



Study of municipal wastewater treatment with oyster shell as biological aerated filter medium

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ABSTRACT

Oyster shell and plastic ball were applied as the media of biological aerated filters (BAF) to treat municipal wastewater in two lab scale upflow BAFs. The results indicated that oyster shell BAF and plastic ball BAF had average chemical oxygen demand (COD) removals of 85.1% and 80.0%, when hydraulic retention time (HRT) was longer than 4 h, and 65.7% and 68% with HRT of 2 h, respectively. In terms of removing ammonia nitrogen ($\text{NH}_3\text{-N}$), oyster shell BAF and plastic ball BAF had average removals of 98.1% and 93.7% for HRT longer than 4 h, and 47.2% and 65.1% for HRT of 2 h, respectively. Total phosphorus (TP) removals of oyster shell BAF were increased to 79.9% and 90.6% as the pH increased to 9 and 10, respectively, while no improvement was observed for plastic ball BAF. The effluent pH of oyster shell BAF was higher and buffered compared with that of the influent, mainly due to the CaCO_3 released from the shell. The oyster shell may also be the main reason to support the BAF a higher $\text{NH}_3\text{-N}$ removal efficiency when HRT was longer than 4 h, compared with plastic ball BAF.

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1. Introduction

Biological aerated filter (BAF) is a novel, flexible and effective bioreactor that provides a small footprint process at various stages of wastewater treatment [1]. BAF was first developed in Europe and then widely applied all over the world as a wastewater treatment system due to its advantages compared to other systems [2]. Stensel and Reiber [3] found that the land required for a BAF system was approximately only one fifth of that needed for plastic medium trickling filters and one tenth of that needed for activated sludge plants. BAF technology is based on the principle of biofiltration through a submerged granular medium that serves two purposes: biological conversion of organic matter by the biomass attached onto the large support medium surface and physical removal of suspended particles by medium filtration. As a promising technology for the decentralised wastewater treatment, BAF removes organic matter, solids and $\text{NH}_3\text{-N}$ in one reactor unit. It can be utilized at both secondary and tertiary stages of wastewater treatment, wastewater reclamation engineering and pretreatment process of newly developed membrane techniques, particularly when low land usage is required in urban areas [4].

Foremost BAFs, as defined by Stephenson [5], contain a granular medium that provides a large surface area per unit volume for biofilm development. The initial purpose of these processes was to obtain

carbon oxidation and solid filtration [6]. In recent years, several technologies using BAF have been developed to treat wastewater from slaughterhouses, pulp, mill industries [7,8], and refractory wastewater such as textile and oil field wastewater [6,9]. In addition, some BAF combination techniques have been studied to treat formalin wastewater and remove nitrogen from low carbon-to-nitrogen wastewater [10,11]. Several model studies have been carried out to improve the performance and theoretical knowledge [12,13].

Medium selection is important for BAF to achieve effluent quality requirements. The media play a key role in maintaining a high amount of active biomass and a variety of microbial populations. The most frequently studied biofilm support media include clay-, schist- or plastic-based ones of various types, such as polyethylene, polystyrene, and polyesterene [14].

Oyster shells are waste product from mariculture and cause a major disposal problem in coastal regions, e.g. southeast China. Shellfish-farming is a large part of the regional economy, since the custom of taking shellfish as a major part of the diet creates a large market of marine products. A large amount of oyster shell is produced every year. Shellfish farms have faced to the problem of disposing oyster shell waste. Oyster shell waste dumped into coastal water or reclaimed land produces a potent smell and disservices surrounding environments. Some of the waste oyster shells are used as limestone in fertilizers and chicken feed, but the usages are limited. The waste oyster shells lead to severe problem of solid waste pollution. Thus, recycle has arisen as an imminent issue in mariculture areas. The ideal solution is to convert the waste oyster shells to a product that is both beneficial and economically viable.

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Table 1
Influent characteristics.

Parameter	Average	Standard deviation (n = 30)
Chemical oxygen demand (COD) (mg/L)	110.4	37.3
NH ₄ -N (mg/L)	28.1	12.4
Total phosphorus (TP) (mg/L)	2.4	0.7
PO ₄ -P (mg/L)	1.7	0.3
pH	7.25	0.2

The purpose of the present research is to study the use of waste oyster shells as a BAF medium. Oyster shell is selected due to its availability, the characteristic shape, good rigidity, outstanding chemical constitutes and biological stability. It is possible that oyster shell releases CaCO₃ into wastewater, since more than 96% of its component is CaCO₃ [15]. The shells supply sufficient alkalinity to enhance the decreasing pH caused by nitrification in BAF. Oyster shell is also good for removing phosphorus from wastewater by producing calcium phosphate precipitation. Moreover, its high roughness surface makes the microorganisms grow and adhere easily. To our best knowledge, this is the first time that oyster shell is used as biofilm carrier in the field of municipal wastewater treatment.

2. Materials and methods

2.1. Wastewater characteristics

The municipal wastewater was collected from a wastewater treatment plant, located at Xiamen University, China. The raw influent was characterized as shown in Table 1.

2.2. Reactor description

Two parallel lab-scale BAF reactors were made of Plexiglas. The reactors were packed with oyster shell and plastic ball, respectively. Waste oyster shells (Fig. 1A) were obtained from a temporary storage near the workplace where oysters were separated from shells. Plastic ball medium (Fig. 1B) was purchased from Tongji University, Shanghai, China. The characteristics of media are listed in Table 2. The reactors (Fig. 2) had an upflow configuration with 1.15 m in height and 0.10 m in inner diameter. The medium was 1.0 m height, with an effective volume of 7.8 L. Since the air was introduced into the reactors with an air diffuser, located at 0.3 m from the downside inlet, an anaerobic area between the air diffuser and downside inlet was formed. The air flow rate was controlled, using an air flowmeter. The

Table 2
The characteristics of the media.

Medium	Diameter (cm)	Packed density (kg/m ³)	Actual density (kg/m ³)	Porosity (%)
Oyster shell	2.0–5.0	250	1390	88
Plastic ball	1.0	95.6	797	82

raw wastewater was pumped into BAF with a peristaltic pump and flowed upward through the filter medium layer. The flow rate ratio of air to water was controlled at 5:1.

The two BAFs were backwashed using a counter-current manner to remove the accumulated suspend solid (SS) and the excess biomass periodically. Backwashing process was designed as follows: after shutting off the feeding valves of the BAFs at the first washing step, air was introduced for 3 min from the bottom of the filter; in the second step, the effluent was transported into the BAFs from the top and the air was sent into the BAFs from the bottom for 5 min; then in the third step the effluent was again introduced back into the top of BAFs for 3 min. The backwash air and water velocities of two BAFs were 13–15 L (m²s)^{−1} and 4–5 L (m²s)^{−1}, respectively.

2.3. Analytical methods

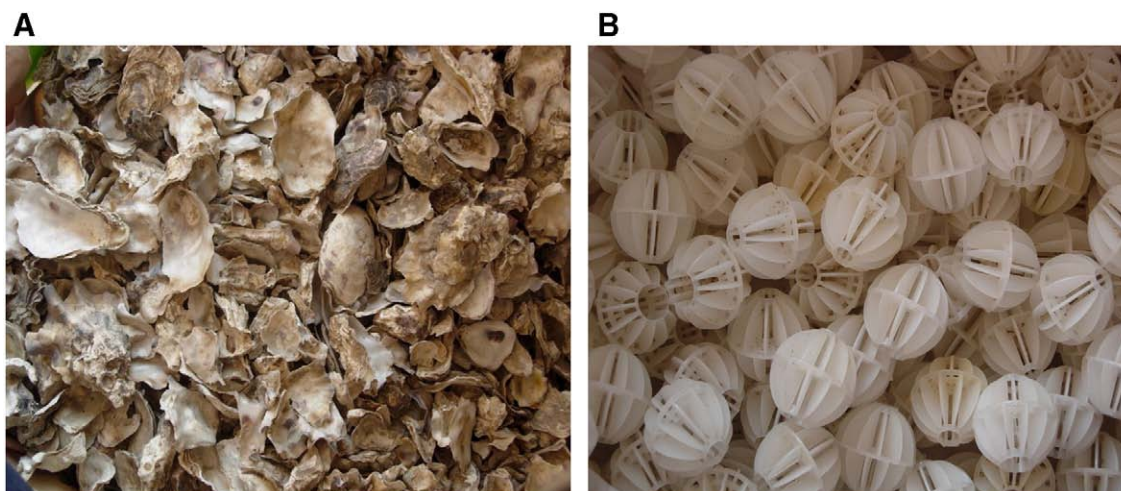
During the study, influent and effluent samples were taken regularly and the concentrations of COD, NH₃-N, and TP were tested according to the standard methods [16]. A pH meter (CyberScan pH510, Eutech Co., U.S.A.) was used to measure temperature and pH. A probe (HI9146, Hanna Co., Italy) was used to measure dissolved oxygen (DO).

3. Results and discussion

Throughout the study, the two BAFs were operated at the conditions of water temperature ranging from 17.3 °C to 23 °C and DO ≥ 2 mg/L. Four HRTs, 12 h, 8 h, 4 h and 2 h were adopted, coincided with hydraulic loadings 0.071, 0.11, 0.22 and 0.44 m³/m²h, respectively. The changing trends of COD, NH₃-N, TP and pH of the influent and effluent are shown in Figs. 3–7.

3.1. COD reduction in two BAFs

From Fig. 3, it was found that two BAFs both processed excellent removals towards COD. Oyster shell BAF had a slightly higher COD removal efficiency compared with plastic ball BAF at HRT longer than

**Fig. 1.** Photos of media. A: Oyster shell. B: plastic ball.

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