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Innovative Design of Wastewater Treatment Plant Based on TRIZ Theory

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Abstract: *With the rapid development of society, the demand for water in agriculture and cities has increased, leading to a shortage of freshwater resources available in people's lives. Therefore, everyone must realize the importance of protecting water resources and saving water. Human life cannot live without water, but the available freshwater resources are very limited. In daily life, people install washing pools in kitchens, bathrooms, and other places, wash their hands in the sink, wash pots and pans, or wash fruits and vegetables. The treated water is discharged directly from the cleaning tank into the groundwater pipeline. If water can be recycled, it can not only save household water costs, but also save water resources. Therefore, it is necessary to carry out innovative design for wastewater treatment devices based on TRIZ theory in this paper to solve this problem.*

Keywords: *TRIZ theory; Sewage treatment device; Innovation; Design*

1. Introduction

Currently, 99% of the domestic sewage generated in the bathrooms, kitchens, and showers of ordinary households, hotels, and apartments is directly discharged into wastewater pipelines, which are uniformly recycled, treated, and reused, resulting in waste of water resources in households and hotel apartments, and increasing the living costs of households, hotels, and apartments. Most of the common domestic sewage recycling devices on the market are large sewage treatment equipment or buried sewage treatment equipment, which are only suitable for large areas, such as water plants and rural areas. Based on the above issues, this article uses TRIZ theory to analyze the key points of the problem and form a series of innovative methods and solutions after thinking about the key points of the problem, resulting in a domestic sewage treatment plan. On this basis, a domestic sewage reuse plan for families and hotel apartments with small floor space, fast processing speed, simple operation, and convenience is designed.

2. Innovative methods based on TRIZ theory

TRIZ was originally designed by Russian scholar G.S. Altschuler (also known as Genrich Achschuler) and colleagues in 1946. Initially, 40000 qualified patents were extracted from 200000 patents and used as optimal solutions to various invention problems. From these most effective solutions, they have extracted basic TRIZ methods for solving inventive problems. These methods can also be widely used in emerging inventive problems to help people obtain the most effective solutions to these inventive problems [1]. TRIZ is translated as a theory to solve the problem of invention. TRIZ theory has successfully revealed the inherent laws and principles of creative inventions, focusing on clarifying and emphasizing the contradictions existing in the system to accurately resolve the contradictions and obtain the ultimate ideal solution. It does not adopt a compromise or compromise approach, but rather examines the entire design and development process based on technological development rather than random behavior. Practice has shown that the application of TRIZ theory can significantly accelerate the process of people's creation and invention, and obtain high-quality innovative products [2]. Utilizing Alih Shuriel and his TRIZ, such as conflict matrix, 76 standard solutions, matter field analysis, ARIZ, AFD, ISQ, scientific effects, DE8 evolution, 40 innovative principles, 39 engineering and technical characteristics, geometry, physics, chemistry, and other engineering principles, commonly used are the macroscopic based contradiction matrix method (conflict matrix method) and the microscopic based material field transformation method.

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3. Water quantity and inlet and outlet water quality

In order to reduce the complexity of domestic sewage treatment, the water quality of the effluent must comply with the standard of "Water Quality of Municipal Miscellaneous Water for Urban Wastewater Reuse" (GB/T 18920-2002) [3]. In combination with the above water quality standards and the "Pollutant Discharge Standard for Urban Wastewater Treatment Plants" (GB/T 18918-2002), the effluent quality standard is determined to be the urban greening standard of "Urban Wastewater Reuse and Urban Miscellaneous Water Quality" (GB/T 18920-2002) [4]. The discharge concentrations of COD, SS, TN (N), and TP(P) not specified in the standard refer to the Class I standard A [5] in the "Emission Standard for Pollutants from Municipal Wastewater Treatment Plants" (GB 18918-2002). The quality of inlet and outlet water shall comply with the Class I B standard specified in the "Discharge Standard for Pollutants from Urban Wastewater Treatment Plants" (GB 18918-2002). See Table 1 below for the design margin and inlet and outlet water quality.

Table 1: Design inlet and outlet water quality

Item	Effluent	Inlet
BOD5 (mg/L)	20	≤180
COD (mg/L)	60	≤350
TP (mg/L)	1.0	≤3.5
NH_3-N (mg/L)	8	≤30
SS (mg/L)	20	≤150
TN (mg/L)	20	≤40
pH	6～9	6～9

4. Design scheme of sewage treatment device based on TRIZ theory

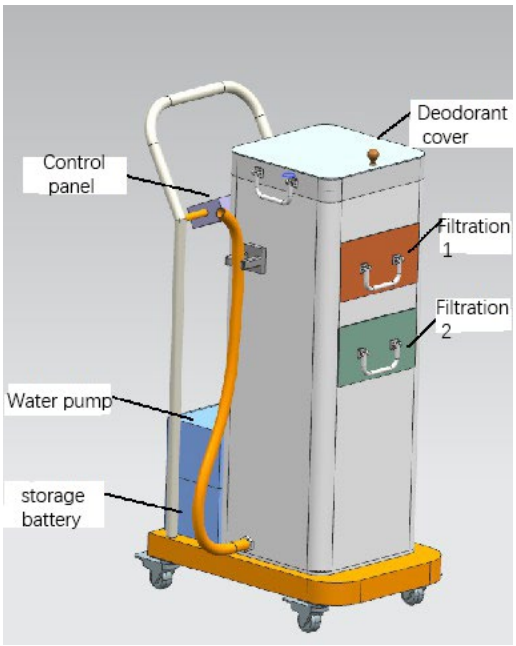

Figure 1: Virtual prototype of domestic sewage recycling device

When installing sewage treatment devices in residents' homes, the design needs to consider costs and operating costs, reflect design principles such as economy, rationality, and energy conservation, and incorporate TRIZ theory. Therefore, the sewage treatment device should achieve small footprint, low cost, low noise, etc. Control investment costs and reduce late operation costs, including power and electricity costs, labor costs, pharmaceutical costs, etc. [6]. Therefore, a sewage treatment device as shown in Figure 1 is proposed. The appearance of the device is composed of filter 1, filter 2, deodorization cover, control panel, water pump, battery, etc. The specific composition is as follows.

(1) The domestic sewage recycling device comprises a first base, wherein the top front end of the first base is fixedly installed with a sewage treatment box, and the top rear end of the first base is provided with a battery. The top of the battery is provided with a first water pump, the left and right sides of the

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rear end of the top of the first base are symmetrically and fixedly connected to the support cylinder, the upper inner cavities of the two support cylinders are symmetrically inserted with adjustment rods, the top of the two adjustment rods are fixedly connected to handrails, and the inner side of the handrails is provided with a PLC control panel; (2) The upper inner cavity of the sewage treatment box can be slidably inserted with a first filter tank, and the middle inner cavity of the sewage treatment box can be slidably inserted with a second filter tank. The outer sides of the first filter tank and the second filter tank are both provided with a first handle, the top inner cavity of the sewage treatment tank is inserted with a conical tank, the top of the conical tank is detachably connected with an odor prevention cover, the left and right sides of the conical tank are symmetrically provided with a second handle, and the bottom of the inner cavity of the conical tank is provided with a mesh plate; (3) A liquid level pipe is arranged on the right side of the sewage treatment box, and a second water pump is arranged at the bottom of the inner cavity of the sewage treatment box. The discharge end of the second water pump is connected to an outlet pipe, the discharge end of the first water pump is connected to an inlet pipe, and the inlet end of the first water pump is provided with a pipe interface; (4) The upper end of the left side of the sewage treatment tank is fixedly connected with a fixed seat, the front and rear ends of the left side of the fixed seat are symmetrically connected with a rod body, the opposite sides of the two rod bodies are symmetrically provided with elastic pieces at four corners, and the opposite ends of the two groups of elastic pieces are symmetrically connected with clamping pieces; (5) The side wall of the adjusting rod body is uniformly provided with fixing holes, the upper end and outer side of the supporting cylinder body are movably connected with an elastic piece, the outer upper end of the elastic piece is fixedly connected with a pull block, and the upper end of the elastic piece facing the supporting cylinder body is fixedly connected with a insertion column; (6) The bottom of the first base is fixedly connected with a buffer seat, a second base is provided directly below the first base, a universal wheel is fixedly installed at the four corners of the bottom of the second base, a buffer slot is provided at the top of the second base, and a damping spring is fixedly installed at the four corners of the bottom of the buffer seat; (7) An activated carbon plate and a PP filter plate are arranged at the bottom of the inner cavity of the first and second filter tanks, and the activated carbon plate is located below the PP filter plate; (8) The upper end of the liquid level pipe is connected to the upper end of the sewage treatment box, the lower end of the liquid level pipe is connected to the lower end of the sewage treatment box, and the liquid level pipe is connected to the inner cavity of the sewage treatment box. The end of the water outlet pipe that is far from the second water pump extends to the left exterior of the sewage treatment box, the end of the water inlet pipe that is far from the first water pump is connected to the upper side wall of the sewage treatment box, and the water inlet pipe is connected to the inner cavity of the sewage treatment box; (9) The number of fixing holes on the side of the adjusting rod body is at least thirty, the end of the insertion column that is far away from the elastic sheet extends to the inner cavity of the first filter tank body and is inserted into the inner cavity of one of the fixing holes, and the insertion column is slidably connected to the inner wall of the fixing hole; (10) The lower end of the buffer seat is located in the inner cavity of the buffer tank, and the lower side wall of the buffer seat is fitted and slidably connected to the upper side wall of the inner cavity of the buffer tank. The bottom of the four damping springs are fixedly connected to the bottom four corners of the inner cavity of the buffer tank [7].

The total phosphorus content in the effluent should be less than 0.5 mg/L, and the removal rate should reach 90%. Chemical phosphorus removal steps should be added to the sewage; SS effluent must be less than 10 mg/L, and secondary treatment is difficult to meet the indicator requirements [8]. In order to carry out advanced treatment, additional filtering units need to be added; In order to meet the total residual chlorine index and total coliform bacteria indicators in the effluent standards, advanced treatment processes need to add disinfection procedures. Therefore, the advanced treatment process is selected as precipitation+filtration+disinfection, in which polyacrylamide (PAM) and polyaluminum chloride (PAC) can be added as flocculants and coagulants.

5. Process flow

The top of the movable base of the sewage treatment device is fixedly installed with a water pump at one end away from the sewage treatment tank, and a pipe is connected between the water pump and the sewage treatment tank. The end of the water pump away from the pipe is connected with a hose. A controller is fixedly installed on the upper side of the sewage treatment tank. A clean water tank is movably inserted at the lower end of the sewage treatment tank, and a cylinder is provided at the upper end of the inner cavity of the sewage treatment tank. The domestic sewage recycling device can achieve efficient filtration of domestic sewage through the mutual cooperation of a filter frame, a water purification tank, a second activated carbon filter layer, a degreasing filter material layer, a first activated

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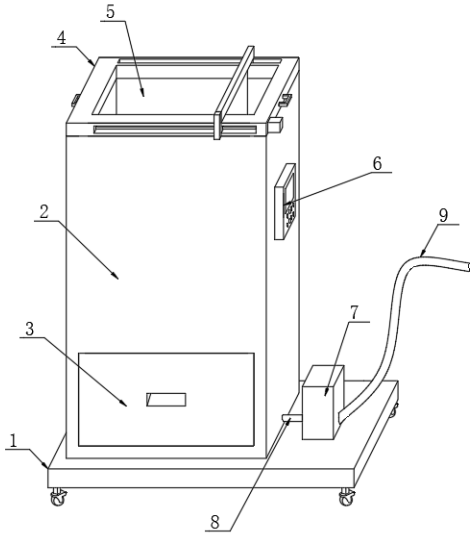
carbon filter layer, a filter screen, and a cylinder, and can be flexibly moved. When using filtered purified water, the purified water can be extracted and used through the cooperation of pumps, pipes, and hoses, increasing the convenience of the sewage treatment process. As shown in Figure 2.



(1. Mobile base; 2. Sewage treatment tank; 3. Clean water tank; 4. Placement rack; 5. Cylinder; 6. Controller; 7. Water pump; 8. Pipeline; 9. Hose)

Figure 2: Structure of sewage treatment device

The front end of the placement frame is provided with a transmission groove, the inner cavity of the transmission groove is rotationally connected with a screw rod, the side of the front end of the placement frame is fixedly installed with a motor, the external thread of the screw rod is connected with a screw block, the external side of the screw block is fixedly connected with a connection block, and the internal side of the upper end of the connection block is fixedly connected with a clamp block. The inner cavity of the placement frame and the cylinder is slidably connected with a connecting plate, the top of the connecting plate is fixedly connected with a connecting rod, the front end of the connecting rod is provided with a card slot, the bottom of the rear end of the connecting rod is fixedly connected with a guide block, the rear end of the placement frame top is provided with a guide slot, and the bottom of the connecting plate is fixedly connected with a rake tooth.

6. Operation

After a period of installation, commissioning, and trial operation of the sewage treatment plant, samples were taken from September to December 2022 to analyze the main indicators CHS, BOD5, NH3-N, and pH. The analysis results are shown in Table 2 below. As can be seen from the table, in October, the COD concentration in the effluent was the highest (54.8 mg/L), with a pollutant removal rate of 82.2%; In December, the effluent concentration of BOD5 was the highest (15.2 mg/L), with a pollutant removal rate of over 90%. In September, the NH_3-N effluent concentration was the highest (3.5 mg/L), and the pollutant removal rate could reach over 80%. After stable operation of the equipment, the removal rates of COD, BOD5, and NH3-N all exceeded 80%, and the pH value of the effluent was 7.2 to 7.6. The effluent index meets the Class I B standard specified in the "Discharge Standard for Pollutants from Urban Wastewater Treatment Plants" (GB18918-2002).

Table 2: Monitoring results of inlet and outlet water quality

Item	September		October		November		December	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
BOD5(mg/L)	138.6	14.5	157.6	14.3	143.2	13.3	161.2	15.2
COD(mg/L)	336.8	47.6	307.6	54.8	267.25	38.5	243.1	35.6
NH_3-N(mg/L)	18.2	3.5	24.6	3.2	21.6	2.3	18.6	2.6
pH	6.8	7.4	6.5	7.5	6.5	7.6	6.8	7.2

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7. Advantages of sewage treatment devices

(1) The domestic sewage recycling device can achieve efficient filtration of domestic sewage through the mutual cooperation of the filter frame, water purification tank, second activated carbon filter layer, oil removal filter material layer, first activated carbon filter layer, filter screen plate, and cylinder, and can be flexibly moved. When using filtered purified water, the purified water can be extracted and used through the cooperation of pumps, pipes, and hoses, increasing convenience.

(2) The domestic sewage recycling device and placement rack facilitate the fixation of the cylinder, the support plate and pull rod facilitate the fixation and placement of the filter frame, and the clean water tank is also convenient to pull out. Multiple structures can be disassembled for easy cleaning and maintenance.

(3) The domestic sewage recycling device is equipped with rake teeth, connecting rods, connecting plates, guide blocks, guide grooves, connecting blocks, threaded blocks, screws, and installed motors to facilitate scraping the top of the filter screen. When pouring domestic sewage, it is easy to scrape open the filter screen, remove impurities and particles deposited on the top of the filter screen, avoid blocking and affecting the downward flow of water, and automatically wipe back and forth during the pouring process to improve efficiency and convenience. The connecting plate can be removed, cleaned, and maintained together with the card slot and card block.

8. Conclusion

In summary, with the increasing attention paid to pollution control in urban and rural areas, it is becoming increasingly important to research portable domestic sewage treatment equipment suitable for local development. Research on decentralized domestic sewage treatment projects with low investment, stable operation, simple management, and low operating costs can provide a solid technical foundation for treating water pollution caused by decentralized discharge. Convenient tools, community, and hotel sewage treatment devices are a model suitable for small-scale sewage treatment, which can be applied to rural and urban areas.

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