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Research Article

Design and Efficiency of a Domestic Sewage Treatment System with Microorganism-membrane on Island Based on Entropy Theory

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Abstract: Domestic sewage treatment by water drainage network plus septic tank is not suitable on very small islands because of traffic and urban infrastructure problem. This study deals with a microorganism-membrane domestic sewage treatment system on small islands, which can degrade and clean the domestic sewage locally by effective microorganism and membrane system and makes the emission in market. Eight kinds of commercial complex microorganisms decompose powder were chosen to analysis the activities of protease, lipase, cellulose and amylase. And relating model based on entropy theory was constructed to evaluate the effect of enzyme activity, then the best commercial complex microorganism decompose powder was confirmed. The designed microorganism-membrane wastewater treatment system was applied to treat domestic sewage on a small island. The results showed that the removal rate of organic matters including the five-day Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD) and ammonia nitrogen (NH_3-N) reached more than 98%. The removal rate of Total Dissolved Salts (TDS) of the outlet water was higher than 99%. This system was especially suitable for small islands domestic wastewater treatment.

Keywords: Domestic sewage, entropy theory, microorganism-membrane system, relating model, wastewater treatment

INTRODUCTION

Recently, island exploitation has been one of the hot topics and more and more people visit small islands. Therefore, how to treat this domestic sewage had been one of the most important problems in order to avoid the pollution. Because of traffic and urban infrastructure problem, sewage treatment by water drainage network plus septic tank is not suitable on small islands. Now, most of the domestic sewage is flowed into ocean directly, which produces severe environmental pollution to island and around ocean.

Membrane separation was a high efficiency wastewater treatment process and had been applied to many industry wastewater treatments in recently years (Visvanathan *et al*., 2000; Chiemchaisri and Yamamoto, 1994). Combining membrane technology with biological reactors for wastewater treatment has led to the development of membrane bioreactors (MBRs). Ultrafiltration as a replacement for secondary sedimentation tanks in the activated sludge process was first described in 1969 by Smith *et al*. (1969) and since then MBRs have been successfully used worldwide in industrial and municipal wastewater treatment in hundreds of applications. The microorganism used in MBRs included photosynthetic bacterium, lactic acid bacterium, yeast and actinomyces. However, most of the researches focused on analysis the activity of one or few kinds of microorganisms and few of the literature investigated to the decompose activity of complex microorganisms. In this study, several commercial complex microorganism powders are chosen for evaluating their applications in MBRs for wastewater treatment on island.

Entropy method was the concept of thermodynamics, which was first introduced by Shannon into the information theory and recently was widely used in the engineering, economic and other fields (Ye, 2010; Li *et al*., 2011; Zou *et al*., 2006).

The objective of the present investigation was to design a MBRs for domestic sewage treatment and optimize the best decompose microorganism powder from several commercial complex microorganism powders. Also, the efficient of BMRs for a small island's domestic sewage treatment was evaluated.

MATERIALS AND METHODS

Reactors set-up and operation: Figure 1 shows a schematic diagram of experimental apparatus consisting of three reactors and a filtration membrane system. Temperature was controlled at 25±1°C using thermostats. A float-ball valve was used to control water level of the two reactors. The membrane module used in the two systems was a bundle of U-shaped

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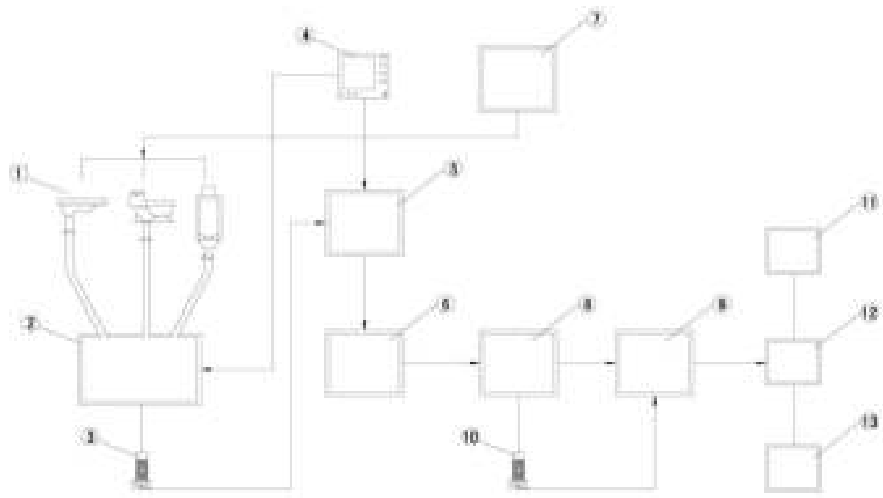

Fig. 1: Schematics of microorganism-membrane domestic sewage purification system; 1-sewage collection enter; 2-sewage collection tank: 3-pump; 4-control system; 5-anaerobic tank; 6-aerobic tank; 7-reuse water tank; 8-filtration system; 9-UV disinfection; 10-pump; 11- ultrasonic atomizing; 12- overflow water treatment; 13-soil osmosis

hollow fibre membranes made of polyethylene with a pore size of 0.1 mm and a filtration area of 0.15 m^2.

In the designed MBR system, the domestic wastewater was fed to the first reactor (2) and the rarity or impurity was removed in this reactor by precipitation. Then the wastewater was pumped into anaerobic reactor (5) and aerobic reactor (6) in order. The commercial complex microorganism powder was added to reactors and the organic substrates were decomposed by the microorganisms into colorless, odorless gas and other inorganic compounds. The pretreated wastewater was flowed into filtration system. The color, odor and microorganism in the wastewater were removed by rough filtration, aeration, absorption and micropore filtration. Last, the out water was sterilized to reach demand of miscellaneous domestic water emission standard.

Experiments carried out: Eight kinds of commercial microorganisms decompose powders (labeled as MDP-1, MDP-2, MDP-3, MDP-4, MDP-5, MPD-6, MDP-7 and MDP-8) were purchased from Tianjin Institute of Industry Microorganisms, Yantai Sukahan Bio-Technology Co. Ltd, Hebi Tianyang Biological Technology Co. Ltd and Shanghai Senhe Environmental Technology Co. Ltd, China. The activities of protease, lipase, cellulase and alfa-amylase in the eight kinds of commercial microorganisms decompose powders were analyzed. The relational model of the four kinds of enzymes activities was constructed based on entropy theory. Then the relation index and relation characteristics of the model were analyzed in order to optimize the microorganism's enzymes combination.

The best commercial microorganisms decompose powder was applied into the BMRs and the efficient was evaluated through measuring the five-day Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), ammonia nitrogen (NH_3-N) and Total Dissolved Salts (TDS) of the outlet water.

Analyses: The COD, BOD_5, NH_3-N and TDS were analyzed according to the standard methods for the examination of water and wastewater (APHA *et al*., 1998).

RESULTS AND DISCUSSION

Enzyme activities of commercial decompose microorganism powders: The lipase, protease, cellulase and amylase activities of the eight kinds of commercial microorganisms decompose powders were analyzed and the results were shown in Table 1. Some studies had reported that major chemical fractions in domestic wastewater were proteins, lipids, starch, sugars and cellulose (Chen and Zhang, 2013; Sydney *et al*., 2011; Confer *et al*., 1995; Sophonsiri and Morgenroth, 2004; Huang *et al*., 2010). These organic matters in domestic wastewater were traditionally characterized by COD, Total Organic Carbon (TOC) and BOD. Elimination of those organic matters was one of the most important targets in wastewater treatment. Therefore, for the apparent reason, the MDP-4 and MDP-8 had higher enzyme activity and might be suitable for sewage treatment.

Evaluation of the enzyme activities by entropy theory: Entropy is the concept of thermodynamics, which was first introduced by Shannon into the information theory and now is widely applied in the engineering, socio-economic and other fields.

In the m factors, n evaluating objects evaluation problem, the entropy of ^{i}th factor is defined (Zou *et al*., 2006) as:

Table 1: The activities of protease, lipase, cellulose and amylase of eight commercial Microorganism Decompose Powders (MDP)

Name	Protease (U/g)	Lipase (U/g)	Cellulase (U/g)	Amylase (U/g)
MDP-1	1333	21	12	330
MDP-2	70	47	13	120
MDP-3	340	64	16	80
MDP-4	10344	329	144	574
MDP-5	1165	30	13	40
MDP-6	254	37	12	30
MDP-7	1713	31	10	30
MDP-8	7737	307	202	597

Table 2: The relating models of enzyme activities of eight commercial Microorganism Decompose Powders (MDP)

	Relating index of model			
Name	Protease	Lipase	Cellulase	Amylase
MDP-1	0.2481	0.3540	0.2578	0.1369
MDP-2	0.2012	0.1763	0.1568	0.1325
MDP-3	0.2522	0.2981	0.2105	0.3021
MDP-4	0.4459	0.3517	0.4622	0.4265
MDP-5	0.1862	0.2321	0.1465	0.2158
MDP-6	0.1454	0.1850	0.3320	0.1852
MDP-7	0.2531	0.2100	0.3124	0.1948
MDP-8	0.2984	0.3547	0.3654	0.3451

Table 3: Evaluation of sewage treatment by microorganism-membrane treatment system with commercial microorganism decompose powder (MDP-4)

Items	Five-day biological oxygen demand (BOD_5, mg/L)	Chemical oxygen demand (COD, mg/L)	Ammonia nitrogen (NH_3-N, mg/L)	Total dissolved salts (TDS, mg/L)
Inner water	6540	13300	853	1700
Outlet water	18.9	84	0.46	31
Removal rate	99.71%	99.37%	99.95%	98.18%

$$H_i = -k\sum_{j=1}^{m} P_u \ln P_u \text{, i = 1, 2, 3…, n} \quad (1)$$

Then select $k = \frac{1}{\ln m}$ plot entropy H_i as:

$$H_i = -\frac{1}{\ln m}\sum_{j=1}^{m} P_u \ln P_u \quad (2)$$

Definition 1: Assuming $X_i \cap X_j = \Phi$, $U(X_i \cap X_j) = h(X_i) \pm H(X_j)$. The $U(X_i, X_j)$ was the degree of relationship of X_i and X_j.

Definition 2: Assuming for arbitrary i, j ($i \neq j$), $X_i \cap X_j = \Phi$, p being arbitrary positive integer, $U(X_1, X_2, \dots, X_p) = \sum_{i=1}^{p} H(X_i) - H(\sum_{i=1}^{p} X_i)$. The $U(X_1, X_2, \dots, X_p)$ was the degree of relationship of X_1, X_2, … and X_p.
The relational index was defined as:

$$U(i,j) = \frac{U(X_i, X_j)}{H(X_j)} \quad (3)$$

From Eq. (2) and (3), the information entropy and relation index could be calculated. The smaller was the information entropy, the smaller the disorder of the system, which indicated that the utility value of the information is greater. On the contrary, the greater was the information entropy, the greater was the disorder of the system, which indicated that the utility value of the information is smaller.

The lipase, protease, cellulase and amylase activities of the eight kinds of commercial microorganisms decompose powders were normalized according Hapke *et al*. (2000) and then were substituted into Eq. (2) and (3) to calculate the relational index of eight kinds of commercial microorganisms decompose powders. The results were shown in Table 2. From the entropy values shown in Table 2, the MDP-4 andMDP-8 had higher entropy values of four kinds of enzymes. Comparison of these two powers, MDP-4 had higher entropy values of protease, cellulase and amylase; however the MDP-8 only had a little higher entropy values of lipase. From these results, the MDP-4 was chosen for the best sewage treatment decompose organisms powder.

Evaluation of sewage treatment by MBR system with MDP-4: The best commercial microorganisms decompose powder, MDP-4, was applied into the BMRs and the efficient was evaluated through measuring the BOD_5, COD, NH_3-N and TDS of the outlet water. And the results were shown in Table 3. The organic matters (BOD_5, COD, NH_3-N) and salts (TDS) of outlet water reached to high removal rate of more than 98%. The removal rate of NH_3-N reached to highest of 99.95%, especially. The removal rate of COD observed in this designed MBR system was higher than that of some reported literatures (Chu *et al*., 2005; Ho and Sung, 2009; Hu and Stuckey, 2006; Huang *et al*., 2011; Salazar-Pelaez *et al*., 2011). The removal of TDS in this designed MBR system was similar to that of some reported literatures (Katz and Dosoretz, 2008; Lee *et al*., 2008; Priyanka and

Surindra, 2011). All of those improved that the designed MBR system and the chosen commercial microorganisms decompose powder (MDP-4) were effective to domestic wastewater treatment.

CONCLUSION

A domestic wastewater treatment system was designed and it combined with biological reactors and membrane technology into a new microorganisms-membrane system. And the commercial microorganism powder was chosen by entropy theory. This system was especially suitable for small islands domestic wastewater treatment. The removal rate of organic matters and total dissolved salt of wastewater reached higher than 98 and 99%, respectively. The quality of outlet water could be satisfied with the demands of miscellaneous domestic water emission standard.

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