Practical application of domestic sewage in a new compound biological filter

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Abstract. The application of a new composite biofilter with a batch-type mud membrane composite biofilter (CSBF) series deep treatment filter (EBF) combination in urban domestic sewage was studied. The results of 20-day operation data show that the new filter process has good removal effect on COD, NH₃-N, TN and TP. The average removal rate of COD during operation is 94.63%, the average removal rate of NH₃-N is 99.02%, and the average removal rate of TN is 77.89%. The average removal rate of TP is 97.99%, and each index is stable to the first-class A standard of GB8978-1996, in which COD, NH₃-N and TP can reach the surface water class IV standard.

1. Introduction
According to the National Bureau of Statistics, the daily sewage treatment capacity of the city as of 2017 is 1.7 × 10⁸ m³ [1]. At present, domestic wastewater treatment plants have adopted traditional activated sludge and biofilter processes such as A/O, A/A/O, SBR, CASS and oxidation ditch. The traditional process started early and the operation effect was widely recognized. As the country's requirements for water environment management become more stringent, the requirements for the effluent quality of sewage treatment plants are raised, and the traditional processes face greater pressure to upgrade. Membrane bioreactor (MBR) process is a popular technique used by domestic sewage treatment plants to improve the quality of effluent. MBR replaces the secondary settling tank with ultrafiltration membrane tank. The sludge concentration in the system is high, the hydraulic retention time is short, and the volumetric loading rate of nitrogen and phosphorus removal is high, especially for SS removal. The MBR process can greatly improve the effluent quality of traditional processes, but MBR has large head loss, high operating energy consumption, and high operating cost of ultrafiltration membrane. Developed a new sewage treatment process for the domestic sewage treatment status. The new process is a new composite biofilter made up of serial batch mud membrane composite biofilter CSBF and deep treatment filter EBF. The difference between CSBF and traditional biofilter is that it adopts the mud membrane composite form. The activated sludge and biofilm coexist in the process system. The floating filter bed filtration function is used to maintain the high concentration of double mud in the biological group. The CASS process is used to adopt the batch batch batch. Operation, combining the advantages of CASS, MBBR and MBR processes. BEF is a deep denitrification and dephosphorization filter column combined with a ceramic filter bed and a sand filter bed. This experiment studied the treatment effect of the new composite filter process on urban sewage.
2. Experimental part

2.1. Experimental equipment and process flow

Integrated sequencing batch mud membrane composite biofilter CSBF and deep treatment filter EBF series new composite biofilter process.

The CSBF unit is a cylindrical tank with a body size of D×H =2600mm×6300mm and covers an area of 5.3 m². There are two stages in the equipment. The first stage is the No.1 downflow anoxic tank. The influent water flows down from the top of the pool. The tank does not aerate to maintain an oxygen-deficient environment. The second stage is the No. II upflow aeration tank, which is filled with water. The aeration system is installed in the tank and is opened in the aeration stage. At the same time, the tank is filled with 2 m ceramsite filter material for biofilming to form a mud film composite environment. In the upper part of the ceramsite layer, a water outlet ring tube is arranged for the equipment to return the nitrifying liquid and the system to effluent. The bottom of the equipment is equipped with a sludge return pump, and the sludge is returned to the No. I downflow anoxic tank. The EBF is a cylindrical device with D=400 mm. The equipment is filled with ceramsite filter material and sand filter. The ceramsite filter material has deep nitrogen and phosphorus removal effect, and also filters pretreatment to reduce the filtration pressure of the sand filter layer.

The experimental equipment operation process is shown in Figure 1.

![Process flow diagram](image)

Figure 1. Process flow diagram

The CSBF adopts a four-stage sequencing batch operation in the aeration stage, the stationary stage, the annular tube return stage and the influent water discharge stage, and the aeration stage II tank aeration, while the top nitrification liquid is stripped back to the No. 1 pool to promote the I number. The sewage from the pool enters the No. II pool, the sewage circulates in the equipment, and is in full contact with the biofilm of the filler, which takes advantage of the biofilm to remove pollutants; the aeration is stopped during the stationary phase, the sludge in the system is freely settled, and the muddy water is separated; Filtering and mixing the activated sludge mixture in the ceramsite to improve the effluent quality in the effluent stage; opening the influent in the influent effluent stage, discharging the effluent through the inlet sump equipment, and simultaneously opening the sludge return, returning the bottom sludge strain and Influent contact achieves denitrification and denitrification. After the CSBF effluent to the relay water storage tank, it is driven into the EBF equipment by the lift pump to deeply remove SS, TN, and TP.
2.2. Influent water quality
The experiment was carried out in a sewage treatment plant in Guangzhou. The experiment used the same source sewage from the sewage plant. The influent water quality and related effluent water quality index during the experiment period are shown in Table 1.

Table 1. Water quality index during the pilot test and emission standards

| Water quality          | COD/(mg.L⁻¹) | ρ(Ammonia nitrogen)/(mg.L⁻¹) | ρ(Total nitrogen)/(mg.L⁻¹) | ρ(Total phosphorus)/(mg.L⁻¹) |
|------------------------|--------------|------------------------------|---------------------------|-----------------------------|
| Influent water quality | 195-323      | 13.5-27.4                    | 16.1-34.2                 | 3.0-3.8                     |
| Level 1 A standard     | ≤50          | ≤5                           | ≤15                       | ≤0.5                        |
| Surface water class IV | ≤30          | ≤5                           | ≤1.5                      | ≤0.5                        |
| standard               |              |                              |                           |                             |

2.3. Experimental methods
When the equipment starts, about 1/3 of the equipment volume of activated sludge is introduced, and the influent flow rate is 20 m³.

The flow/d is gradually increased to 50 m³/d. When the effluent COD removal rate is 65%, the ammonia nitrogen removal rate is 65%, and the TN and TP removal rate is 20%, which is considered to be completed [2]. After the completion of the membrane, the 1 h cycle sequencing batch operation was carried out, in which the aeration phase was 25 min, the sedimentation phase was 10 min, the gas stripping was refluxed for 5 min, the influent water was discharged for 20 min, and the influent flow rate was maintained at 6.6 m³/h. 5:1, HRT 10.2 h, take 20 days of running data analysis, the water quality indicators need to be tested during the experiment. COD: dichromate method, HJ 828-2017; NH₃-N: Nessler reagent spectrophotometry, HJ 535-2009; TN: alkaline potassium persulfate digestion UV spectrophotometry, HJ 636-2012; TP: molybdenum Ammonium ammonium spectrophotometry, GB/T 11893-1989.

3. Results and discussion

3.1. New composite filter to remove COD
During the experiment, the influent COD fluctuated at 195-323 mg/L, the average influent was 266 mg/L, the effluent COD was 23.0 mg/L, and the minimum was 8.0 mg/L. The average effluent amount is 13.9 mg/L, and the average removal rate of COD is 94.63%. The effluent COD stability is superior to the first-class A standard of the comprehensive wastewater discharge standard GB 8978-1996, which can reach the surface water class IV standard.

The traditional biofilm method has high biofilm density and strong impact load resistance, but the removal rate of organic matter is generally 70% to 90%, and the removal rate of COD by activated sludge method can reach 90% to 98% [3]. The CSBF system is a mud-film composite environment with both high-density biofilm and activated sludge, which combines the advantages of both. Therefore, the CSBF system can cope with fluctuations in water quality and also have a high COD removal rate. The rise of COD in the effluent occurred in the early stage of operation. The reason for the analysis was that the equipment had just completed the membrane, and the influent treatment had not yet reached a completely stable state, so the initial stage of operation would be affected by the fluctuation of water quality to some extent. After the system is running stably, the new composite filter has a stable COD removal effect, and the effluent COD is maintained below 16 mg/L, which is less affected by fluctuations in the influent water quality, which proves that the process has strong impact load resistance and good performance. COD removal effect.
3.2. New composite filter to remove NH3-N

The effect of the new composite biofilter on NH3-N is shown in Figure 4. During the experiment, the concentration of NH3-N influent water fluctuated from 13.5 to 27.4 mg/L, and the average influent NH3-N concentration was 20.94 mg/L. During the rainy days, the influent NH3-N concentration decreased correspondingly. Influent NH3 The -N concentration is more affected by the climate. The effluent NH3-N has a maximum concentration of 0.55 mg/L, a minimum of 0.04 mg/L, and an average effluent concentration of 0.2 mg/L, which is far superior to the Class A standard of GB 8978-1996 and can reach the Class IV standard for surface water. The NH3-N removal rate of the equipment can reach 99.02% on average. In an aerobic environment, the nitrifying bacteria in the sewage oxidize NH3-N to nitrite and nitrate to remove NH3-N in water. Nitrification autotrophic bacteria have a long generation time and are more demanding on substrate, dissolved oxygen and pH conditions. Relatively high concentrations of organic matter in sewage, heterotrophic bacteria are prone to growth disadvantage [4]. The biological filter filled by the device provides an attachment point for microbial growth, and the microorganism grows on the surface of the filter to form a biofilm richer biofilm, which contains nitrifying bacteria with a long generation cycle [5]. Therefore, compared with the activated sludge method, the nitrifying bacteria in the biofilm method can exert nitrification and remove the NH3-N effect.

More stable and reliable. The new composite filter combines activated sludge and biofilm to provide excellent treatment of NH3-N.

Under the condition of gas to water ratio of 5:1, the NH3-N of the equipment effluent is maintained below 0.55 mg/L. The removal effect of NH3-N is less affected by the concentration of NH3-N in the influent, and the treatment effect is excellent, stable and reliable. The effluent NH3-N is 0.55 mg/L at the beginning of the operation. The reason for the analysis is that the equipment has just completed the membrane at this time, and the system operation has not yet reached complete stability. Therefore, the effluent NH3-N is slightly higher than the overall effluent level. The effluent NH3-N is maintained below 0.3 mg/L.

3.3. New composite filter to remove TN

The effect of the new composite biofilter on TN treatment is shown in Figure 5. During the experiment, the influent TN mass concentration fluctuated from 16.1 to 34.2 mg/L, and the influent TN mass concentration also decreased in rainy days, which was significantly affected by the climate. The effluent TN average mass concentration is 5.34 mg/L, the highest is 9.3 mg/L, the lowest is 3.0 mg/L, and the average removal rate is 77.89%, which can be stabilized to the Grade A standard of GB 8978-1996.

There was an increase in the fluctuation of TN in the early stage of operation, which was due to the fact that the system had not completed the complete stable operation phase. The effluent TN is maintained at 3.0-6.9 mg/L. This is because the system is basically stable at this stage. In addition, when this stage encounters rainy days, the influent TN concentration decreases and the pollution load decreases, resulting in a lower effluent TN mass concentration. At the end of the experiment, the effluent TN has a tendency to increase with the increase of the influent mass concentration, indicating that the fluctuation of the influent TN concentration will affect the removal effect of the new composite filter on TN. The removal of TN from wastewater is carried out by using denitrifying bacteria under anoxic conditions, using carbon sources in the water to complete the denitrification reaction with NOx---N as an electron acceptor, and converting NOx--N into N2 into the atmosphere. There are two new types of composite filters in the environment where denitrification can be achieved. One is the biofilm on the surface of the filler. Affected by mass transfer resistance, the biofilm will gradually form an aerobic, anaerobic and anoxic anaerobic environment from the outside and inside. Denitrification can occur in the biofilm inner denitrifying bacteria to convert NOx--N into N2 [6]. The second is the No. I downflow anoxic tank, which is not aerated in the pool and provides an oxygen-deficient environment for denitrifying bacteria. The equipment starts the sludge return at the same time as the influent water outlet stage, and the refluxed denitrifying bacteria are in full contact with the influent carbon source, and the influent carbon source can be utilized to the maximum extent to remove the TN. The new composite
filter effluent TN has been stable to the first-class A standard, but there is still room for optimization. The optimization method is to change the nitrification liquid reflux mode from the gas stripping reflux to the sludge pump reflux. The reason is that the gas stripping reflux saves the running cost, but the DO value of the reflux water is increased, which may damage the oxygen-deficient environment at the top of the I-cell. The denitrification reaction proceeds.

3.4. New composite filter to remove TP
The effect of the new composite biofilter on TP treatment is shown in Figure 6. The influent TP mass concentration during the experiment was between 3.0 and 4.8 mg/L. The effluent TP average mass concentration is 0.07 mg/L, the highest is 0.27 mg/L, and the average removal rate is 97.99%, which is significantly better than the first-class A standard of GB 8978-1996, and can reach the surface water class IV standard.

The TP mass concentration of the effluent reached a maximum value of 0.27 mg/L in the initial operation stage after the completion of the membrane installation, and then the TP removal effect tends to be stable as the system enters the stable operation stage, and the late effluent TP is maintained below 0.1 mg/L. Significantly low GB 8978-1996 Grade A standard of 0.5 mg/L, basically stable to reach the surface water class IV standard of 0.3 mg/L, indicating that the new composite filter tank TP removal effect is stable and good. In the sewage treatment, general biological phosphorus removal and chemical phosphorus removal methods remove TP. Biological Phosphorus Removal The TP in the effluent is transferred to the activated sludge by the polyphosphorus microorganisms in the anaerobic phosphorus release, and the aerobic excess phosphorus absorption characteristics, and the sewage TP is removed by discharging the excess sludge. Chemical dephosphorization is carried out by speculating a mixture of aluminum chloride (PAC) and polyaluminum ferric chloride (PAFC) into water to convert TP into phosphate precipitate and then remove it by precipitation or filtration. The CSBF filter in the new composite filter consists of an anoxic tank No. I and an aeration tank No. II. It has an anaerobic and aerobic alternating environment and therefore has biological phosphorus removal conditions. The CSBF filter effluent and PAFC are mixed into the EBF advanced treatment filter and chemically removed by phosphorus to enhance TP removal. Confidence composite filter has both biological phosphorus removal and chemical phosphorus removal conditions, and the combination of the two makes the system have a good and stable phosphorus removal capacity.

4. In conclusion
The new composite filter is made up of a serial batch mud membrane composite biofilter (CSBF) and a deep treatment filter (EBF). CSBF is divided into two groups: oxygen-free aerobic two-stage, filled with 2 m filler in aerobic tank for biological membrane, activated sludge at the bottom of the tank, and mud-film composite environment in the system, which combines biofilm method and activated sludge method. The utility model has the advantages of good pollutant removal efficiency and impact load resistance, and the fluctuation of the influent water quality has little influence on the effluent water quality. EBF is compounded with crushed filter material and sand ratio.

The biological filter column process enhances SS, TN, and TP removal. CSBF 1 h operation cycle allocation: 25 min in the aeration phase, 10 min in the sedimentation phase, 5 min in the gas stripping, 20 min in the influent water, and 6.6 m3/h in the influent flow during operation, the gas to water ratio is 5:1, and the HRT is 10.2 h, monitoring the 20-day operation data, the results show that the new composite biofilter has a stable and reliable removal effect on COD, NH3-N, TN, TP, and other pollutants. During the monitoring period, the average COD of pollutants entering the water was COD266.05 mg/L, the concentration of NH3-N was 20.94 mg/L, the concentration of TN was 24.46 mg/L, the concentration of TP was 3.67 mg/L, and the average effluent quality was 13.96 mg/L. NH3-N concentration 0.21 mg/L, TN mass concentration 5.34 mg/L, TP mass concentration 0.07 mg/L; the average removal rate reached 94.63%, 99.02%, 77.89%, and 97.99%, respectively. The effluent stability reached the first-class A standard of GB8978-1996, and COD, NH3-N, and TP reached the surface water class IV standard.
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