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Research Article

INVESTIGATING THE PERFORMANCE OF MOVING BED OR BIOFILM REACTOR IN THE REMOVAL OF OIL AND GREASE FROM BESAT HOSPITAL WASTEWATER

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Key words: Moving bed biofilm reactor, Oil and grease, Hospital wastewater.

ABSTRACT

Background and objective: Hospital wastewater is a special significance in terms of health when compared with other types of wastewater due to the presence of hazardous agents. If this wastewater is introduced into wastewater collection system by treating it incompletely, it causes of several problems like imbalance of biological systems for urban wastewater treatment plant. Oil and grease are among the main compounds of wastewater and can cause overflowing of wastewater from sewers. The aim of this study is to investigate the efficiency of moving bed biofilm reactor (MBBR) system in removing oil and grease from hospital wastewater.

Materials and Methods: This study was carried out at pilot scale with a continuous hydraulic flow of hospital wastewater and the effect of filling percentage of K1 media, hydraulic retention time, MLSS concentration and COD was investigated with the results analyzed by SPSS 19.

Findings: Based on the results, the greatest efficiency of oil and grease removal as well as COD via K1 media, with a retention time of 24 h and filling percentage of 70%, was 98.9 and 95.6%, respectively.

Interpretation and Conclusion: The MBBR system with K1 media can decrease the concentration of oil and grease in wastewater down to standard levels.

INTRODUCTION

The output wastewater of hospitals contains different pathogenic microorganisms, drug compounds, hazardous toxic compounds, solid wastes, radioactive chemicals, and radioactive isotopes. The discharge and introduction of these compounds into the human environment specially to surface and groundwater cause major risks and problems for human beings (Sharafi, *et al.*, 2014). Among the compounds present in these wastewaters are oil and grease. The oil and grease in collection and treatment systems create some problems, where through sedimentation in sewers they cause clogging of pipes and overflow of wastewater from sewers (Williams, *et al.*, 2012). According to the estimation by EPA in the US, 74% of overflow of health wastewater is caused by coagulation of oil and presence of fat, oil and grease (FOG) (Iman, *et al.*, 2014). Moreover, the oil and grease are relatively resistant and stable organic compounds which are not easily biodegradable and are not treatable either using conventional methods (Xinhua and Xiangfeng, 2004). Hence, collection and treatment of this type of wastewater using a systematic method are necessary. Although biological methods of suspended type such as activated sludge are effective in removing organic

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carbon and nutrients from urban wastewater, they result in some problems including sedimentation of sludge, requiring a larger sedimentation tank and reactor, and circulation of biomass. Nevertheless, biofilm systems do not have these problems and can be applied with certainty for removing organic carbon and nutrients. As we know, there are two technologies for biological treatment of wastewater: activated sludge and trickling filter. MBBR is a combination of these two processes (Borkar, *et al.*, 2013).

This system enjoys the advantages of both states of attached growth and suspended growth including small and compressed size of the system, complete removal of solids, improved sedimentation, stability of the system, no fouling of the filters, and reduced sludge production (Diez, *et al.*, 2013). Moreover, in terms of attached growth, they have the advantages of good transfer of oxygen, autoregulation of the thickness of the biofilm and simple distribution of the liquid flow in raw wastewater (Lee, *et al.*, 2004). Therefore, as the efficiency and performance of combinational systems for removing different pollutants have been proven and many studies have been carried out on these systems at various scales and reported in literature, the efficiency of MBBR system for treating hospital wastewater and removing oil and grease from hospital wastewater has remained understudied. This research was conducted with the aim of investigating the efficiency of MBBR system for removing oil and grease from hospital wastewater. (Galgale, *et al.*, 2010) investigated the performance of MBBR in removing phenol and TDS where they utilized an 8-L plexi glass and a bed with a diameter of 16 mm, length of 16 mm and area of 339 m^2/m^3. The COD removal efficiency in an HRT of 44 h was obtained as 97.44% and TDS was achieved as much as 88.36% (Galgale, *et al.*, 2010). Asmita. sh- *et al.*, (2013) investigated the efficiency of MBBR in removing nutrients from wastewater. The system had the ability to remove PO_4-P by 65.9%, NH_4-N by 75%, DOC up to 95.8%, and COD up to 91.1% (Shrestha, 2013). Diez, *et al.*, (2012) examined the performance of an MBBR system in treating wastewaters containing oil and grease, where at COD loading of 5.1 kg COD/m^3. d, the COD removal efficiency was achieved as 97% (Diez, *et al.*, 2012). (Dong, *et al.*, 2012) studied the performance of MBBR of membrane filtration in treating wastewaters containing azo dye reactive brilliant red X-3B-. In this study, two reactors with 35% of suspended biofilm were used. Eventually, it was found that the system had the ability to remove dye, COD, and SS by 90, 85, and 94%, respectively, and thus had a desirable performance (Dong, *et al.*, 2012). (Colic, *et al.*, 2008) explored the performance of MBBR in treating candy production wastewater where UASB and MBBR were utilized for the treatment. They observed that the system removed almost all oil, grease, TSS, and BOD (Colic, *et al.*, 2008).

MATERIALS AND METHODS

In this research, a 100-L bioreactor of plexiglass was used as pilot. The dissolved oxygen is provided by two compressors. The pilot intended in this research includes 1. Waste water storage tank, 2. Peristaltic pump, 3. MBBR reactor, 4. Aeration pump, and 5. Sedimentation tank. The outline of the pilot is illustrated in (Fig. 1 and 2), Tables 1 and 2. The media used in this research is of K1 type (Kaldnes), with the following specifications (Ødegaard, 2006).

Launching the reactors

At the beginning of the launching, 30% of the reactor

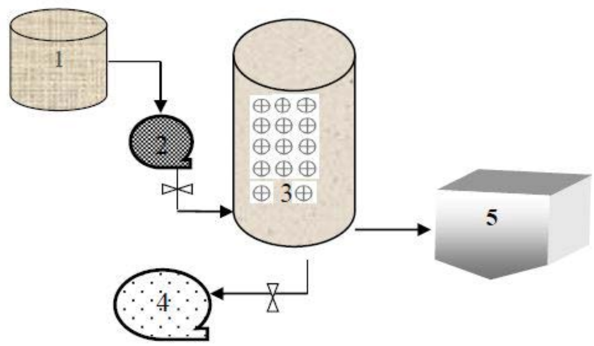

Fig 1. The outline of the pilot.

Table 1. The specifications of the utilized reactor.

Value	Property
105 lit	Total volume
91 lit	Effective volume
150 cm	Total height
130 cm	Overflow height
30 cm	diameter
4 mm	thickness

Fig 2. Outline of the k1 Kaldnes media.

was filled with Kaldnes Media, one third with the sludge returning from the secondary sedimentation basin of the hospital treatment plant, and the rest was filled with raw wastewater. The reactor was thereafter exploited in a batch way. Next, utilizing air pump and adjustment of aeration, the dissolved oxygen was adjusted between around 2 and 3.5 mg/L. By regulating the input flow rate to the reactor, the hydraulic retention time was altered and by manually adding biological sludge deposited in the secondary sedimentation basin devised in the intended pilot, the concentration of suspended solids was also adjusted. The pH of wastewater in this investigation was within the range of 7.3-8.5 and the temperature was adjusted between 20 and 25°C. In order to accelerate the growth of biofilm, dry milk with a concentration of 33 g/L was utilized 5 times for 20 days. After 10 weeks, a sensible growth was observed on the Kaldnes Media. At this stage, the reactor was shifted to continuous state to investigate the degree of removal of oil and grease from hospital wastewater across different conditions (Fig. 3).

Table 2. The specifications of the media of k1 type.

Value	Property
0.92-0.96 g/cm^3	Specific weight
7 mm	thickness
10 mm	diameter
Poly propylene-poly ethylene	material

Fig 3. Outline of the media-containing reactor.

First, at filling percentage of 70% and retention time of 12 h, a wastewater containing oil and grease equal to 187 mg/L was fed into the reactor. After 48 h (four times the retention time), the output concentration was measured, which was obtained as 18 mg/L. In the next stage, the total liquid present in the reactor, i.e., suspended liquid suspension, was removed from the system and a wastewater was introduced to the reactor with the same initial concentration. At the same retention time following 48 h, the output concentration was measured, calculated as 80 mg/L. In order to measure oil and grease, gravimetry method was utilized and to measure COD, Closed method was utilized based on 5220B instruction (APHA A, WEF, 1999; Borgeei, *et al*., 2011).

RESULTS AND DISCUSSION

Parameters influencing oil and grease removal

1. The effect of hydraulic retention time: Based on the results obtained from (Fig. 4), there is a significant relationship between the hydraulic retention time in the efficiency of MBBR system for the removal of oil and grease from hospital wastewater with K1 Media (p-value <0.05). With increase in hydraulic retention time from 8 to 12 and then to 24 h, the efficiency grew from 80.67 to 86.8 and then to 91.3%. So, 24 h is the optimal hydraulic retention time for removing oil and grease from hospital wastewaters using K1 Media with a filling percentage of 70% (Fig. 4).

2. The effect of filling percentage: Based on the results obtained from (Fig. 5), there is a significant relationship between the percentage of K1 Media for the removal of oil and grease from hospital wastewater by the MBBR system (p-value <0.0001). With increase in the filling percentage from 30 to 50 and then 70, the efficiency increased from 76.33 to 88.23 and then to 94.83%.

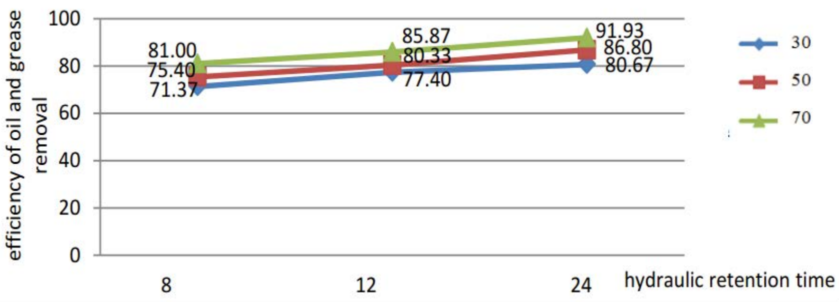

Fig 4. The diagram of efficiency of oil and grease removal versus hydraulic retention time by individual concentration of microorganisms.

Is a significant relationship between the concentration of suspended microorganisms in the efficiency of MBBR system for the removal of oil and grease from hospital wastewater with K1 Media (p-value <0.05). With increase in the concentration of microorganisms, the removal efficiency increases (Fig. 6). According to the results presented in the Table 3, there is a significant relationship between hydraulic retention time, concentration of microorganisms, and filling percentage with the output of oil and grease and their removal efficiency.

Parameters influencing COD removal

1. The effect of hydraulic retention time: Based on the results obtained from (Fig. 7), there is a significant relationship between the hydraulic retention time in the efficiency of MBBR system for the removal of COD from hospital wastewater with K1 Media (p-value <0.05). With increase in the hydraulic retention time from 8 to 12 and then to 24 h, the efficiency increased from 75.96 to 81.5 and then to 88.46%. The 24 h is thus the optimal hydraulic retention time for the removal of COD from hospital wastewater using K1 Media with filling percentage of 70%.

2. The effect of filling percentage: According to the results presented in (Fig. 8), there is a significant relationship between the filling percentage of K1 Media for the removal of COD from hospital wastewater by MBBR system (p-value <0.0001). With increase in the filling percentage from 30 to 50 and then to 70%, the efficiency increased from 72.33 to 82.8 and then to 90.8%.

3. The effect of the concentration of microorganisms: According to the results obtained from (Fig. 9), there is a significant relationship between the concentration

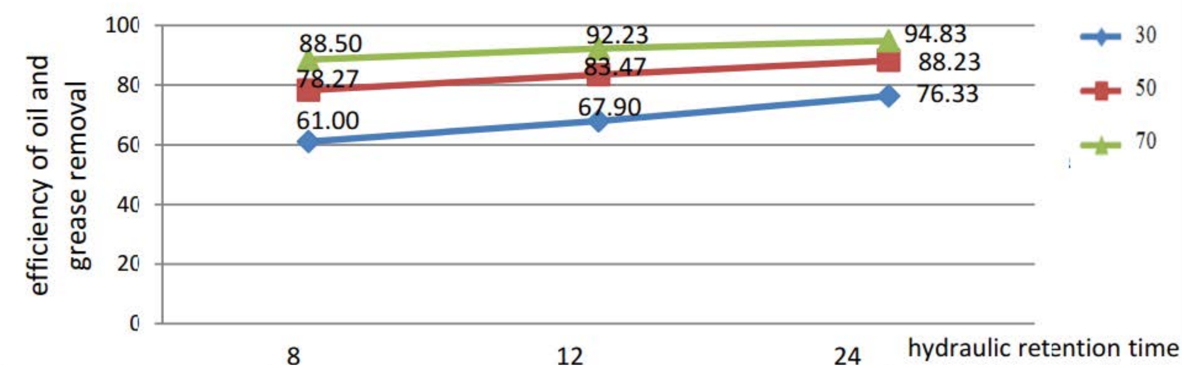

Fig 5. The diagram of efficiency of oil and grease removal versus hydraulic retention time by individual filling percentage.

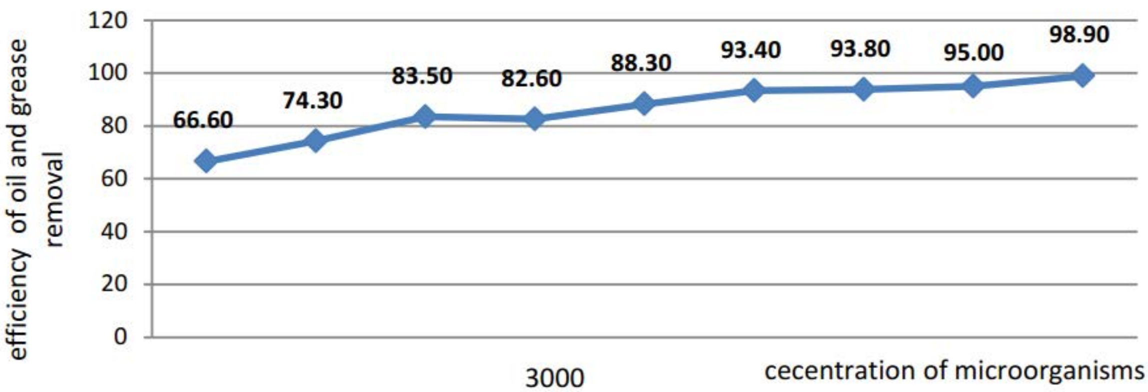

Fig 6. The diagram of the efficiency of oil and grease removal versus the concentration of microorganisms.

Table 3. The spearman correlation oil and grease output and oil and grease removal efficiency.

P-value	Spearman correlation	Dimensions	Parameters
0.010	-0.350	Oil and grease output	Hydraulic retention time
0.006	0.370	Oil and grease removal efficiency	
0.004	0.382	Oil and grease output	The concentration of microorganisms
0.009	0.352	Oil and grease removal efficiency	
<0.0001	-0.839	Oil and grease output	Filling percentage
<0.0001	0.845	Oil and grease removal efficiency	

of suspended microorganisms in the efficiency of MBBR system for the removal of COD from hospital wastewater using K1 Media (p-value <0.05). With the increase in the concentration of microorganisms, the removal efficiency increases.

According to the results presented in the Table 4, there is a significant relationship between hydraulic retention time, concentration of microorganisms, and filling percentage with output COD and its removal efficiency. According to the results presented in the Table 5, there is a significant relationship between the removal efficiency of oil and grease and COD. (Hebbar and Jayantha, *et al.*, 2014) investigated the removal efficiency of oil and grease from output wastewater of facilities such as restaurants, hotels, cafeterias, etc. using Laterite grain column at a real scale. They monitored parameters including the column's height, the size of grains, and flow rate. The results of their investigation revealed that oil and grease was reduced by over 97.6% (Hebbar and Jayantha, *et al.*, 2014). (Sindhi and Shah, 2012) investigated the performance of MBBR in removing BOD and COD at laboratory scale. During a retention time of 20 min and sedimentation time of 4 h, the removal efficiency was achieved as 60-64 and 80-85%, respectively (Sindhi and Shah, 2012). (Zafarzadeh, *et al.*, 2011) examined the efficiency of MBBR containing Kaldnes Type 1 media in removing organic and nitrate compounds under limited conditions of dissolved oxygen in wastewater. The

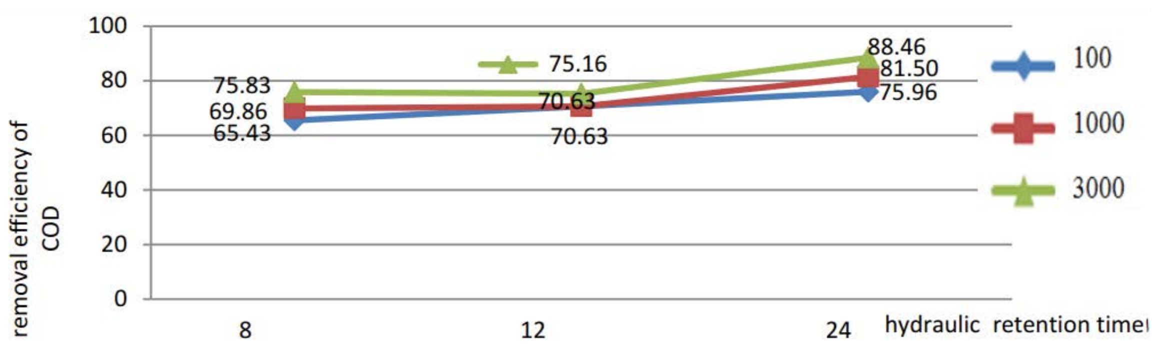

Fig 7. The diagram for the removal efficiency of COD versus hydraulic retention time by individual concentration of microorganisms.

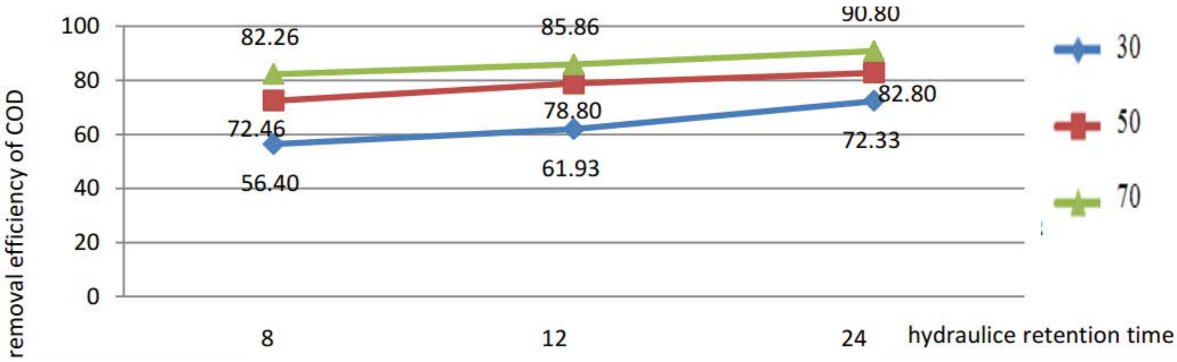

Fig 8. The removal efficiency of COD versus hydraulic retention time by individual filling percentage.

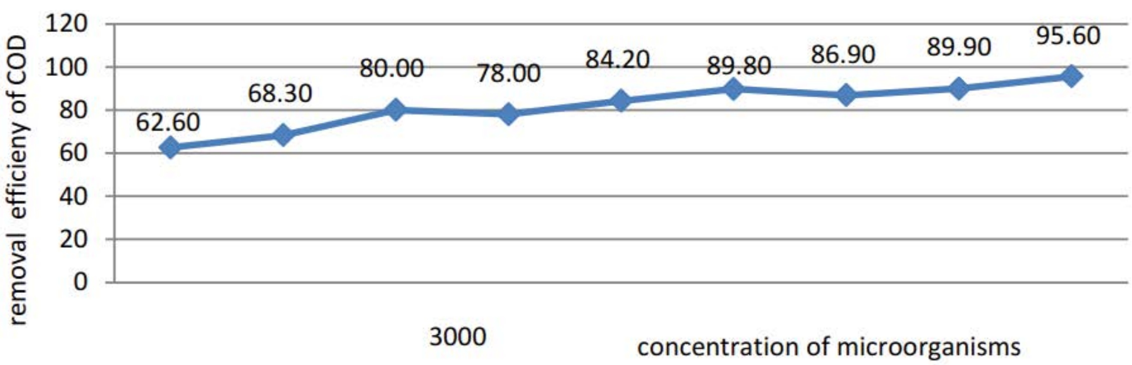

Fig 9. The diagram for the removal efficiency of COD versus concentration of microorganisms.

Table 4. The Spearman correlation of output COD and Removal efficiency of COD.

P-value	Spearman correlation	Dimensions	Parameters
0.005	-0.379	Output COD	Hydraulic retention time
0.003	0.396	Removal efficiency of COD	
0.002	0.413	Output COD	The concentration of icroorganisms
0.004	0.384	Removal efficiency of COD	
<0.0001	-0.804	Output COD	Filling percentage
<0.0001	0.815	Removal efficiency of COD	

Table 5. The correlation coefficient of oil and grease removal efficiency and removal.

Removal efficiency COD	Oil and grease removal efficiency	Parameters
1	0.994	Correlation coefficient
2	< 0.0001	P-value

greatest removal efficiency was achieved as much as 92% at a loading of 0.127-0.181 mg/m^2 day based on the biofilm area in an anoxic reactor in the presence of organic carbon (Zafarzadeh, *et al*., 2011). In the research carried out by (Kavoosi and Borgheei, 2005), for biological treatment of wastewater using pumice as the support of biofilm in MBBR, it was found that the ability for COD removal was as great as 82%, and if retention time was lengthened from 12 to 16 and then to 24 h, the efficiency increased from 66 to 76 and then to 82% (Kavoosi and Borgheei, 2005). According to the research conducted by other researchers including (Delnavaz, *et al*., 2008) the on treatment of aniline-containing wastewater with MBBR, with filling percentages of 30 and 50, COD removal efficiency was as great as 83 and 85% respectively, with increase in the filling percentage, the removal efficiency also increased. The largest COD removal efficiency was achieved as 91% at a hydraulic retention time of 72 h and filling percentage of 50%. In order to investigate the effect of attached and suspended microorganisms in removing aniline, via the discharge of wastewater, the suspended microorganisms were discharged out of the reactor and the removal efficiency was examined by the biofilm attached to the Medias. At 72 h, removal efficiency was achieved as 82%, showing an 8% decrease when compared with the period before reactor discharge. This suggested the major role of microorganisms in removing aniline (Delnavaz, *et al*., 2008). In a research carried out by (Andreottola, *et al*., 2003) where the concurrent efficiency of active carbon and MBBR was investigated, it was observed that COD removal efficiency increases with increase in the hydraulic retention time (Andreottola, *et al*., 2003.

CONCLUSIONS

Based on the investigations, the following conclusions were obtained:

1. According to the available diagrams, with the increase in retention time, filling percentage, and concentration of microorganisms, the system efficiency was enhanced.

2. According to the obtained efficiencies, it can be stated that MBBR system has a good efficiency for the removal of oil and grease and COD of hospital wastewater.

3. Considering the efficiencies obtained at different input concentrations of oil and grease and COD to this reactor, it was found that this system enjoys a high stability in its performance for removing oil and grease and organic compounds from hospital wastewater.

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