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NITROGEN AND PHOSPHORUS REMOVAL BY SUBMERGED MEMBRANE BIOREACTOR

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ABSTRACT

In this examination we have studied wastewater treatment for nitrogen and phosphorus removal using a membrane bioreactor with domestic wastewater. The results show that nitrobacteria was influenced greatly by pH, which we controlled between 6.5 to 7.0 (appropriate to nitrobacteria). The removal rate of NH_4^+-N is 99% and the concentration of effluent NH_4^+-N is below 0.5 mg/L; because of the high DO value in the denitration section, the denitrobacteria was restrained and the effluent TN value was high, but the removal rate of TN can also reach 80%; the removal of TP is due to sample sludge and microorganism growth.

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1. INTRODUCTION

The undesirable growth of algae in receiving waters has directed attention to the importance of removing plant nutrient elements, as well as carbonaceous pollutants, from waste waters. Nitrogen and phosphorus is the critical factor leading to the eutrophication of many surface waters. Biological treatment of domestic sewage does not effectively remove nitrogen and phosphorus, the elements of greatest concern [1-5]. The membrane bioreactor (MBR) has been gaining great attention in wastewater treatment, inasmuch as membrane filtration promises a complete solid-liquid separation, prevents failure of biological systems due to biomass loss and/or bulking, and maintains high mixed liquor suspended solids (MLSS) in the reactor [6-7].

In this study, a submerged membrane bioreactor system with UF membrane is introduced for nitrogen and phosphorus treatment of domestic wastewater.

2. MATERIALS AND METHODS

2.1. Reactor and Operation

The fully automatic submerged membrane bioreactor used in the experiment was designed and constructed jointly by Liaoning University of Petroleum and Chemical Technology and Tokyo University. The schematic diagram of the process flow and pilot plant setup is shown in Figure 1. Influent (raw water) was transferred by a submersible pump to a feed influent tank through a strainer, which retained and prevented large suspended solids from clogging the membrane. From the feed water tank, feed water was pumped to a slantwise sheet sedimentation tank and overflowed into a preposition denitrification anaerobic section (A), and then into a postposition aerobic section (O). In the final stage, a membrane filtration pump (P3 in Figure 1) withdrew clear water through the submerged membranes in the aerobic tank at a flow rate of 42 L/hr. The membrane filtration pump ran intermittently (13 min ON/4 min OFF) at operating pressures of 0-50 kPa, where zero means shutdown and 50 kPa means the membrane can act under normal condition when pressures are below 50 kPa. The aerobic tank was aerated continuously. Capacities of all reactor tanks are indicated in Figure 1. The membrane module used was Polyvinylidene Fluoride (PVDF) flat sheet membrane, a product from TORAY, Japan. The membrane had a pore size of 0.08 μm, a porosity of 70%, and an effective filtration area of 0.45 m^2. Fouling of the membrane was prevented by providing intense aeration and intermittent effluent discharge (13 min ON/2 min OFF). The fouling would be minimized by intermittent aeration and continuous NaClO dosing when the membrane was fouling. A 4-section membrane module of high durability and large flow capacity was used in the experiment. Each section of the membrane module could be removed easily for maintenance and cleaning.

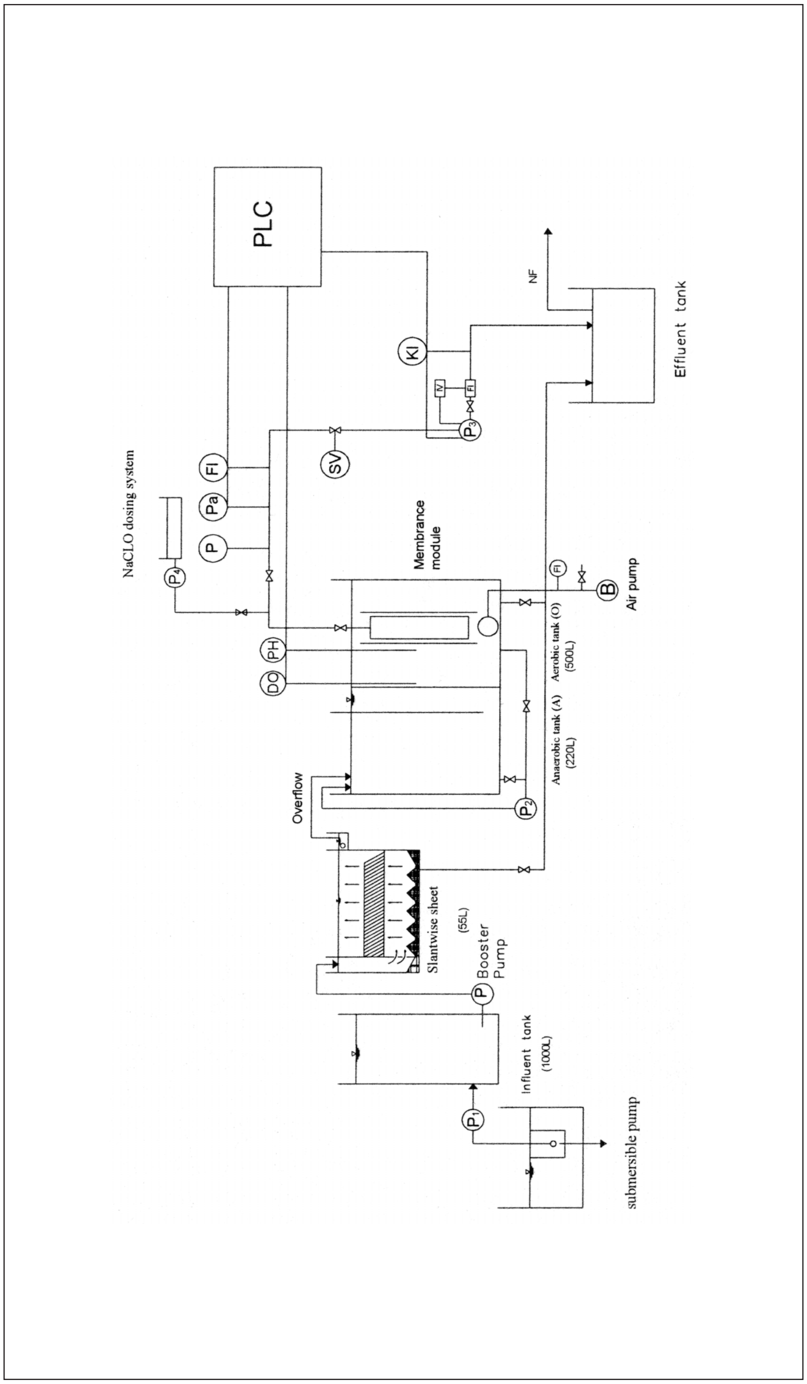

Figure 1. Schematic diagram of A/O MBR for wastewater treatment.

2.2. Wastewater Characteristics

Characteristics of wastewater are tabulated in Table 1.

2.3. Analytical Methods

To monitor the performance of reactors, samples of influent and effluent were analyzed for selected parameters using qualified instruments and procedures (see Table 2) [8].

3. RESULTS AND COMMENTS

3.1. NH_4^+-N Removal

In order to study the elimination effect of NH_4^+-N in the membrane bioreactor, the experimental operating conditions are: DO value control above 4.5 mg/L, influent pH value of 7.0~8.1, reactor's temperature of 13°C~17°C, HRT at 17.14 h. The elimination effect of NH_4^+-N in the membrane bioreactor is shown in Figure 2.

As shown in the chart, (1) in the first 15d, the NH_4^+-N elimination effect is quite bad, the elimination rate reaches 77.12% slowly. On the one hand, this is because the influent ammonia nitrogen load is big, but the nitrifying bacteria generation time is long, so the multiplication speed is slow. On the other hand, because the pH of the aerobic process is 4.65~5.8 and has not performed to control, low pH has an inhibitory action on ammonia nitrogen degeneration [9].

Table 1. Characteristics of Wastewater

Temperature/°C	DO/mg·L^{-1}	PH	NH_4^+-N/mg·L^{-1}	TN/mg·L^{-1}	TP/mg·L^{-1}
13-17	4.5-5.5	7.0-8.1	29.84-75.1	40.67-88.97	3.03-6.49

Table 2. Analytical Method for Determining Experimental Wastewater Quality

Item	Method
pH	pH meter (pHs-3C, China)
NH_4^+-N	Nesster's reagent colorimetry
TN	Potassium persulfate dispels ultraviolet spectrophotometric method
TP	Ammonium molybdate spectrophotometric method

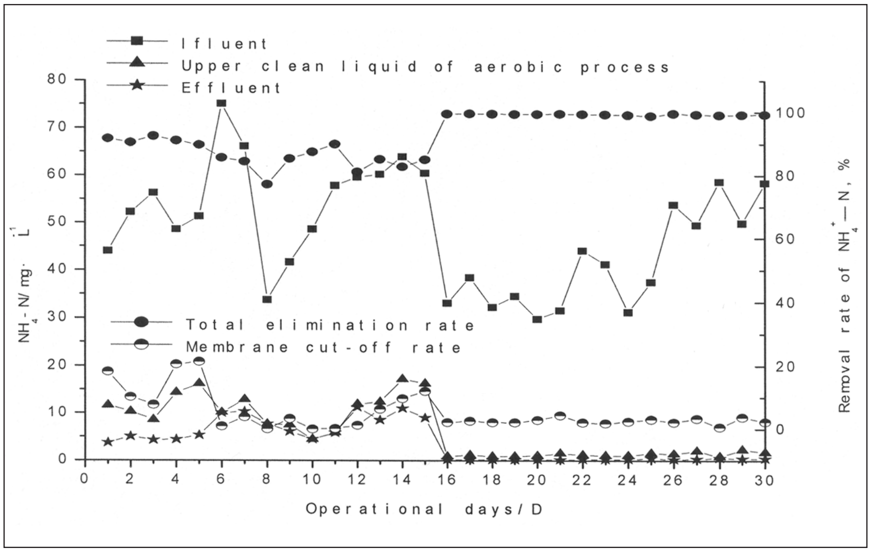

Figure 2. Influent and effluent ammonium changed with time.

In the latter 15d, the NH_4^+-N elimination rate rises above 99%, because sodium bicarbonate added to the aerobic process controls the pH in the 6.5~7.0 range, enabling it to achieve suitable pH scope for nitrogen removal. (2) The value of NH_4^+-N removal by membrane is low, indicates that the elimination of NH_4^+-N depends on microorganisms in the membrane bioreactor; the reason for the membrane module's limited interception function is the small molecular weight of NH_4^+-N. (3) In the membrane bioreactor, the sludge residence time is long, makes the generation time long, allowing nitrifying bacteria to accumulate gradually in the system; simultaneously, dissolved oxygen is high, enabling the full nitration of NH_4^+-N in the waste water, where the effluent stabilizes below 0.5 mg/L.

3.2. TN Removal

As shown in Figure 3, effluent TN value is high because, in the reactor, in order to ensure nitrifying bacteria's nitration conditions as well as appropriate membrane surface washout intensity, the returned sludge leads the high DO value of the anerobic process, causing denitrifying bacteria suppression. In the membrane bioreactor, the average removal rate of TN can rise above 80%, because the membrane bioreactor apparatus does not carry a row of sludge besides the sample. The assimilation of sewage ammonia nitrogen and of organic nitrogen also enables TN to achieve certain levels of elimination.

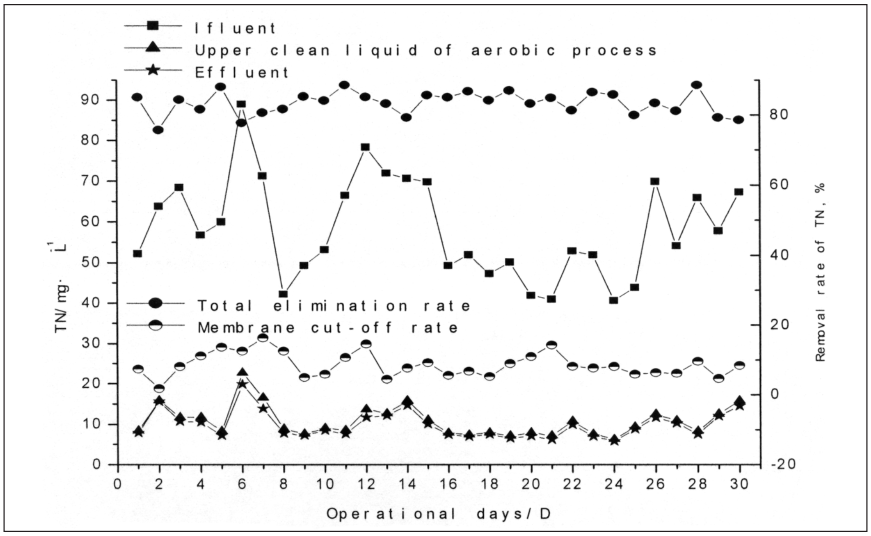

Figure 3. Influent and effluent TN changed with time.

3.3 TP Removal

The total phosphorus elimination effect in the membrane bioreactor is shown in Figure 4. In this experiment, besides the sample, a row of sludge is not carried; theoretically speaking, the phosphorus elimination effect is not present. But in the experiment, it was discovered that the phosphorus level in effluent was reduced. The reason mainly seems to be that the partial phosporus as carried over along with the sample sludge. In conventional active sludge systems, phosphoric quantities of active sludge lie generally for dry weight between 1.5% ~ 2.3% and with normal microorganism growth [10]. In the membrane bioreactor, the nutrition from which the microorganism grows is more similar to that with conventional active sludge BOD5:TN:TP=100:5:1. Therefore the microorganism may remove the partial nitrogen and the phosphorus during degeneration of the organic pollutant. In this experiment the phosphorus elimination was mainly caused by microorganism growth. As shown in Figure 4, the membrane cut-off rate of TP may reach 19.43%, because the membrane filtration function caused the phosphate, which is difficult to dissolve; the phosphorus and the calcium magnesium ion production settling was kept in the reactor, thus strengthening the total phosphorus elimination.

4. CONCLUSIONS

(1) The NH_4^+-N elimination rate in A/O integration membrane bioreactors may reach above 99%. The effluent stabilizes basically below 0.5 mg/L, but the

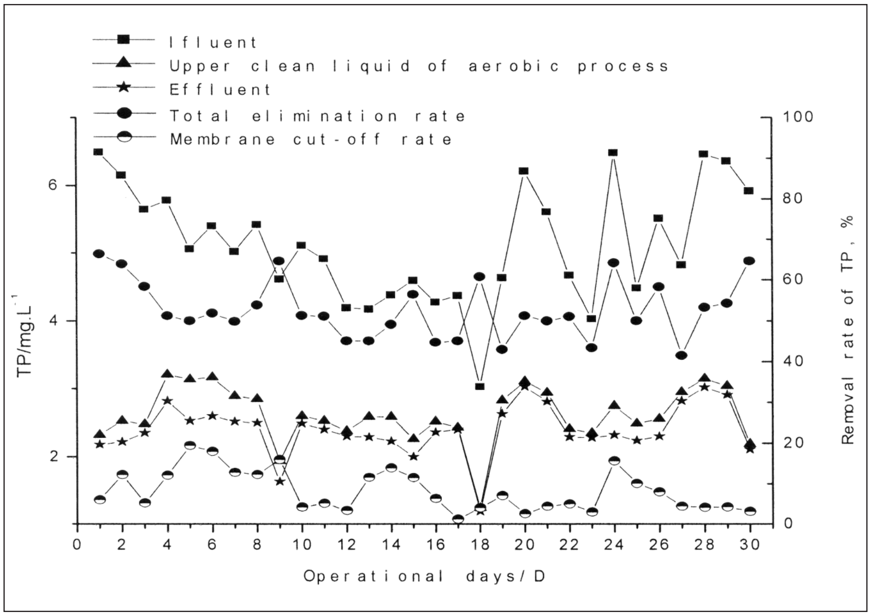

Figure 4. Influent and effluent TP changed with time.

nitrifying bacteria is markedly influenced by pH. To achieve the ideal elimination effect, one must control the pH of the aerobic process. This was done here by adding the sodium bicarbonate.

(2) To ensure nitrifying bacteria's nitration conditions as well as the membrane surface washout intensity, simultaneously the returned sludge leads the high DO value of anerobic process, causes denitrifying bacteria suppression and influencing the removal rate of TN. An 80% elimination rate can be achieved.

(3) This A/O integration membrane bioreactor does not carry on a row of sludge, but also to a certain extent eliminates TP, because the sample sludge has carried over the partial phosphorus and allows the microorganism growth to consume the partial phosphorus.

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