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Efficiency of a Bed Biofilm Reactor Using a LECA Carrier to Treat Hospital Wastewater

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Abstract

Hospital wastewater is of great environmental concern because it contains a variety of hazardous microbial and chemical substances. This study aims to investigate the efficiency of a moving bed biofilm reactor (MBBR) with a light expanded clay aggregate (LECA) carrier for treating hospital wastewater. This pilot study used a Plexiglas reactor that had a volume of 100 L, a continuous upflow hydraulic regime, and a LECA carrier to test removal of chemical oxygen demand (COD) from wastewater in a public hospital. To assess MBBR efficiency, the study used retention times of 8, 12, and 24 hours, filling percentages of 30% and 50%, and mixed liquor suspended solids (MLSSs) of 1000, 3000, and 5000 mg/L. The results indicated that using a single LECA carrier in an MBBR system was not sufficient to remove organic materials from hospital wastewater, because the carrier could not be completely suspended. After some modifications, consisting mainly of returning activated sludge, the system was 83% efficient at removing COD using a LECA carrier at a retention time of 24 hours, with 50% filling, and 5000 mg/L of MLSS.

Keywords: Moving Bed Biofilm Reactor, Hospital Wastewater, LECA Carrier

1. Introduction

Wastewater is a major cause of contaminated water resources. To avoid such contamination, wastewater must be properly collected, treated, and returned to the water cycle. Hospital wastewater has a wide range of pathological micro-organisms, chemicals, hazardous substances, radioactivity, and organic and inorganic compounds (1). If hospital wastewater is discharged into absorbing wells or urban wastewater systems, it can contaminate water resources (2).

Several approaches have been used to treat hospital wastewater. Hazrati et al. evaluated a treatment for hospital wastewater that combined pre-ozonation and coagulation with a flocculation process using coagulants and coagulant aids (poly aluminum chloride and cationic polyelectrolyte). They found that 200 mg/L of poly aluminum chloride and 1 mg/L of cationic polyelectrolyte removed chemical oxygen demand (COD), biological oxygen demand (BOD5), and total suspended solids (TSS) at efficiencies of 84%, 81%, and 50%, respectively. In addition, pre-ozonation at a rate of 19.8 gO_3/hour for 15 minutes removed COD, BOD5, and TSS in the coagulation and flocculation process at efficiencies of 87%, 54%, and 89%, respectively (3). In a study of performance of wastewater treatment plants at medical sciences universities in Iran, Dehghan et al. found that three treatment plants had extended-aeration, activated-sludge treatment systems and one had a fixed film-activated, integrated-sludge system. None met the BOD5 and COD standards for effluents (4).

In recent years, the use of biofilm systems to treat wastewater biologically has increased worldwide (5). Moving bed biofilm reactors (MBBRs) have gained popularity to treat a wide range of wastewater from hospitals and industries because of the following features of these systems: 1, the treatment is continuous; 2, the system has no fouling, no need for backwash, and no need to return the sludge; 3, the biofilm has a low hydraulic decline and a high specific area; 4, the system is highly efficient, having no canalization or accumulation of flow; 5, the process offers flexible design, convenient navigation, and control; 6, the process is highly stable and resistant to a variety of shocks; 7, the system is small and coherent and has low operational and capital costs (6, 7). A light expanded clay aggregate (LECA) carrier consists of light, expanded clay grains, obtained by expanding clay in rotary kilns at a temperature of about 1200°C. LECA's remarkable features include light weight, low heat conductivity, resistance to fire, chemical durability, and stability. Its light weight and high specific area (about 525 m^2/m^3) have resulted in use of this aggregate in various units in water- and wastewater-treatment plants. Chemically, these aggregates contain 66% SiO_2, 17%

Al2O_3, 7% Fe_2O_3, and 2.5% CaO, Mg, Ti, Na and K compounds. However, use of these aggregates at large scales with high aeration crushes a portion of the carriers' volume, which can result in strategic problems in the unit (8, 9). The main reason for the lightness of LECA grains is the presence of air both inside and between the grains. Given the shell grading, this air occupies 73% - 88% of the entire space (8).

Nori et al. (2008) investigated the extent of surfactant removal by an MBBR system using a LECA carrier. Their study used three 5-L reactors to study the efficiency of removing sodium dodecyl benzene sulfonate (SDBS), sodium dodecyl sulfate (SDS), and cetyl trimethyl ammonium bromide (CTAB) at various retention times. The results showed that the best efficiency was achieved under batch-loading conditions with 50% of the reactor volume of the LECA carrier filled. The study obtained efficiencies of 90.95% and 93%, respectively, for SDBS (at COD = 900 mg/L), SDS, and CTAB (both at COD = 1200 mg/L), (8). In addition, using a LECA carrier in an MBBR reactor, Kavoosi et al. (2005) achieved 82% removal of soluble COD under an input load of 1.766 kg COD/m_2 at the retention time of 24 hours (9).

The ever-increasing need for higher-quality wastewater output to preserve the quality of surface water has resulted in a greater tendency to use hybrid systems (10). The efficiency and performance of hybrid systems have been proven to remove various contaminants, and many studies have been conducted at various scales on these systems. More operational and executive information is needed to increase the efficiency of removing various contaminants from hospital wastewater. Therefore, this study aimed to investigate the efficiency of an MBBR for removing organic compounds from hospital wastewater.

2. Materials and Methods

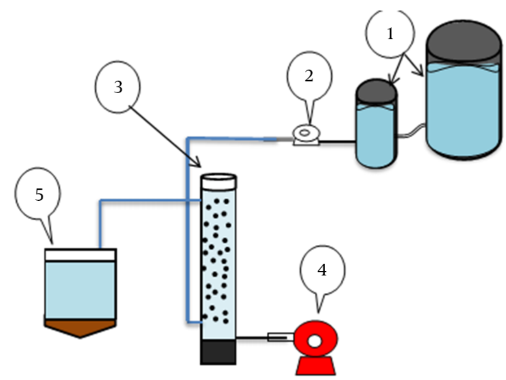
2.1. Reactor

This pilot study used a bioreactor with a moving bed that had a 100-L volume. The reactor was cylindrical and made of Plexiglas. Its inner diameter was 30 cm and its total height 150 cm, giving it an effective volume (the volume of the fluid available inside the reactor aside from the volume of the reactor) of 95 L. The air required to provide soluble oxygen and rotate the bed's materials throughout the reactor's volume was provided by an air compressor through tubes added to the bottom of the reactor. Figure 1 shows the overall outline of the pilot reactor.

2.2. Bed Specifications

The study used a bed consisting of mineral shells, modified with clay (LECA), having a specific weight of 0.25 - 0.35 g/m^3, a diameter of 8 - 12 mm, and a specific growth surface of 500 m^2/m^3. Figure 2 shows a schema of the carriers.

Figure 1. The Outline of the Pilot Reactor



1, Wastewater injection tanks; 2, peristaltic pump; 3, bioreactor; 4, air compressor; 5, secondary sedimentation tank.

Figure 2. LECA Carriers

2.3. Method

This study used fillings of 30% and 50%, retention times of 8, 12, and 24 hours, and concentrations of 1000, 3000, and 5000 mg/L of mixed liquor suspended solids (MLSS) to investigate the extent of COD removal from hospital wastewater. It should be noted that the parameters for dissolved oxygen, temperature, and pH were 2 - 3.5 mg/L, 25 - 27°C, and 7.3 - 8.5, respectively, and were regularly controlled to maintain conditions conducive to the microorganisms' biological activities. All experiments were conducted according to the standard method for water and wastewater testing (11) and were conducted twice to check their accuracy.

3. Results and Discussion

3.1. Effects of Retention Time and Filling Percentage

Figure 3 shows the mean of the measurements of efficiency and retention time for each test condition. The removal efficiencies obtained for COD removal with a LECA bed at 30% filling and at retention times of 8, 12, and 24 hours were 49%, 56%, and 67%, respectively. At 50% filling, the removal efficiencies were 60%, 50% and 71%, respectively. One of the most important parameters for purifying organic compounds in biological systems is the retention time. Various studies have shown that removal efficiency increases with increased retention time.

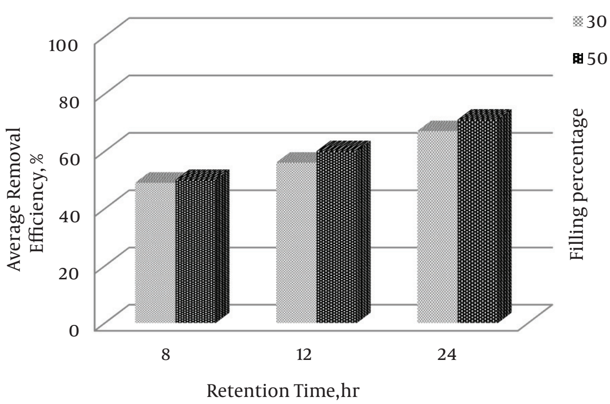


Figure 3. Effects of Hydraulic Retention Time and Filling Percentage on Removal Efficiency of COD (MLSS Concentration in This Mode Was 1000 mg/L)

When the amount of COD in wastewater entering the reactor is high, increased retention time reduces the amount of COD in the effluent. The optimal retention time is important, as is the size and number of reactors used and the amount of aeration. Ayati et al. compared the retention time required in an MBBR system with the time required by other conventional treatment systems under the same conditions and found that the retention time for the activated-sludge system, the extended-aeration system, the sequencing batch reactor (SBR) system, and the MBBR system were 4 - 8, 18 - 36, 8 - 36, and 1 - 2 hours, respectively (12).

While they require lower retention times, MBBR systems have some operational problems that decrease their efficiency, including sedimentation and the fact that the carriers are not completely suspended in the reactor (13). In the current study, incomplete suspension of the LECA carrier and its resulting lack of contact with the wastewater, along with the air inside the reactor, may be the main reasons for the LECA carrier's low efficiency. To increase its efficiency, longer retention times are needed; however, longer hydraulic retention times require increased bioreactor volumes and increased aeration rates, both of which increase the economic and capital costs (6).

$$\frac{Theremovalefficiencyafterthewithdrawlofsuspendedmicrobialmass}{Thetotalefficiencyofthesystem} = \frac{12}{60} \times 100 = 20 \quad (1)$$

3.2. Effect of MLSS

Figure 4 shows the influence of MLSS concentration on COD removal efficiency. As MLSS increased from 1000 to 3000 to 5000 mg/L, the removal efficiency increased from 35% to 71% to 83%, respectively. An important advantage of the MBBR system is that the return-activated sludge is not required because of the crucial role of attached microbial mass (biofilm) in treating pollutants (7). To overcome the fact that the LECA carrier was not fully suspended in the reactor due to low density and the resulting inappropriate growth of biofilm on the carrier, the amount of return-activated sludge needed to be increased (9); however, doing so resulted in increased operational costs and problems in the field scale.

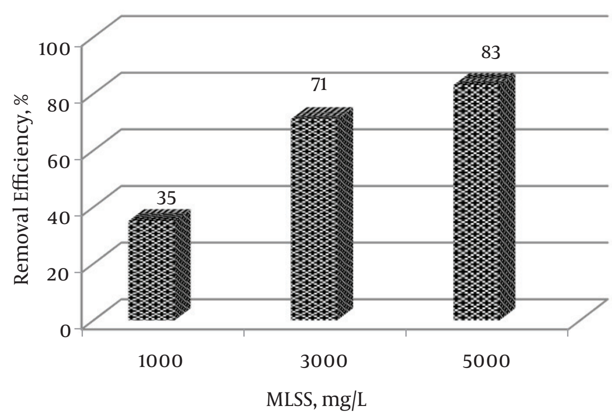


Figure 4. Effect of MLSS Concentration on COD Removal Efficiency (in This Mode, Hydraulic Retention Time and Filling Percentage were 24 Hours and 50%, Respectively)

To examine the effects of attached microbial biofilm and suspended mass, the reactor was 50% filled with the LECA carrier and the effect of removing each of the biomasses at the retention time of 12 hours was assessed. Based on the values obtained from equations 1 and 2 below (9, 14), it was concluded that only a very small portion (12%) of the biofilm that formed on the part of the LECA carrier in constant contact with the wastewater was effective in removing organic compounds, while a great percentage of the removal was related to mixed liquor volatile suspended solids (MLVSS).

To calculate the contribution of the suspended mass in the total efficiency of the systems, we can use the following relationship.

$$100 - 20 = 80 \quad (2)$$

where 100, 20, and 80 are the overall contributions of mass, attached mass, and suspended mass in the reactor respectively.

Considering that suspended microbial growth contributed more than did attached growth or high flow, return of the sludge in the system was required to achieve a desirable efficiency (9). This may be one of the disadvantages of using the LECA carrier in this method of treating hospital wastewater.

4. Conclusions

Since biofilm plays an essential role in degrading pollutants in MBBR systems, any challenge to the growth of biofilm reduces the efficiency of the treatment process. The present study showed that a reactor using a LECA carrier could not effectively remove organic matter from hospital wastewater. The LECA carrier insufficiently mixed with the wastewater, reducing the contact between itself and both the influent wastewater and diffused air, which, in turn, significantly decreased the surface area available for biofilm growth. Thus, it seems that the system tested cannot achieve WHO standards for COD in effluent wastewater. While increasing the sludge-recycling rate and the hydraulic-retention time appeared to enhance COD removal, this strategy is not cost-effective when applied at a real-world scale.

Footnote

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