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Anaerobic Biophysical Coupling Treatment Technology for Domestic Sewage in Northwest China

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Abstract

A rural domestic sewage treatment technology with low transportation and low energy consumption to be used in rural areas in the alpine and arid regions of northwest China is discussed. In addition, a three-stage integrated anaerobic biophysical coupling treatment technology was studied, the optimal process parameters were determined, and an operating treatment device was developed. Experimental results show that the effluent water met the Farmland Irrigation Water Quality Standard (GB 5084-2021) for greening irrigation and realizing comprehensive water resource utilization. The hydraulic retention time was 48 h, the influent temperature was greater than 10 °C, the pH was between 6 and 9, and the salt concentration was between 600 and 2700 mg/L. Under these conditions, the CODCr, SS, TP, and NH3–N removal rates of the three-stage integrated anaerobic biophysical coupling treatment technology were 69.41%, 82.61%, 14. 16%, and 12.99%, respectively. On the basis of the integrated development of the three-stage integrated anaerobic biophysical coupling treatment technology, the integrated device has a processing capacity of 0.50 m³/d and the CODCr, SS, TP, and NH3–N removal rates were 72.96%, 85.97%, 12.33%, and 12.58%, respectively. The demonstration application uses an integrated device with a processing capacity of 3.60 m³/d. The CODCr, BOD5, SS, TP, and NH3–N removal rates were 69.88%, 48.89%, 82.48%, 14.07%, and 38.34%, respectively.

Keywords

Cold and arid areas, rural domestic sewage, anaerobic biophysical coupling treatment technology, pollutant removal rate

1. Introduction

In northwest China, water is dry and cold and winter is cold. Currently, commonly used domestic sewage treatment processes include A2O [1, 2], SBR [3], MBR [4, 5], land leachate [6], and constructed wetland [7] and their combined processes [8-21]. These processes have high sewage treatment efficiency and good operation effect but have problems such as complex process route, high operating cost, high operating and maintenance demand, low resource utilization rate, and great seasonal impact. For example, in the Qinghai Province in northwest China, investigation of domestic sewage treatment revealed human sewage treatment without septic tank composting, black and ash water mixed into rural centralized treatment facilities, lack of financial support and professional and technical personnel, some rural sewage treatment technology and equipment operation difficulties, equipment damage and idle, low sewage resource utilization, and no pathogen risk awareness. As a result, its rural domestic sewage has not been effectively treated, the rate of utilization of nontraditional water sources is low, the degree of utilization of sewage and wastewater resources is not high and the means is single, and the comprehensive water-saving effect is poor, which affect the health of rural residents in the economically underdeveloped areas of northwest China.

Several studies have shown that a biological anaerobic process is a simple, efficient, and low-consumption sewage treatment process [22]. Due to drought and water shortage in northwest China, its sewage treatment must be based on resource utilization, low energy consumption, and simple operation and maintenance process. A biological anaerobic process does not need aeration in the operation process, which reduces the energy consumption and the operating cost. However, a single-stage biological anaerobic treatment technology has disadvantages such as long hydraulic retention time (HRT), large equipment volume, high operating temperature, and low efficiency of domestic sewage treatment. It is necessary to improve the process technology to further improve the rate of removing pollutants from sewage and improve the effluent quality. Due to the low temperature during winter in northwest China, microbial activities are greatly reduced and the removal effect is affected, so the method of burying below the permafrost is adopted to ensure stable operation of the improved anaerobic process during winter. It is necessary to urgently study a green sewage treatment technology with low energy consumption and low operating and maintenance costs, without pathogenic microorganisms based on the treatment and recycling of rural domestic sewage, and with the effluent water meeting the Farmland Irrigation Water Quality Standard (GB 5084-2021). Research on anaerobic biophysical coupling treatment technology to treat rural domestic sewage in the northwest alpine region provides a reference for rural domestic sewage treatment in northwest China.

2. Materials and methods

2.1 Water quality status in the study area

The water sample was from a village in the Haixi Prefecture, Qinghai Province, which is about 2,966 m in altitude and where the annual precipitation is much less than the annual evaporation. The domestic sewage of the village has the following characteristics: (1) Water is less during winter and more during summer; (2) the sewage production and discharge time is not continuous, concentrated in the morning and evening; (3) the TDS is high due to the regional environmental background value; and (4) the number of coliforms exceeds the standard. The water quality of the inlet and outgoing water in the study area is shown in Table 1. The effluent meets GB 5084-2021 and is used for greening irrigation and realizing water resource utilization.

Table 1. Water quality of the inlet and outgoing water in the study area

Index	CODCr mg/L	BOD5 mg/L	SS mg/L	TP mg/L	NH3-N mg/L	pH	FC MPN/L
rural domestic sewage Farmland irrigation	<370	< 150	<280	<4.6	<32	6.5-8.9	9.2×105
water quality standard (dry crop)	≤200	≤ 100	≤ 100	—	—	5.5-8.5	4×104

2.2 Main index analysis method

According to the water quality testing standard issued by the Ministry of Ecology and Environment of the People's Republic of China, the weight method (GB 11901- 1989), the dichromate method (HJ 828-2017), ammonium molybdate spectrophotometry (GB 11893- 1989), nanoreagent spectrophotometry (HJ 535-2009), and the dilution and inoculation method (HJ 505-2009) are used for SS, CODCr, TP, NH3–N, and BOD5, respectively.

2.3 Experimental methods, materials, and equipment

2.3.1 Experimental methods

(1) An anaerobic biophysical coupling wastewater treatment technology was designed with bioanaerobically enhanced mixing–ultraviolet (UV) sterilization coupling according to research results. The process conditions of the microdynamic biophysical coupling wastewater treatment technology were studied, and the HRT, filler, and other process parameters were determined. The effects of temperature, pH, salt concentration, and other main factors on the pollutant removal rate were explored, and the best process operation parameters and operating conditions were obtained.

(2) On the basis of the new microdynamic biophysical coupling treatment technology for rural domestic sewage with multistage biological anaerobic mixing–UV sterilization coupling, an integrated microdynamic biophysical coupling sewage treatment device was developed to optimize the equipment.

(3) Engineering demonstration of the optimized equipment was performed, and a village in the Haixi Prefecture, Qinghai Province, was selected as the demonstration site. The integrated microdynamic biophysical coupling sewage treatment device was run on the spot, and its operation effect in practical applications was explored.

2.3.2 Experimental materials

The fillers used were suspended ball (XFQ, PP + PU), comet (HXS, PP + PET), biological rope (SWS, PP), suspended (XF, PP), elastic (TX, PP), and combined (ZH, PP + PVA) fillers. The experimental materials were a 50 L plastic bucket, a constant-temperature heating bar, and a 180-r/min adjustable-speed mixing unit. The compounds used for water quality index testing were all pure for analysis.

2.3.3 Experimental equipment

The following were used in the study: a 6B-6C COD reflux digestion instrument, an LDZX-75KBS vertical autoclave cooker, an HWS- 150B constant-temperature incubator, an SHZ-D circulating water vacuum pump, a TATUNG oven, a HACH DR6000 UV–visible spectrophotometer, an A3 atomic absorption spectrophotometer, a Hitachi SU8010 biSEM, a Laika CPD300 critical point drying instrument, and other water quality index detection equipment.

3. Results and analysis

3.1 Determination of process conditions

3.1.1 Determination of filler and HRT

Due to the different porosity values, specific surface areas, and materials of different fillers, the total amount of attached microorganisms and the contact area of the microbial membrane are different, yielding different sewage treatment efficiencies. The HRT mainly affects the pollutant removal efficiency by changing the contact time between microorganisms and pollutants in water. In the experiment, the six different fillers were used to conduct domestic sewage microbial film hanging. The filler materials are shown in Figure 1.

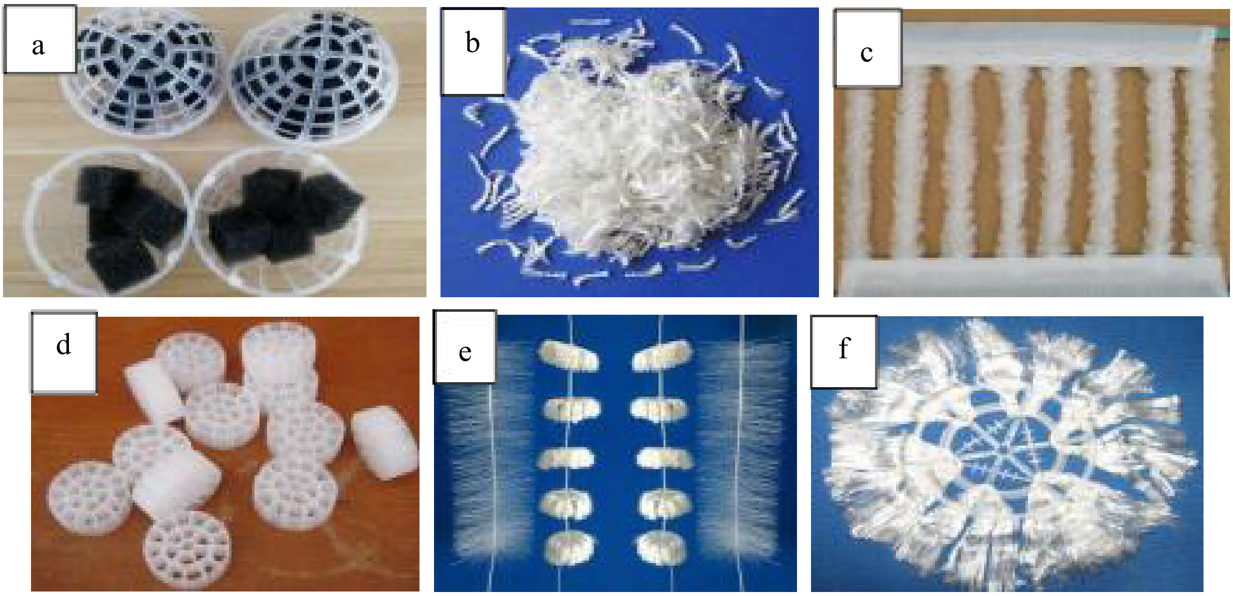

Figure 1. Images of the different fillers.

Figures 1(a)–(f) show the XFQ, HXS, SWS, XF, TX, and ZH fillers, respectively.

Each filler was hung for two weeks, and the experimental results are shown in Figure 2.

Figure 2 shows the degree of microbial enrichment in the fillers. In the microbial SEM images, there are significant differences in the attachment of microorganisms on the different fillers. The surface of the XFQ filler has the highest degree of microbial enrichment and the largest number of microorganisms. The XFQ packing is most suitable for microbial growth and film hanging and biological anaerobic process packing.

The pollutant removal efficiencies of the different fillers under different HRTs were determined and compared with that without a filler to determine the optimal combination of filler and HRT. The experimental results are shown in Figure 3.

In Figure 3(a), the CODCr removal rate reaches the maximum value of 41.96% when the HRT reaches 84 h without a filler and reaches the maximum value when the HRT reaches 48 h after adding the XFQ filler. The CODCr removal rate reached the maximum value of 56.49% when the HRT reached 60 h after adding the HXS filler. Thus, the HRT was 48 h and the XFQ packing was used as the optimal process parameter for CODCr removal. In Figure 3(b), without a filler, the SS removal rate reaches the maximum value of 64.70% when the HRT reaches 48 h. After adding the XFQ filler, the SS removal rate reached the maximum value when the HRT reached 48 h. The SS removal rate reached the maximum value of 73.36% when the HRT reached 48 h after adding the ZH filler. Thus, the HRT was 48 h and the XFQ packing was used as the best process parameter for SS removal. In Figure 3(c), the TP removal rate reaches the maximum value of 16.31% when the HRT reaches 48 h without a filler and reaches the maximum value when the HRT reaches 24 h after adding the ZH filler. The TP removal rate reached the maximum value of 15.30% when the HRT reached 24 h after adding the XF filler. Thus, the ZH filler has the most significant effect on the improvement of the TP removal rate. In Figure 3(d), the NH3–N removal rate increases with the increase in HRT when the HRT is less than 72 h. When the HRT was 72 h, the NH3–N removal rate was 21.21% without a filler, 19.95% after adding the SWS filler, and 19.18% after adding the TX filler. In Figure 3(d), the BOD5 removal rate is 38.03% without a filler and 57.65% with the XFQ filler. After adding the TX filler, the BOD5 removal rate reached the maximum value of 53.04% when the HRT reached 48 h. Thus, the XFQ filler had the most significant effect on BOD5 removal.

From the above analysis, when the XFQ packing is used and the HRT is 48 h, the CODCr, BOD5, SS, TP, and NH3–N removal efficiencies are 57.28%, 57.65%, 74.06%, 12.68%, and 14.58%, respectively. The removal effect of CODCr, BOD5, and SS is good, but the removal effect of TP and NH3–N is not good. This is because the organic pollutant removal efficiency by anaerobic microorganisms is obvious, the enrichment of microorganisms on the surface of the added XFQ filler is significantly higher than those of the other fillers, the total amount of microorganisms is high, the distribution of microorganisms is uniform, and the efficiency of removing CODCr and BOD5 from sewage is high. The removal of SS is through packing retention and natural sedimentation. A single-stage anaerobic process packing has a limited retention effect and mainly relies on the natural sedimentation of suspended solids to remove SS. The SS removal efficiency is different. The removal of TP and NH3–N requires both anaerobic and aerobic microorganisms. In the aerobic state, aerobic nitrifying bacteria convert ammonia nitrogen into nitrite nitrogen and nitrate nitrogen through nitrification reaction; on the contrary, in the anaerobic state, anaerobic denitrifying bacteria convert nitrite nitrogen and nitrate nitrogen into ammonia nitrogen through denitrification reaction. It is reduced to gaseous nitrogen to achieve the removal of ammonia nitrogen. After releasing phosphorus in the anaerobic stage, the phosphorus-accumulating bacteria can absorb phosphorus beyond their physiological needs in the aerobic stage and store it in their bodies as polymerized phosphorus to form phosphorus-accumulating sludge; finally, phosphorus passes through the sludge. Discharge achieves the purpose of removing phosphorus from sewage. A single-stage anaerobic process can only meet some of the conditions for nitrogen and phosphorus removal. The conversion of ammonia nitrogen into nitrite nitrogen and nitrate nitrogen is low and the phosphorus accumulation effect of phosphorus-accumulating bacteria is not good, so the nitrogen and phosphorus removal efficiency is low. To improve the effect of traditional single-stage biological anaerobic treatment, the proposed improved process adopts a multistage biological anaerobic treatment technology to improve the pollutant removal efficiency.

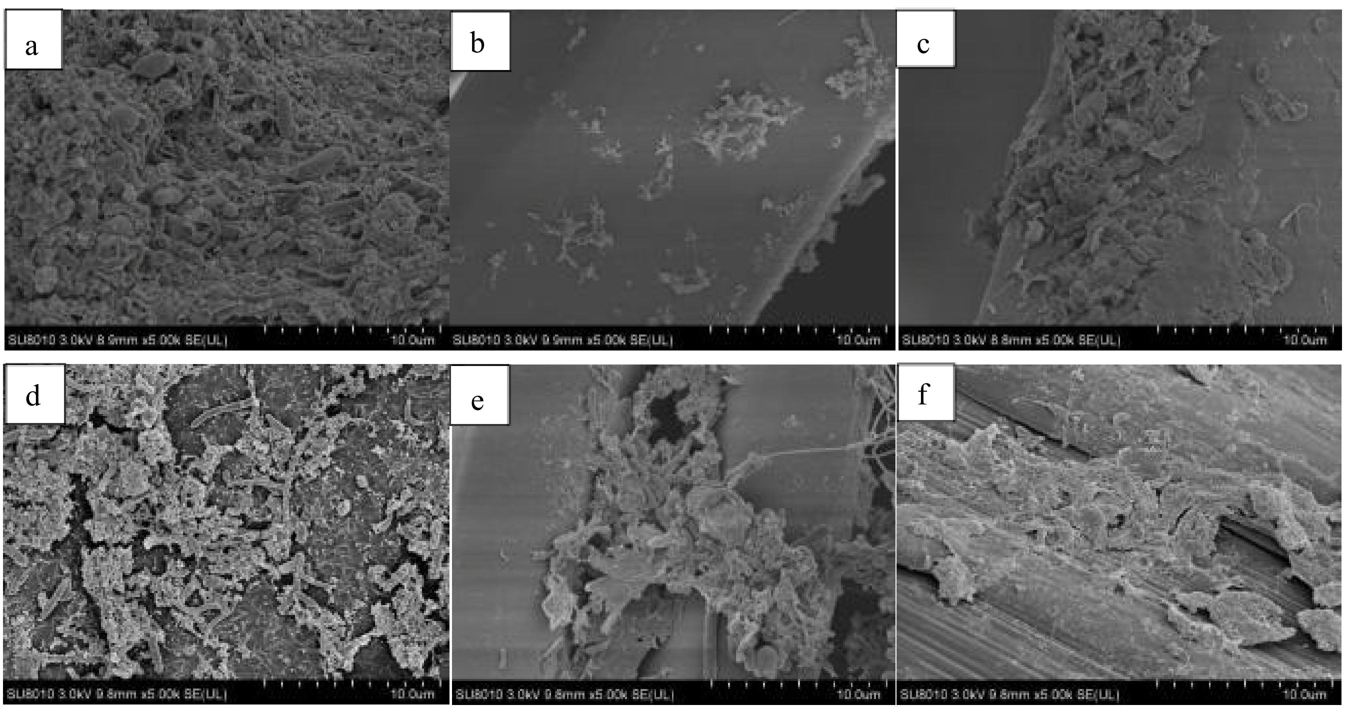

Figure 2. Microbial SEM map of the microbial enrichment in the different fillers.

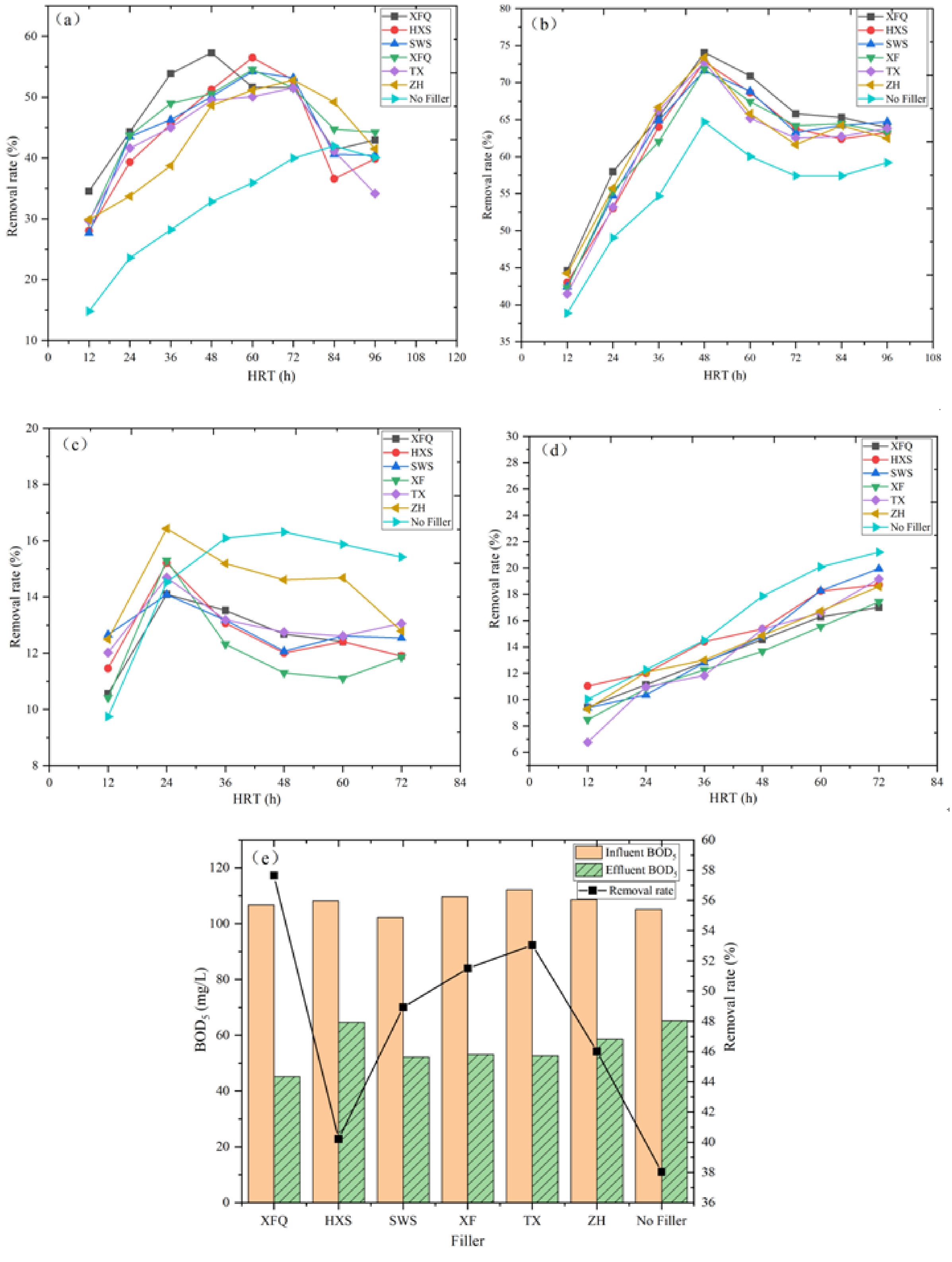

Figure 3. CODCr, BOD5, SS, TP, and NH3–N removal efficiencies with different fillers and HRTs.

3.1.2 Effect of temperature on pollutant removal efficiency

Temperature mainly affects the pollutant removal efficiency by affecting the microbial activity. After the biological anaerobic process microbial film was stable, the effect of different temperatures on the pollutant removal efficiency was tested. The initial test temperatures were 10 ℃, 20 ℃, 30 ℃, 40 ℃, 50 ℃, and 60 ℃. After determining the optimal temperature range, the temperature range was narrowed and the experimental temperature was determined according to the results. The results are shown in Figure 4.

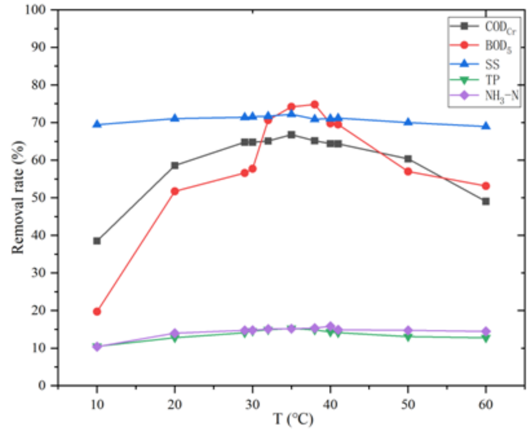

Figure 4. Effect of temperature on the CODCr, BOD5, SS, TP, and NH3–N removal efficiencies.

In Figure 4, the CODCr removal rate is the highest (66.79%) at 35 ℃ and the lowest (38.50%) at 10 ℃. The BOD5 removal rate was the highest (74.82%) at 38℃ and the lowest (19.72%) at 10℃. The SS removal rate was the highest (72.20%) at 35 ℃ and the lowest (68.96%) at 60 ℃. The TP removal rate was the highest (15.24%) at ℃ and the lowest (10.47%) at 10 ℃. The NH3–N removal rate was the highest (15.83%) at 40 ℃ and the lowest (10.38%) at 10 ℃. When compared with the experimental results in section 3. 1. 1, under anaerobic conditions, temperature has a great influence on the CODCr and BOD5 removal rates and has a little effect on the SS, TP, and NH3–N removal rates. The optimal temperature of the anaerobic process was 35℃, and the CODCr, BOD5, SS, TP, and NH3–N removal efficiencies were 66.79%, 74.20%, 72.20%, 15.17%, and 15.24%, respectively. The results show that anaerobic microorganisms are significantly affected by temperature and a suitable temperature will increase the metabolic rate of microorganisms, thereby improving the pollutant removal rate. In the case of biological anaerobic treatment projects which need to be well insulated, the release of heat of anaerobic reaction is used to ensure the efficiency of treating domestic sewage.

3.1.3 Effect of pH on pollutant removal efficiency

pH mainly affects the pollutant removal efficiency by affecting the microbial activity. After the stable operation of the microbial film in the biological anaerobic process, the effect of pH (4.00– 10.00) on the pollutant removal efficiency was tested. The pH in the test was 3.90, 4.67, 5.85, 7.15, 8.35, 9.15, and 10.09. The results are shown in Figure 5.

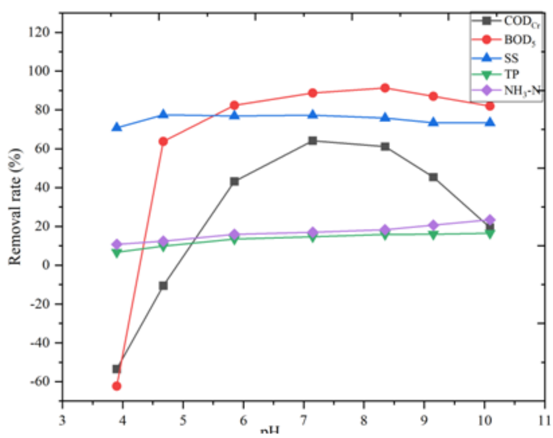

Figure 5. Different pH pairs for the CODCr, SS, BOD5, TP, and NH3–N removal efficiencies.

In Figure 5, the CODCr removal rate is the highest (64. 15%) when pH = 7.15 and the lowest (−53.47%) when pH = 3.90. The BOD5 removal rate was the highest (64.15%) when pH = 8.35 and the lowest (−62.32%) when pH = 3.90. The SS removal rate was the highest (77.50%) when pH = 4.67 and the lowest (70.83%) when pH = 3.90. The TP removal rate was the highest (16.50%) when pH = 10.09 and the lowest (6.70%) when pH = 3.90. The NH3–N removal rate was the highest (23.46%) when pH = 10.09 and the lowest (10.76%) when pH = 3.90. When pH = 3.90, the CODCr and BOD5 removal rates showed negative values, indicating that a large number of microorganisms died, resulting in the increase in CODCr and BOD5 values. The results show that if the anaerobic process works normally and achieves good treatment effect, the pH of the influent must be adjusted between 6 and 9, and to achieve the best removal efficiency, the pH must be adjusted between 7 and 8. The main reason is that pH will seriously affect the microbial activity. When the pH is too low, the microbial activity in the anaerobic process will be greatly inhibited and even cause mass death of microorganisms, yielding low efficiency in removing various pollutants. In the actual application of domestic sewage, it must be monitored in time and the pH value that is too low or too high must be adjusted in time to ensure normal operation of the process.

3.1.4 Effect of salt concentration on pollutant removal efficiency

The environmental background value of the water salt concentration in the study area is relatively high, about 1800 mg/L. After the biological anaerobic process microbial film formation is stable, the effect of different TDS concentrations (600, 900, 1200, 1500, 1800, 2100, 2400, and 2700 mg/L) on the pollutant removal efficiency was tested. The results are shown in Figure 6.

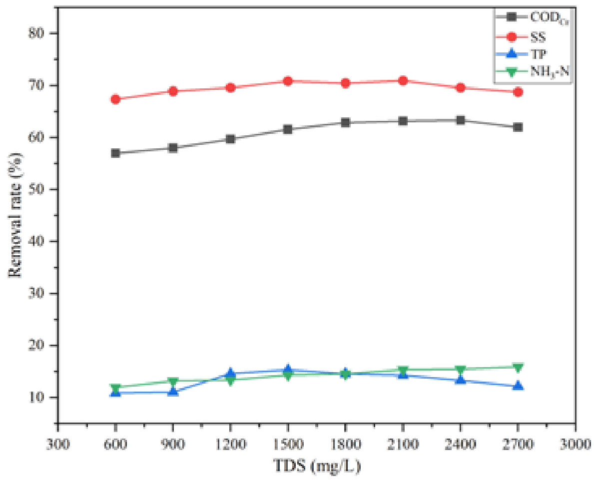

Figure 6. CODCr, SS, TP, and NH3–N removal efficiencies for different TDS concentrations.

In Figure 6, the CODCr removal efficiency is the highest (63.32%) when TDS = 2400 mg/L and the lowest (56.96%) when TDS = 600 mg/L. The SS removal efficiency was the highest (70.91%) when TDS = 2100 mg/L and the lowest (67.35%) when TDS = 600 mg/L. The TP removal efficiency was the highest (14.52%) when TDS = 1500 mg/L and the lowest (10.30%) when TDS = 600 mg/L. The NH3–N removal efficiency was the highest (15.87%) when TDS = 2700 mg/L and the lowest (11.93%) when TDS = 600 mg/L. The experimental results show that when the TDS concentration is between 600 and 2700 mg/L, the pollutant removal rate mainly increases first and then decreases but the effect is not obvious, indicating that the microbial activity is less affected in this salinity range. The anaerobic process can operate normally. The reason is that microorganisms can tolerate a wide range of salt concentrations. This salinity range belongs to the tolerance range of microorganisms and has a little effect on the activity of microorganisms.

3.2 Three-stage integrated anaerobic biophysical coupling treatment technology and device

3.2.1 Three-stage integrated anaerobic biophysical coupling treatment technology

It is concluded in section 3. 1. 1 that the single-stage anaerobic process has low CODCr and SS removal efficiencies. To improve the pollutant removal rate and the effluent to meet the requirements of greening irrigation, a three-stage integrated anaerobic biophysical coupling treatment technology was adopted. The first stage of the technology is the anaerobic stage with suspended ball fillers inside and the dissolved oxygen in the water being about 0.4 mg/L. The second stage is the anaerobic stage with suspended ball fillers inside and the dissolved oxygen in the water being about 0.05 mg/L. The third section is the facultative oxygen section where there is no filler and a UV sterilization device and a stirring device were installed. A UV lamp was used to kill the pathogenic bacteria, and stirring increased the dissolved oxygen concentration in the water and improved the effect of disinfecting the pathogenic bacteria. The dissolved oxygen was about 0.8 mg/L. The CODCr, SS, TP, and NH3–N removal efficiencies of the three-stage integrated anaerobic biophysical coupling treatment technology are shown in Figure 7.

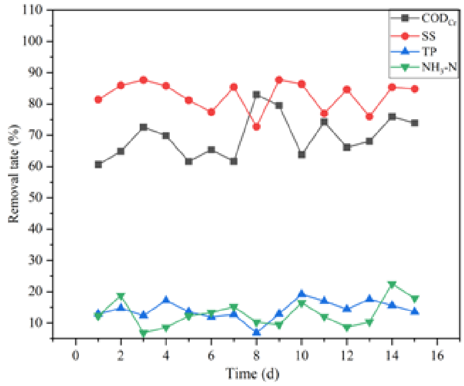

Figure 7. Three-stage integrated anaerobic biophysical coupling treatment technology: CODCr, SS, TP, and NH3-N removal efficiencies.

In Figure 7, the highest, lowest, and average CODCr removal rates of this process are 82.95%, 60.61%, and 69.41%, respectively. The highest, lowest, and average SS removal rates were 87.68%, 72.73%, and 82.61%, respectively. The highest, lowest, and average TP removal rates were 19.17%, 6.83%, and 14.16%, respectively. The highest, lowest, and average NH3–N removal rates were 22.50%, 6.86%, and 12.99%, respectively. When compared with the experimental results in section 3. 1. 1, the three-stage integrated anaerobic biophysical coupling treatment technology has a better improvement in the CODCr and SS removal rates than the single-stage anaerobic process, and the removal rate is increased by 12. 13% and 8.55%, respectively, which are in line with experimental expectations. The three-stage integrated anaerobic biophysical coupling treatment technology adopts the way of inlet and outlet, which improves the contact efficiency of the sewage and fillers, and makes full use of the retention effect of fillers and biofilms, thereby improving the CODCr and SS removal efficiencies. Through stirring, the microorganisms and sewage were fully mixed, and the aerobic microorganisms can participate in the sewage treatment by stirring and micro-aeration, so that the CODCr removal rate is further improved.

3.2.2 Three-stage integrated anaerobic biophysical coupling sewage treatment device

According to the above test results, a three-stage integrated anaerobic biophysical coupling sewage treatment device (hereinafter referred to as the integrated device) was designed. The integrated device was mainly composed of a three-format tank, an XFQ filler, a stirring device, a UV sterilization device, and a solar energy device. The schematic diagram of the device and the physical map are shown in Figure 8. When building the physical object, the corners were rounded. The designed daily processing capacity of the integrated device was 500 L. The sewage enters the integrated device after the flow is adjusted by the regulating tank and the flow meter. When flowing through the packing, the suspended solids are retained and filtered by the packing and the organic matter is filtered by the water and the odor attached to the packing. Oxygen and the microorganisms are converted into small molecular organic matter and finally converted into methane and carbon dioxide to achieve the purpose of sewage treatment.

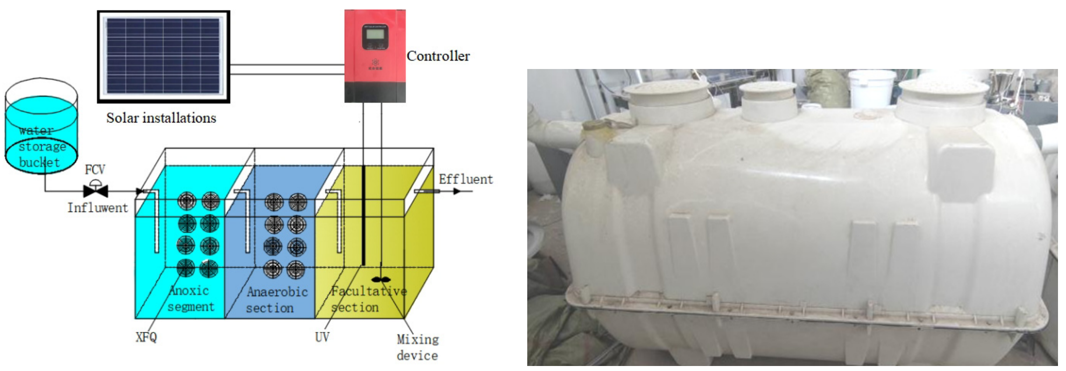

Figure 8. Schematic and physical diagrams of the three-stage integrated anaerobic biophysical coupling sewage treatment device.

3.2.3 Integrated device operation

The XFQ packing was placed in the integrated device, the HRT was 48 h, the inlet water temperature was adjusted not lower than 10 ℃, the pH was between 6 and 9, and the TDS was between 600 and 2700 mg/L. The irradiation time of the third grid of the UV lamp was 8 h and the rotating speed of the stirring device was 30 r/min. The treatment effect of the integrated device is shown in Figure 9.

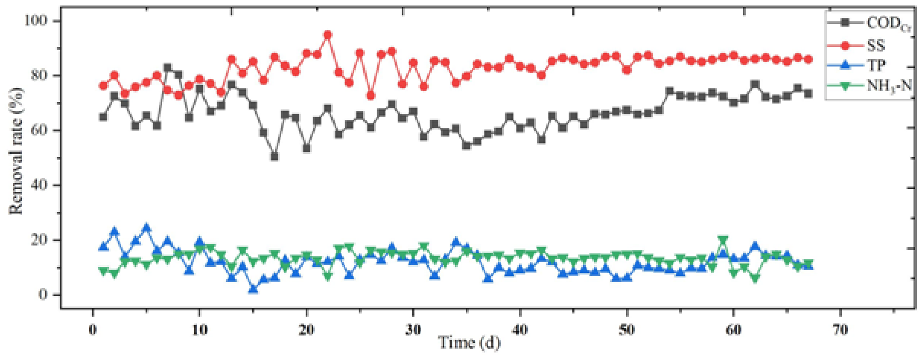

Figure 9. CODCr, SS, TP, and NH3–N removal efficiencies of the integrated device.

In Figure 9, various pollutants are removed after the device was continuously operated for 67 days after film hanging; the device fluctuates greatly in the early stage of the operation and is relatively stable in the later stage. The total average CODCr, SS, TP, and NH3–N removal rates were 66.67%, 82.93%, 11.75%, and 13.59%, respectively. The average removal rates in the past 15 days were 72.96%, 85.97%, 12.33%, and 12.58%, respectively. The integrated device removal effect is improved.

The test results show that the integrated device runs smoothly, which is close to the experimental results of the three-stage integrated anaerobic biophysical coupling treatment technology and meets the experimental expectations. The integrated device has a good removal effect on CODCr and SS and the effluent pollutant concentration is low. The TP and NH3–N removal rates were about 12%. The effluent contained a large amount of nitrogen and phosphorus elements. For irrigation water, the use of chemical fertilizers can be reduced and the resource utilization rate is high. It is suitable for the treatment and reuse of rural domestic sewage in the northwest region. According to the experimental results, all effluents met the requirements of GB 5084-2021. Moreover, to ensure the pollutant removal efficiency, the concentration of pollutants in the influent water of the device is higher than that of ordinary rural domestic sewage, which basically meets the treatment and reuse of rural domestic sewage in the northwest region, and has a wider application range.

3.3 Project demonstration

3.3.1 Project demonstration scale

According to the survey, the project demonstration was selected in a village in the Haixi Prefecture. The project demonstration service area was 4,000 m^2, covering 20 households. The daily sewage treatment was calculated based on four people in each household and a per capita daily sewage production volume of 45 L:

$$W = \frac{20 \times 4 \times 45L/d}{1000L/m^3} = 3.60\,m^3/d$$

According to the calculation results, the daily sewage treatment of the project demonstration was 3.60 m^3.

3.3.2 Effect of project demonstration operation

The effect of the project demonstration operation is shown in Table 2.

Table. 2 Pollutant removal efficiency of the integrated device of the project demonstration

Index	CODCr	BOD5	SS	TP	NH3-N
Influent / (mg/L)	211.29	105.68	182.67	5.83	25.04
Effluent / (mg/L)	63.65	54.01	32.00	5.01	15.44
Removal rate / %	69.88	48.89	82.48	14.07	38.34

The operating results of the engineering demonstration unit are similar to those of the laboratory unit. The CODCr and SS removal rates have slightly decreased, whereas the TP removal rate has slightly increased and the NH3–N removal rate has significantly increased. The operating effect is slightly worse than that of the laboratory treatment. It is an integrated device with a volume of 0.5 m^3/d, but the quality of the effluent basically meets the design requirements and GB 5084-2021, which can be used for greening irrigation.

4. Conclusion

(1) A three-stage integrated anaerobic biophysical coupling treatment technology was developed for rural domestic sewage in the northwest region, and the process operating conditions were determined: A suspended ball packing was used, the HRT was 48 h, the influent temperature was greater than 10 °C, the pH was between 6 and 9, and the TDS was 600–2700 mg/L. Under these conditions, the average CODCr, SS, TP, and NH3–N removal rates of the three-stage integrated anaerobic biophysical coupling treatment technology were 69.41%, 82.61%, 14.16%, and 12.99%, respectively. On the basis of this technology, the laboratory has developed a three-stage integrated anaerobic biophysical coupling sewage treatment device. The treatment capacity of the device was 0.5 m^3/day, and the average CODCr, SS, TP, and NH3–N removal rates were 72.96%, 85.97%, 12.33%, and 12.58%, respectively. The removal efficiency was high and the effluent of the device met GB 5084-2021.

(2) The project demonstration field operation of the three-stage integrated anaerobic biophysical coupling sewage treatment device was conducted. The demonstration device can treat 3.60 m^3 of sewage per day and can treat and reuse 1314 m^3 of domestic sewage every year. The project demonstration can cover 20 households with water and the demonstration area exceeded 4000 m2. The CODCr, BOD5, SS, TP, and NH3–N removal rates were 69.88%, 48.89%, 82.48%, 14.07%, and 38.34%, respectively. The treatment effect is good, the operating cost is low, the operation is simple, no professional operation and maintenance are required, and the effluent meets GB 5084-2021, which can be used for greening irrigation, and is suitable for use in rural areas for domestic sewage recycling.

In general, the device has a simple process, convenient management, and a small footprint, which can effectively solve the problems of untreated domestic sewage and low resource utilization rate in rural areas in the northwest region. This study provides reference and demonstration for the construction of treatment facilities.

Fund project

Research and Integrated Demonstration of Highland Arid Agriculture and Animal Husbandry Area Sewage Wastewater and Domestic Waste Treatment Technology 2022-SF-137.

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