such as cellulose, starch, sugar, fat, protein, and inorganic salts such as nitrogen and phosphorus. In addition, sewage contains a variety of microorganisms and pathogens and the town's ecological status is very important. A large amount of nitrogen, phosphorus and other nutrients in the sewage are directly discharged into lakes, rivers and other water bodies, which will cause eutrophication of the water body and cause serious consequences. The drinking water source of villagers is mostly shallow groundwater, and domestic sewage has become a new hidden danger of drinking water safety in rural areas, seriously affecting people's health. In addition, the eutrophication of water bodies has led to a decrease in the appreciation of the landscape environment, which has affected the economy of some regions with tourism as the pillar industry.

3. Technical mode analysis of rural domestic sewage treatment

3.1. Systematic mode of ecological treatment

The land treatment system mainly uses the physical, chemical and biological synergistic effects of the soil, plant and microbial complex system to decompose the degradable pollutants in the sewage to achieve the purpose of sewage purification. According to the different land treatment systems of the target objects, it can be divided into the slow infiltration ecological treatment system, the rapid infiltration treatment system, the ecological treatment of the slope flow wetland treatment system, and the underground infiltration ecological treatment system. The land treatment system has the characteristics of simple structure and convenient maintenance, which is suitable for small and medium villages with flat terrain, low slope and relatively concentrated life. Constructed wetland is a composite system composed of substrates, plants, microorganisms and water bodies designed and constructed artificially. It uses the design of microbes and plants in the physical composite ecosystem and uses special microbes, water, chemistry and biology to purify sewage. Through filtration, adsorption, precipitation, ion exchange, plant absorption, microorganisms and the effluent of the biological filter flows into the surface constructed wetland. The organic ecosystem in the wetland further purifies the sewage. The developed roots of aquatic plants absorb nitrogen, phosphorus and other organic matter in the sewage to reduce the nitrogen, phosphorus and other pollutant indicators. Fig. 1 shows the framework of rural domestic sewage treatment for rural environment improvement.

Constructed wetlands are relatively economical in construction investment, with a high utilization rate and relatively safe operating load. However, the quality of effluent water depends heavily on operation and maintenance and management, which can be used as a transitional sewage treatment technology in areas with ordinary economic conditions and is in use. It is necessary to strengthen operation and maintenance management and channel-type ecological ditch has a high idle rate. Due to the vertical baffle design of sewage, the normal operation depends on the accurate estimation of the sewage volume, otherwise it will cause all the treatment systems to be paralyzed, the risk is high, and the investment is expensive, and it occupies land. The area is large and land acquisition is difficult, so unless it is used under particularly good construction environment conditions, it is generally not recommended to use this process technology. The integrated equipment occupies less land, the later operation and maintenance are simple, the effect of nitrogen and phosphorus removal is average, the effluent can reach the comprehensive discharge standard, and the construction investment is relatively expensive. It can be

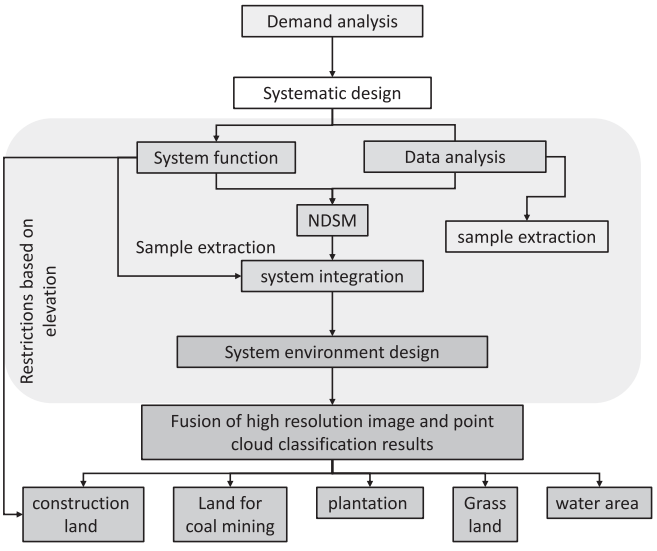

Fig. 1. Framework of rural domestic sewage treatment for rural environment improvement.

used in areas with better economic conditions and low requirements for nitrogen and phosphorus removal. In view of the problems of unpowered constructed wetland technologies currently used in rural domestic sewage treatment, such as easy clogging, low winter treatment efficiency, lack of integrated equipment, and high construction costs, this mode combines regional and river basin water quality improvement target needs, and comprehensive Considering the development of rural economy and changes in population mobility, a reasonable choice of unpowered constructed wetland technology.

Chinese-style sewage treatment means that the sewage in the area is concentrated in some way and then connected to the nearby municipal sewage pipe network through pipelines. This treatment method is suitable for areas where the distance to the urban sewage pipe network is relatively short, and the cost of constructing collection and transportation pipelines is less than that of direct construction of sewage treatment projects. The systematic modes of ecological and biological treatment of rural domestic sewage are shown in Fig. 2. It has the characteristics of low investment, quick results, short construction period, and convenient management. Distributed sewage treatment refers to dividing a larger area into several smaller units and the independent system, separate pipe network system, construction of sewage treatment facilities does not intersect each other, in order to achieve the greatest economic and environmental benefits. This method is to first make microorganisms form a bio-community film on the surface of artificially provided inert solids and other filter materials or carriers, and filter or carrier sewage through contact with biofilms. Organic pollutants in the sewage are absorbed as nutrients for microorganisms to multiply and the organic matter in the wastewater is purified. The investment and operating cost of biofilm is relatively high, but it has strong impact resistance, less sludge treatment process, small floor space, high sewage load, good effect. In areas with dense populations and relatively tight land resources, biological treatment can be considered.

3.2. Systematic mode of biological treatment

During the operation of the rural domestic sewage treatment project, there was a large amount of mud and sand accumulation in the grid well and the grit channel. The various design and construction links were investigated and it was found that the sewage pipe network was not constructed in accordance with the design requirements of the construction drawing during the actual construction process. Rain and sewage diversion is changed to rain and sewage combined; there is no effective grille in the system to intercept garbage and no settling tank in the inspection well to settle and remove mud and sand, resulting in a large amount of solid garbage, stream cement sand, construction mud, etc. entering the pipe network, and finally entering the sewage treatment facility affects the normal operation of the facility. If the elevation and length of the perforated pipes are not strictly controlled according to the requirements of the construction drawings, and the level of the water distribution pipes is not enough, it will directly cause a large amount of water on the inner surface of the ecological bed, which will affect the underflow or surface flow treatment effect and cause the tube body to tilt, and improper fixing methods will cause water leakage on the wall (Fig. 3). After the excavation of the foundation trench, relevant personnel should be notified to inspect the trench and the water distribution method uses perforated pipes for water distribution. If the actual geological conditions and the design are inconsistent with the overall construction, the corresponding foundation treatment should be done after consultation with the design unit, construction unit, and supervision unit to avoid structural differences, because groundwater reverse seepage, the main body of the facility collapses due to insufficient capacity, seepage, etc.

River Bang treatment technology uses the river in-situ oxygenation system to accelerate the re-oxygenation process of the water body to increase the dissolved oxygen level of the water body, restore and enhance the vitality of aerobic microorganisms in the water body. Through the metabolic activities of microorganisms in the river, and the accompanying physical, chemical and physical chemical processes, the sewage makes the organic pollutants, nutrient elements and other pollutants in the wastewater undergo multi-level conversion, degradation, and removal, thereby realizing the purpose of harmlessness, resource utilization and reuse of wastewater. The live sewage is collected in the biological filter through the pipeline, and the microcrystalline composite filter material is placed in the biological filter. The filter material has excellent adsorption performance and specific surface area, which provides superior microorganisms living space on the surface of

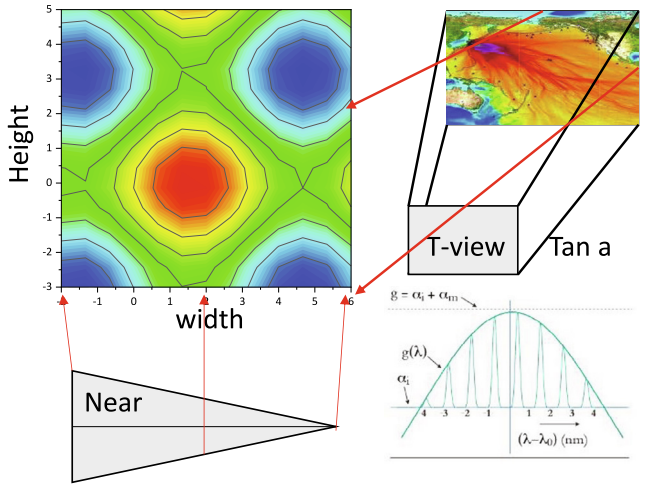

Fig. 2. Systematic modes of ecological and biological treatment of rural domestic sewage.

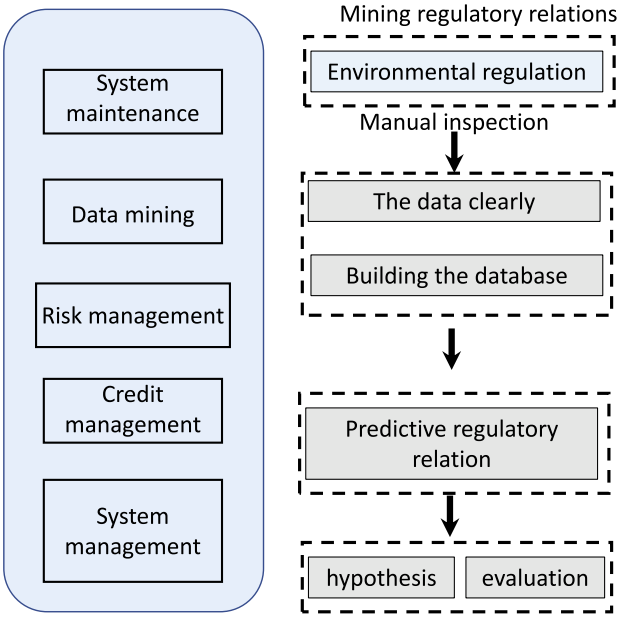

Fig. 3. Treatment efficiencies of ammonia (a), phosphorus (b), organic matter (c) and heavy metal (d) in rural domestic sewage.

the microcrystalline filter material. Under good nutrient conditions, microorganisms multiply rapidly, the biomass increases sharply, and the diversity of microbial species increases and becomes a combination of natural and artificial processes. Under the action of the viscous substances secreted by the microorganisms, the microorganisms adsorb each other, forming a large number of highly active bio-films on the surface of the filter material, and quickly degrade water pollution. At the same time of rapid decontamination, the deodorizing and decolorizing functions of the microcrystalline composite filter material will be clearly manifested, the odor of sewage will be greatly reduced, the transparency of the water body will be improved, and the water body sensory will be significantly improved.

During the investigation process, due to the influence of objective factors such as testing equipment and professional technology, it was impossible to conduct a detailed investigation of the pipeline network. However, combined with field surveys of some pipe networks, feedback from operation and maintenance personnel, and analysis of influent pollutant concentrations, it is found that the current collection rate of rural domestic sewage is relatively high, which provides a good basic condition for rural domestic sewage treatment. However, due to the early stage of the pollution control work, different places have paid attention to the construction of sewage treatment systems, and underestimated the pipeline arrangement and pipeline network construction, resulting in uneven pipeline network quality and the collection and treatment of rural domestic sewage. In order to save the cost of pipe network construction, some construction units and villages discharged rainwater and sewage into the collection pipe network. The combined rain and sewage construction method increases the actual operating pressure of the terminal, reduces the residence time of domestic sewage in the terminal, causes problems such as unsatisfactory treatment effects, and indirectly wastes treatment investment. When the rainy season comes, a lot of rainwater pours in, causing sewage, scum and sludge to overflow from the manhole cover, resulting in harsh environmental impacts. In addition, the survey found that due to the quality problems of the pipeline network construction and the construction of infrastructure projects such as road repair and demolition, the collection pipeline network of some terminals was damaged and flooded.

4. Improvement of rural environment by domestic sewage treatment

4.1. Effect evaluation of rural domestic sewage treatment

The underground infiltration ecological treatment system distributes sewage into the underground soil layer with a certain structure and good diffusion performance. The sewage moves to the surrounding and downwards through the soil capillary infiltration and soil infiltration, in the soil, microorganisms and plant systems. Under the comprehensive purification function, the type of sewage treatment process that meets the requirements of treatment and utilization. The surface flooding ecological treatment system uses surface water distribution or low-pressure and high-pressure spraying to control the distribution of sewage onto the slopes with perennial pastures, gentle slopes, and low soil permeability, so that the sewage flows slowly along the slopes on the surface and the type of sewage treatment process that can be fully purified (Fig. 4). The process objectives of the treatment system include direct treatment of sewage, reprocessing or advanced treatment of sewage after artificial or other processes, using sewage to create wetland nature reserves, and providing valuable ecological habitats for wild communities. In this treatment system, part of the mixed sewage is absorbed by the remediation plants,

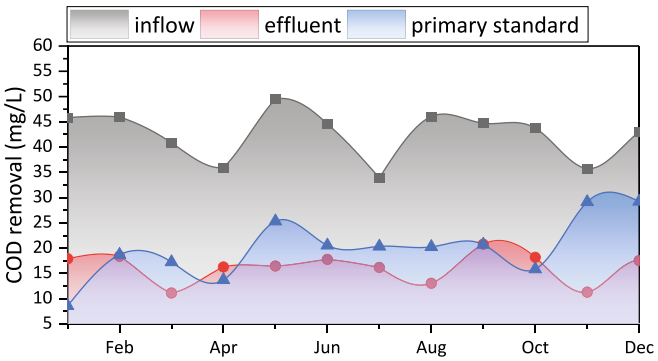

Fig. 4. Relationship between proportion of treatment costs and concentration ratio of organic matter with systematic mode of ecological treatment (a) and systematic mode of biological treatment (b).

and part of the pollutants in the process of infiltrating the subsoil are intercepted by the soil medium, or absorbed, utilized or fixed by the roots of the remediation plants, or transformed by the microorganisms in the soil, and degraded into non-toxic or low-toxic components.

Domestic sewage treatment also includes sewage treatment facilities in which earthworms are added as auxiliary treatment in wetlands. According to the theory of ecology, the longer the food chain through which energy flows in the environment; the greater its consumption and the less pollutant remain in the sewage. By extending the wetland food chain structure, adding microanimals to improve the artificial wetland, enhancing the biological synergistic purification effect of microorganisms and earthworms; at the same time, earthworm shuttle for food in the mechanism enhances the permeability of the soil and reduces the probability of wetland clogging. Improve the efficiency of system pollutant removal. As a sewage treatment engineering technology with low investment, low energy consumption, low operating cost, and high ecological environmental benefits, constructed wetland technology has been widely used in the practice of rural domestic sewage treatment. Its disadvantages are large area and low processing load high and low temperatures in winter will cause unsatisfactory treatment effects if plants cannot grow normally. The direct economic benefits of using sewage for farmland consumption include reducing the application of chemical fertilizers, reducing the cost of advanced sewage treatment for nitrogen and phosphorus removal, and increasing farmland crop yields. Indirect economic benefits include saving a large amount of limited water resources, alleviating the contradiction between the supply and demand of agricultural water, and the use of sewage for farmland is more reasonable and economical than rainwater and long-distance water diversion.

The process of activated sludge secondary treatment and deep purification of constructed wetlands has now become a common method for upgrading and upgrading municipal sewage plants. This combination of processes is also suitable for concentrated villages with a large amount of water, but its applicability to scattered villages is questionable. The detection of ammonia and other organic sources mainly contains organic substances such as cellulose, starch, sugar, fat, protein, and inorganic salts such as nitrogen and phosphorus. In addition, sewage contains a variety of microorganisms and pathogens and the town's ecological status is very important. Therefore, if the two processes are combined, for rural decentralized sewage treatment, both professional sewage treatment operations and wetland greening maintenance are required, which doubles the workload of operations. Therefore, it is recommended to use a single aerobic biological treatment technology or anaerobic pretreatment for decentralized rural sewage

treatment, so as to maximize the advantages of the two methods. Under low temperature conditions in winter, the degradation of pollutants by microorganisms and the absorption of plants are significantly lower than in other seasons. Therefore, both traditional biochemical treatment technology and constructed wetland technology are facing the problem of reduced treatment efficiency in winter, and the nitrogen removal process is most affected.

4.2. Impact of rural domestic sewage treatment on ecological environment indicators

The sewage treatment device uses a combination of treatment methods such as precipitation, anaerobic hydrolysis, anaerobic digestion, and contact oxidation. After entering the treatment facility, the sewage is hydrolyzed and digested in the anaerobic section, and the concentration of organic matter is reduced. The filter tank performs jet oxygenation, and the air in the oxidation ditch is naturally aspirated by the air-pulling pipes distributed along the channel. The mixed flow expanded bed anaerobic biological filter is the core technology unit of the entire device, which overcomes the shortcomings of the traditional anaerobic filter that is easy to block and the reactor is inconvenient to maintain and repair, which is the main functional area for removing pollutants. Through the anaerobic unit, most of the organic matter in the sewage is removed, and the concentration of organic matter entering the aerobic unit is low. At the same time, due to the unique anaerobic metabolism mechanism, the biodegradability of the organic matter that is not directly removed is significantly improved after hydrolysis and acidification (Fig. 5). The low-concentration, good biodegradability sewage enters the final treatment link, namely the aerobic unit, which makes aerobic metabolism easier, and at the same time, the metabolism is more complete and thorough. Due to the limitation of the original treatment site, it is required that the new treatment process must have the characteristics of small area, high treatment efficiency, and can meet the requirements of nitrogen removal.

Regardless of household level, village level, or town level technology, according to the treatment principle, it can be divided into bio-film method, activated sludge method and ecological method. Different methods have their own advantages and disadvantages and activated sludge method is a traditional sewage treatment technology. However, it has a larger footprint, higher infrastructure costs, higher operating costs, and impact resistance and poor capacity, high sludge production, and other problems. The bio-film method generally has a small footprint, high pollutant removal rate, strong impact resistance, low sludge production, and difficult to occur the advantages of sludge expansion and high acceptance by the public are generally slow to start and difficult to manage. Although the ecological law has low operating costs and low management difficulty, it has problems such as large area and low acceptance by the public, and it is easy to suffer. The enterprises participating in the sewage treatment of villages and towns mainly adopt technologies such as biological contact oxidation and activated sludge method, while fewer enterprises adopt the ecological method. The biological contact oxidation process is usually based on the activated sludge method by adding fillers to achieve mud film mixing, so as to realize the complementary advantages of the traditional activated sludge method and the bio-film method, and has strong adaptability in the sewage treatment process of villages and towns.

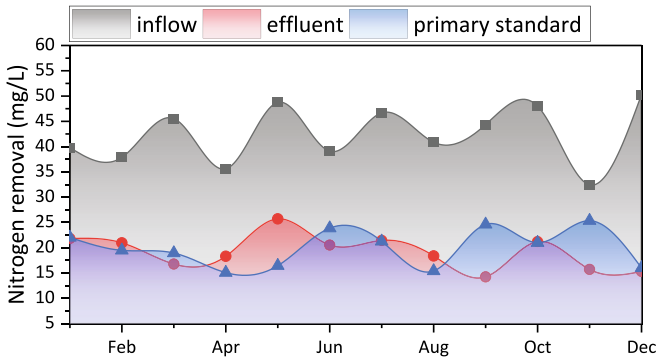

Fig. 5. Effect evaluation of rural domestic sewage treatment and its impact on ecological environment indicators.

In view of the characteristics of rural domestic sewage and the status quo of rural economy and technology, micro-powered, high-load, fully automatic sewage treatment facilities have received widespread attention for their good compliance and economic efficiency. However, the traditional underground infiltration is basically a non-powered type, and the effluent is not satisfactory. The system load capacity is improved through measures such as micro-dynamic aeration and uniform water distribution. The high-load percolation field formula is to increase the distance of the sewage in the lateral transport and downward infiltration through a similar pulse inflow method, thereby increasing the interception and adsorption of pollutants in the soil. At the same time, the intermittent oxygenation method is adopted, and the same eight cycles per day are used to improve the ability of microorganisms to decompose, transform and remove pollutants, and significantly increase the daily load of infiltration. After the sewage passes through the grid, the larger suspended matter, floating matter, fibrous material and solid particulate matter in the sewage are removed, thus ensuring the normal operation of the subsequent treatment structures and reducing the burden of pollutants on the subsequent structures. According to the actual situation in the operation of the sewage treatment facility, the grid slag is regularly inspected, cleaned, transported and processed, and part of the suspended matter is removed through the primary sedimentation tank, as well as large suspended organic and inorganic substances.

5. Discussions

5.1. Applicability evaluation of different rural domestic sewage treatment technologies

The optimization of rural domestic sewage treatment plan is complex system engineering, which is necessary to consider the sewage treatment efficiency of the sewage treatment plan and the operation efficiency of sewage treatment. It must not only meet the economic feasibility, but also meet the design requirements technically and operate. Management must be in line with the actual conditions of the countryside; it must not only meet the short-term sewage treatment needs of the rural areas, but also consider the long-term sewage treatment needs of the rural areas. Therefore, the selection of rural sewage treatment plan is fuzzy and incompatible, which is a multi-attribute and multi-objective problem. The technical comparison of rural domestic sewage treatment schemes is generally based on the principle of cost-effectiveness, comparing whether its process technology, including sewage, sludge treatment process technology, main structure technology, automatic control technology is advanced and reasonable (Fig. 6). The specific content of the comparison includes the removal rate of pollutants by each process, the disposal rate of sludge, and the degree of process automation. Since the main use of rural sewage treatment projects is farmers, if the operating cost exceeds the farmers' economic affordability, farmers will be less motivated to use the sewage treatment project or even choose not to apply. This

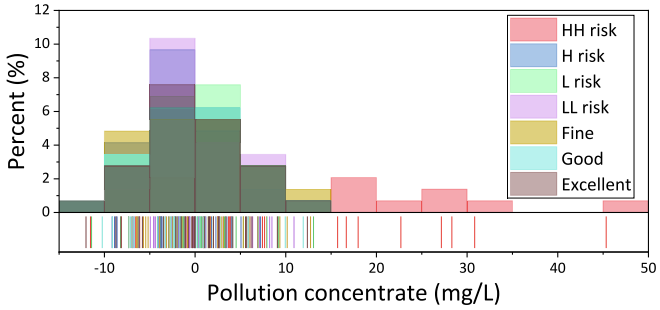

Fig. 6. Treatment efficiency evolutions of different sewage components with ecological treatment (a) and biological treatment (b).

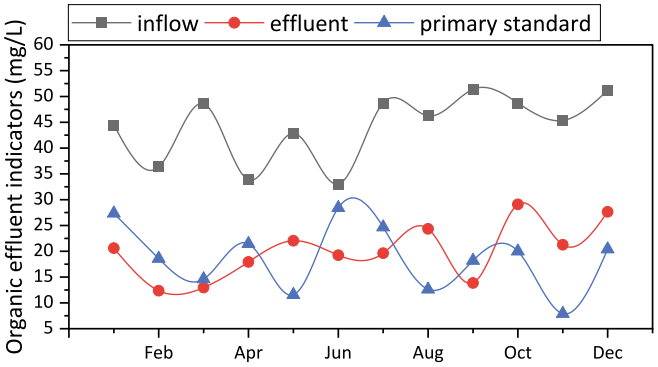

Fig. 7. Relationship between removal rates and concentration of five different sewage components.

is also the main reason why sewage treatment facilities in many rural areas cannot operate normally after they are completed.

The content of cadmium and lead in the soil after sewage irrigation is significantly different from that of clean water irrigation, and there is no significant difference in arsenic. However, as the concentration of irrigation sewage increases, the content of heavy metals in the soil also increases. Sewage irrigation has a significant effect on improving the respiration intensity of soil. The respiration intensity of soil irrigated by treated sewage is higher than that of untreated soil. Therefore, compared with the untreated sewage used for agricultural irrigation, the sewage treated by the sewage treatment station is more conducive to soil safety and soil fertility. The organic effluent indicators details have the advantages of simple construction, low basic investment, no power, no personnel management, and low maintenance costs. The biological contact oxidation process has the advantages of small land occupation, less infrastructure, strong load-bearing capacity, simple maintenance, and low cost. The selection of rural sewage treatment technology needs to fully consider the current situation of weak economic strength in rural areas and low peasants' ability to bear. At the same time, the selection of wastewater treatment process should be comprehensively considered in accordance with the design of wastewater inlet water quality, effluent water quality requirements, process area and scale. Its pollution resistance and hydraulic load are strong, and its impact resistance performance is good; it is not only suitable for the treatment of domestic sewage, but also for certain industrial wastewater, agricultural wastewater, acidic mine wastewater and Liquid sludge also has better purification ability.

5.2. Quantitative description of the improvement of rural environment

The amount of domestic sewage in rural areas is small but relatively scattered, and the lives of rural residents are relatively simple, and the water consumption of residents is significantly lower than that of urban residents. Therefore, the amount of rural domestic sewage is relatively small. However, the life of rural residents is relatively scattered in space, and the discharge of domestic sewage is also relatively scattered. This small but scattered situation leads to the destruction of the ecological system every bit, and it is difficult to attract people's attention in the early stage. In terms of sewage treatment, it is also more difficult to start, and the cost of treatment is higher. Due to the influence of the work and rest rules of rural production and life, there are also certain differences in the discharge time of rural domestic sewage in a day. In addition, since most of the domestic sewage discharge systems in rural areas have not been popularized, most of them are discharged along the ditch or into the nearby waters, which makes the rural sewage discharge extensive (Fig. 7). The combined treatment technology in rural domestic sewage treatment technology is relatively used the most, and among the combined technologies, biological and ecological technologies are used the most frequently, indicating that on the one hand, the composition of rural domestic sewage is complicated, and on the other hand, low operating costs must be considered, which requires a variety of process combination to achieve the purpose of strengthening the purification capacity of the system and reducing operating costs.

In rural areas, decentralized sewage treatment systems are mainly adopted due to scattered housing and small drainage volume. The decentralized sewage treatment system saves costs than the centralized system and can be used in decentralized rural areas. Due to the relatively backward economy in rural areas, sewage collection is difficult, and there is a lack of funds and technical personnel. In the selection of sewage treatment technology, measures should be taken according to local conditions such as topography, hydrological conditions, climate, village geographic scope, population distribution, rural industries and economic conditions, sensitive areas and drainage methods in different regions to minimize investment and operating costs. Due to the difficulty of collecting and dispersing domestic sewage in rural areas, scholars prefer to adopt decentralized treatment methods in rural areas. Due to the large regional heterogeneity in rural areas, there is no mode of sewage treatment that can be applied to all areas. Future research should also focus on the regional applicability and economics of sewage treatment technology as the main research direction. For example, the anaerobic baffle-vertical flow constructed wetlands of different substrates have different effects in the treatment of domestic sewage. It is still necessary to further evaluate the removal efficiency of different substrates on the pollution components of domestic sewage. In future studies, the combination of different substrates can be considered to improve the treatment effect of constructed wetland system.

The problems in the sewage collection pipe network are common problems in most rural sewage treatment facilities. Because the residents in rural areas live relatively scattered and the terrain is uneven, it is difficult for sewage to enter sewage treatment facilities through gravity flow. At the same time, due to lack of system planning and weak rural collective economy, most villages do not have a complete sewage pipe network. The drainage system in the village is mainly through natural or artificially constructed trenches, and most of these trenches are open. Sewage is visible. In villages with better economic conditions, a cover plate is installed on the trench to prevent the odor from spreading out. Basically, domestic sewage flows through the ditch in the village to the ponds, farmland, and river ditches in the low-lying areas of the village, which is a combination of rain and sewage. Due to the insufficient pipeline network, the small collection area and the narrow household access area of the established rural sewage treatment facilities, the sewage collection rate is low. Most of the septic tanks in rural areas have been used for many years or have

been damaged and some are built under houses and cannot be remodeled. In addition, the underground soil in some areas is relatively loose. Very low, and basically no anti-seepage treatment, the septic tank directly seeps into the ground, polluting the groundwater, and causing great difficulties for sewage collection.

6. Conclusions

Taking a town in Xuzhou City, Jiangsu Province, China as an example, this paper analyzes the systematic mode of ecological treatment of rural domestic sewage, proposes the systematic mode of biological treatment of rural domestic sewage, conducts technological mode analysis of rural domestic sewage treatment, implements the effect evaluation of rural domestic sewage treatment, describes the impact of domestic sewage treatment on rural environment indicators, explores the improvement of the rural environment by domestic sewage treatment, discusses the applicability evaluation of different rural domestic sewage treatment technologies, and finally performs the quantitative description of the effect of domestic sewage treatment on the improvement of rural environment. The life of rural residents is relatively scattered in space, and the discharge of domestic sewage is also relatively scattered and this small but scattered situation causes the damage to the ecosystem to be small and small. Therefore, regardless of household-level, village-level, or town-level technology, according to the treatment principle, it can be divided into bio-film method, activated sludge method and ecological method. Different methods have their own advantages and disadvantages. In rural areas, decentralized sewage treatment systems are mainly adopted due to scattered housing and small drainage volume. The decentralized sewage treatment system saves costs than the centralized system and can be used in decentralized rural areas. The problems in the sewage collection pipe network are common problems in most rural sewage treatment facilities. Because the residents in rural areas live relatively scattered and the terrain is uneven, it is difficult for sewage to enter sewage treatment facilities through gravity flow. The study results show that the integrated technology refers to the small and medium-sized sewage treatment device developed by combining the pretreatment, secondary and advanced treatment technologies of rural domestic sewage, which is an important development direction of rural domestic sewage decentralized treatment technology. Therefore, to develop a set of low-cost, high-efficiency domestic sewage treatment technologies suitable for rural areas based on actual conditions is the only way to build a resource-saving and environment-friendly rural environment. The study results in this paper provide a reference for further researches on treatment and technology of domestic sewage for improvement of rural environment in China.

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Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

The data used to support the findings of this study are available from the corresponding author upon request.

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