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Treatment of Micro-Polluted Natural Water Body by Aerobic Biofilm Process

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This paper aims to improve the natural water bodies contaminated by some chemical substances, for example, the phosphorus, in modern times. A hanging nylon aerobe biofilm reactor will be verified for its functions by culturing and testing in the real environment. Analysis results reveal that the hanging nylon biofilm reactor is more economical and efficient than the biological aerated filter. It is concluded by observation under different conditions that this type of hanging nylon aerobic biofilm reactor has been proven to be effective in the field.

1. Introduction

This paper focuses on the phosphorus pollution in the natural water bodies micro-polluted by modern industry. Here we propose a new type of hanging nylon aerobic biofilm reactor to remove phosphorus in wastewater synchronously. Next, the performance of phosphorus removal and phosphorus storage are explored to conclude the study progress by two phases. In the first phase, use the new biofilm reactor to treat synthetic wastewater, discuss whether it is feasible to enrich and culture high-concentration phosphorus-accumulating bacteria on the conventional biofilm within a short time, and verify it from reactor operation efficiency, phosphorus removal rate, and enrichment of phosphorus accumulating bacteria and other dimensions. After the enrichment of phosphorus-accumulating bacteria, the second phase starts to get the high-concentration phosphate recovery liquid by growing enrichment in the aerobic phase, and explore how the enrichment process and various factors affect it.

2. Literature review

Water is a very important natural resource. There is great demand for water for human life activities and production activities, and water is also a limiting factor for the sustainable development of human society. Of the total amount of water in the earth, only 3% of the fresh water is available, and most of the fresh water is found in the Polar Regions in the form of ice and snow, so the available fresh water is less than 1% of the total water. In recent years, due to the growth of the population in the world and the social and economic development, the water consumption has increased rapidly, and the waste and pollution of water resources have caused the shortage of water resources.

The water resources situation in China is also severe. The annual flow of rivers in China ranks sixth in the world, and the per capita occupancy is only 110th in the world and 1/4 in the world's per capita water. In addition, the distribution of water resources in China is uneven, and more than 80% are distributed in the South and Yangtze River basins, resulting in water amount shortage of water resources in the northwest and other places. The drought and water shortage make the contradiction between supply and demand of agricultural water resources very prominent. In addition to the influence of human life and industrial production, even in the south with abundant water, water quality shortage has appeared, water pollution is widespread and the waste phenomenon is very serious. These factors lead to the increasing shortage of water resources available in China. China has been listed as one of the 13 countries with poor water resources by the United Nations. The phenomenon of water shortage in cities and towns began in the late 1970s of last century and gradually spread from the coast and the north to the mainland. By the end of 1995, there were

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nearly 320 cities with water shortages in the more than 620 cities of the country, more than 110 of which were seriously short of water. The monthly water shortage was up to 16 million m^3, the annual water shortage was up to 6 billion m^3, and the industrial loss was up to 200 billion yuan.

The biofilm treatment of sewage is a kind of aerobic biological treatment technology which is parallel to activated sludge. As early as the end of the nineteenth Century, the United Kingdom used sewage to filter crude filter materials and purified it, and achieved good results so that biofilter began to come out. In the twentieth Century 20~30, a large number of biofilm reactor systems with biofilter as the major form were constructed. However, in the 40~50 years, the biofilter has gradually been replaced by activated sludge process because of its low water load and low organic load, large volume of construction, poor environmental sanitation, and clogging of biofilm. Until 1960s, with the great production of new organic synthetic materials, various artificial synthetic fillers made of polyethylene, polypropylene, polyphthalamines and other plastics have been widely used, which greatly improved the specific surface area and void ratio. And accompanied by the further increased water quality requirements in society, the biofilm reactor has achieved a new development. In 1970s, in addition to ordinary biofilter, biological rotary table, submerged biofilter and biological fluidized bed technology have been greatly studied and applied. In recent years, biofilm reactors have attracted more researchers and engineers' attention because of their unique advantages, and a large number of new biofilm reactors have emerged. Biofilm is an ecological system composed of highly dense aerobic bacteria, anaerobes, facultative bacteria, fungi, protozoa and algae. The solid medium attached to it is called filter material or carrier. In the process of filling flow, the mass transfer area of the biofilm and organic matter and dissolved oxygen is increased, and the mass transfer rate is increased, which not only strengthens the mass transfer process, but also improves the utilization ratio of dissolved oxygen.

Konar and Patek used BiowinTM simulation software to simulate many aspects of the nitrogen removal process of four stages of influent biological nitrogen, the distribution of influent flow, the carrying of dissolved oxygen in the aeration zone, the adding point of external carbon source and the internal circulation of nitrate in the aeration area (Konar and Patek, 2016). Based on the chemometrics of de-nitrification and nitrification, the theoretical denitrification rate of two-segment sublevel activated sludge process was investigated by Vivekanandan (Vivekanandan et al., 2017). Pereira and others discussed the four-level A/O processes. When the sludge reflux ratio increased, the nitrate nitrogen removal from the first section of the anoxic region increased significantly (Pereira et al., 2016). Ge Shijian and so on, in a large sewage treatment plant, carried out treat of low COD/N domestic sewage with subsection nitrogen and phosphorus removal process in a pilot scale. In the water COD load of 0.79~0.93kg/ (m^3·d) and 4 flows distribution ratio conditions, the average effluent COD concentration and removal rate were (43.7 ± 8.35) mg/L and (83.8 ± 3.86)%, respectively, and the removal contribution of anaerobic and anoxic areas for COD was as high as 60.2%~76.2% (Rott et al., 2017).

Biological treatment, especially aerobic biological treatment, is the most economical and practical wastewater treatment plan. However, for high concentration organic wastewater, aerobic biological treatment cannot guarantee the final effluent quality, but also consume and waste a lot of energy (Mishima et al., 2017). At this time, the use of anaerobic biological treatment as pre-treatment process of aerobic biological treatment will not only help to ensure the quality of the final effluent, but also save the energy consumption of the wastewater treatment, and recover the energy contained in some of the wastewater. Physical treatment and chemical treatment are both very efficient means of wastewater treatment, but because of high operating costs, they are often placed at the end of the treatment process as a means of depth treatment. Physical treatment and chemical treatment are widely used in the treatment of high concentration organic wastewater. Because much high concentration organic waste water is difficult to be biodegraded, physicochemical treatment sometimes needs to be used as a main processing means (Nidhees and Tsa, 2017). Aerobic biological treatment of wastewater refers to the treatment of wastewater in the aerobic environment by using aerobic microorganisms, including facultative microorganisms, to degrade organic pollutants in waste water into low energy inorganic substances. In the treatment of high concentration organic wastewater, the biological treatment can not only be used as a two-stage treatment means, but also can be matched with other treatment methods, and the anaerobic aerobic biological treatment combination is more common (Skoczko et al., 2017). For example, sugar cane wastewater can be treated by aerobic biological treatment alone as a two-stage treatment. For the high concentration organic wastewater containing some chemicals difficult to degrade, such as polyester dyeing wastewater and polyester dyeing wastewater, the aerobic biological treatment combination can be used as the two-stage treatment means. Like all kinds of dyeing and finishing wastewater, sugar beet wastewater and acid waste water in landfill leachate, anaerobic aerobic biological treatment combination can be used as the two-stage treatment means (Taufer et al., 2017).

To sum up, the above research work is mainly to study the aerobic biological membrane method. As a result, based on the present situation, this article starts from the aerobic biological membrane process industrial micro pollution natural water body case. Aiming at the problem of too fast decline speed of water flux of the ultrafiltration system, poor tolerance ability to influent salinity impact of biological treatment system in the engineering, and more serious bubble problem, this paper analyses the reasons that may cause the water quality of production wastewater through consulting a lot of scientific research literature. And then it puts forward the scheme for improving the route of wastewater quality and the route of improving treatment process, and through the small laboratory test and production test, we verify and get effective improvement scheme. Finally, on the basis of activated sludge No. 1 model, a mathematical model can be built to simulate the wastewater of activated sludge treatment.

3. Method

The hanging nylon filler is immersed in the sludge recovered from the oxidation ditch in aerobic phase in a sewage treatment plant for 24 h, and the sludge is enriched on the filler. Put the reactor in a DF-101s magnetic agitator kettle heated in thermostatic water bath and keep it at a constant temperature, stir it at the bottom uniformly. Three pumps DZ-2X are used to complete the aerobic influent and repellent work. A minitype 250W air compressor connected with hoses and aeration stones is placed in the reactor to provide aerobic aeration. The main body of the reactor consists of 2 strands of nylon fillers hung up in a 2L container. The installation process is followed: a lift pump 1 pumps the aerobic water into the reactor, and the air compressor provides the aeration conditions. After the closure of the reaction, the lift pump 3 will bleed off the solution from the reactor. See Figure 1 and 2 for experiment installations.

Figure 1: Freezing dryer

Figure 2: Hash DRB200 digestion instrument

Choose commonly used hanging nylon as biofilm filler, and adopt the activity sludge process for biofilm formation according to the filler conditions and the experiment objective. Take the sludge in the aerobic oxidation ditch of AA/O process in a municipal wastewater treatment plant as the inoculation sludge, and immerse the nylon filler in the inoculation sludge for 24h during the biofilm formation phase, do not migrate it into the anaerobic reactor until the filler in white is no longer visible, i.e. the sludge is attached to the filler.
Take synthetic wastewater as the influent, i.e. the aerobic substrate therein, and mix it with water by a ratio of 1:9. In general, sodium acetate or sodium propionate is used as a simulation wastewater carbon source. Studies suggest that sodium acetate can stimulate the metabolism of polyphosphate bacteria more than sodium propionate, so that we choose easily absorbable sodium acetate as a carbon source. The leading indicators in the mass of synthetic wastewater are: 200mg·L-1COD, 5mg·L-1PO43—P, 40mg·L-1NH4+-N, trace CaCl2·2H2O, MgSO4·7H2O, EDTA·2Na and microelement, add NaHCO3 to adjust the influent pH to 7.5; in aerobic substrate, 2000mg·L-1COD, 40mg·L-1NH4+-N, natural pH value, minor CaCl2·2H2O, MgSO4·7H2O, EDTA·2Na and trace elements. There is no excessive temperature control during the experiment. Only when the water temperature falls below 25 °C, heat it up in the water bath to keep the water temperature at 25°C.

Relevant studies suggest that the aerobic working time of the biofilm reactor is set to 6 h in order to obtain a better treatment effect. The influent flow of the reactor reaches 119mL•min-1, and the influent time is about 15min. The rotor at the bottom of the vessel keeps rotating to make the solution in the reactor evenly mixed.
The COD concentration of synthetic wastewater is set to 200 mg•L-1 in line with the practical situation in south Jiangsu. Some studies have shown that there is a transfer process of dissolved oxygen in the liquid phase and biofilm phase of biofilm reactor, as well as film interior, so that the biofilm process requires more aeration rate than the traditional activated sludge process. In the similar situation, the content of phosphorus in the effluent can be made lower by improving the aeration rate; on the other hand, the increasing aeration will also break up the active biomass formed originally in the biofilm. Given that the aeration rate in the aerobic phase of this process is controlled at (3±0.5). Mg•L-1. Part of the phosphorus-accumulating bacteria in the culture environment adapts to the pH range of 6 ~ 9, there are another part of them that grow up in pH range of 6~8. In the alkaline environment, these bacteria will have a better performance, and combined with the actual wastewater, the influent pH is adjusted to 7.5. Phosphorus accumulating bacteria have a growth temperature in the range of 10°C ~35°C. The higher the temperature, the faster the metabolic activity of the microorganism is. In this experiment, the temperature should be controlled at 25°C by heating in a water bath if room temperature is low.
The routine monitoring indicators in the experiment are measured using the standards specified by the State Environmental Protection Administration. The specific indicators are shown in Table 1. Other parameters are all subjected to the literature. The chemical agents used during the test are all analytically pure.

Table 1: Analysis method summary table

Monitoring item order	Monitoring method	Instrument and equipment
NO_3--N	Ultraviolet spectrophotometry with amino sulfonic acid	DR5000 ultraviolet spectrophotometer
NO_2--N	N- (1- naphthalene) - ethylenediamine photometric method	DR2800 spectrophotometer
NO_4--N	Nnshi reagent spectrophotometric method	DR2800 spectrophotometer
PO_4^{3+}-P	Antimony spectrophotometric method	DR2800 spectrophotometer
TP	Potassium persulfate digestion - molybdenum antimony spectrophotometric method	DR2800 spectrophotometer
COD	Potassium dichromate method	DR2800 spectrophotometer
TN	Potassium persulfate oxidation UV Spectrophotometry	DR5000 ultraviolet spectrophotometer

3. Results and analysis

The hanging nylon is chosen as biofilm filler since it is cheap and easy to access. It features high strength and good toughness. Beyond that, it can also well maintain the biofilm morphology in general bioreactors. According to the filler condition and the experiment objective, the active sludge process is used for biofilm formation. Take the sludge in the aerobic phase oxidation ditch of a municipal sewage treatment plant as the inoculation sludge. In the biofilm culturing phase, the nylon filler is immersed into the inoculated sludge for 24 h, and not transferred into the aerobic alternating reactor until the filler in white is completely invisible, that is, the sludge attaches to the filler. During the startup phase, due to aeration flushing and agitating disturbances, sludge that just attaches to the filler will fall off. The sludge left on the filler will gradually adapt to the hydraulic conditions in the reactor and form a layer of stably attached biofilm. Supervise the operating conditions of the reactor to determine whether it operates stably. Continuously measure the CODs and orthophosphate concentrations of the influent and effluent. Plot routine curves, as shown in Fig. 3 and 4: COD concentration of the aerobic effluent is kept below 50mg·L-1 in 10 days after reactor operates; the phosphorus concentration in the effluent during the aerobic phase is close to zero; after continuously stable operation at this treatment level for 50d, the effluent can reach the drainage class A standard and has a good stability; the influent water quality of the reactor fluctuates, good effluent is still maintained. It is proved that the reactor has a certain resistance to impact load. This process simulates the synthetic wastewater with water quality characteristics in a certain area, in the case when the influent has lower COD concentration (about 200mg/L), and the phosphorus content is about 6 mg•L-1, the effluent can reach a good treatment level. The hanging nylon biofilm reactor has better efficiency in removal of COD and phosphorus in the sewage than the existing biological aerated filter process, no need to perform backwash. As compared to the biological aerated filter, it outperforms in economy and efficiency.

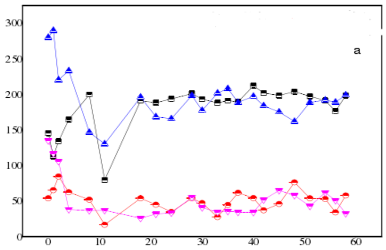


Figure 3: Conventional curves (a)

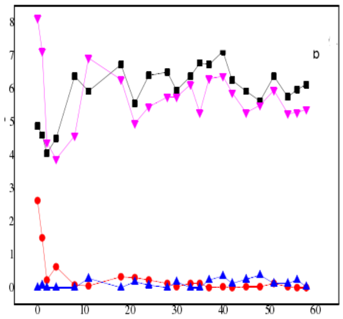
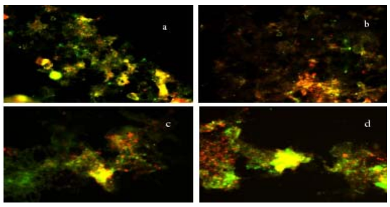


Figure4: Conventional curves (b)



(a) Original inoculation (b) 20d(c) 35d (d) 50d

Figure 5: Fluorescence in situ hybridization diagram

In this experiment, compared to the suspended biofilm in the existing sequence batch SBBR reactor, the hanging nylon biofilm shortens the effluent stabilization time from 25 days to about 10 days with higher operation efficiency. In the operation mode of reactors, its flow state is much simpler than that of the SBBR reactor. It features high efficiency and easy to operate.
In order to investigate how the phosphorus-accumulating bacteria before and after the start of biofilm reactor change, the abundance of these bacteria in the sludge sample cultured for 20, 35, 50d from the original inoculation sludge are analyzed by FISH. When acquiring the sludge samples on the biofilm, it is required to consider the control variables in the sampling phase. At different times, it is agreed to collect the sludge on the biofilm in the middle of the reactor. The specific process of acquisition is as follows: after the reactor is bled off, remove the biofilm filler and cut out a small section from middle part using a scissors, note that the upper and lower joint parts on the filler should not be reached when cutting it. Wear the sterilizing gloves to remove the sludge from the filler and place it into the container, and then go to the next step of the experiment. A fluorescence in situ hybridization is shown in Fig. 5, where bright yellow is a CY3-marked fluorescent probe PAOmix (red) and a FITC-marked EUBmix (green) superimposition color. The fluorescence intensity is calculated by the biological image analysis software LASCore to obtain the phosphorus-accumulating bacteria as a percentage of the total.
Thickness affects two factors important for biofilms: the mass transfers of oxygen and organic matter. These two factors directly determine the content of active microorganisms on the biofilm and affect the treatment efficiency of the biofilm reactor. For this reason, biofilm reactor requires appropriate flow state or periodic backwash to maintain the proper thickness of the microorganism layer above it. Over thickness will result in barriers to mass transfer of the active substances, forming an aerobic zone, so that high concentration

microbial strain and ideal treatment effect cannot be obtained. It is therefore necessary to realize the performance of the biofilm reactor by the biofilm thickness.

4. Conclusion

This paper mainly uses aerobic biomembrane reactor to work, while aerobic microorganisms of the reactor are cultured. The state of microorganisms should be observed at three different time frames, that is, 6h, 2h and 3h. The results show that the best microorganism state is at 6h. Later, the reactor displays that after the reactor operates for 10 days, the orthophosphate removal rate from effluent is stabilized at 95% or more; after 50 d, the micro-phosphorus-contaminated water bodies are detected, it is found that phosphorus and organic matter in water have been removed. During the culture process, the absorption and release rates of phosphorus in the reactor gradually build up to the peaks on the 48th day, i.e. 8 mg•(L•h)-1 and 6 mg•(L•h)-1 from 3.4 mg·(L·h)-1, respectively. It is proved that the phosphorus-accumulating bacteria continue to enrich and the reactor efficiency is improved. More comprehensively, this paper proposes a proper process for culturing aerobic biofilm reactors since it can effectively clean up phosphorus-contaminated water bodies. However, due to multiple elements that contaminate the modern water bodies, the sewage treatment process involving aerobic biofilm reactor still has a big gap to be filled in the future.

Reference

Konar R., Patek M., 2017, Numerical simulation of dissimilar weld joint in sysweld simulation software, Tehnicki Vjesnik, 24, 137-142, DOI: 10.1016/j.advengsoft.2016.08.012

Mishima I., Hama M., Tabata Y., Nakajima J., 2017, Improvement of phosphorus removal by calcium addition in the iron electrocoagulation process, Water Science & Technology A Journal of the International Association on Water Pollution Research, 76(3-4), 920, DOI: 10.2166/wst.2017.256

Nidhees P.V., Tsa S., 2017, Arsenic removal by electrocoagulation process: recent trends and removal mechanism, Chemosphere, 181, 418, DOI: 10.1016/j.chemosphere.2017.04.082

Pereira N.M., Shah I., Biyani N., Shah F., 2016, Frontal lobe tuberculoma, Oxford Medical Case Reports, 2016(1), 12, DOI: 10.2139/ssrn.2953718

Rott E., Minke R., Steinmetz H., 2017, Removal of phosphorus from phosphonate-loaded industrial wastewaters via precipitation/flocculation, Journal of Water Process Engineering, 17, 188-196, DOI: 10.1016/j.jwpe.2017.04.008

Skoczko I., Struk-Sokołowska J., Ofman P., 2017, Seasonal changes in nitrogen, phosphorus, bod and cod removal in bystre wastewater treatment plant, 18(4), 185-191, DOI: 10.12911/22998993/74361

Taufer G., Horn B.C., Stülp S., Hilgemann M., Taufer G., Horn B.C., 2017, Application of chemometrics for the optimization of phosphorus removal process by electrocoagulation, Revista Virtual De Quimica, 9(4), 1734-1746, DOI: 10.21577/1984-6835.20170100

Vivekanandan B., Jeyannathan K., Ra A.S., 2017, Sensitivity of effluent variables in activated sludge process, Chemical Product & Process Modeling, DOI: 10.1515/cppm-2017-0028