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Treatment of Medical Wastewater by Moving Bed Bioreactor System

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ABSTRACT
The hospital wastewater is considered as a complex mixture, populated with microbial and a variety of toxic substances. The performance of EEC USA moving bed biofilm reactor (MBBR) with polyethylene media as biofilm support carrier, packaged wastewater treatment plant with a capacity of 250 m^3/day was evaluated for treating the wastewater from Al-Batul hospital of Baquba city in Iraq in terms of the organic matter and suspended solid removal, along with nitrification and microbial growth for medical wastewater. The test results showed that the average removal efficiency of biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and total suspended solid (TSS) were 79.5%, 74.5%, and 78%, respectively. The system offers good nitrification with the efficiency of 79%. The system shows a weak formation of biomass on carriers, only 1.93 g TSS/m^2 of media, corresponding to 32% of the suspended biomass in the reactor.

Keywords: MBBR, BOD removal, COD removal, SS removal.

INTRODUCTION

Several provenance of sewage could contribute to the load of pollutants discharged in water bodies, especially medical sewage (Tatiana et al., 2011). In general, hospitals are characterized by higher wastewater streams than conventional households (400–1200 l/bed.d vs. 100 l/capita.d) (Gautam et al., 2007; Suarez et al., 2009).

The hospital wastewater is considered as a complex mixture, populated with pathogenic microorganisms. The hospital wastewater additionally contains an assortment of harmful substances, for example, pharmaceuticals, radionuclide, solvents, and disinfectants for medical purposes in an extensive variety of concentrations due to laboratory and research activities or medicine excretion (Verlicchi et al., 2010). The contact of hospital poisons with aquatic ecosystems leads to the damage of the natural environment and creates a biological imbalance (Emmanuel et al., 2005; Kajitvichyanukul et al., 2006). The hospital waste poses a serious health hazard to the health workers, public and air flora in the area (Ekhaise and Omavwoya, 2008).

Wastewater treatment is a major term, which is utilized in relation to the processes and operation to reduce the harmful properties of wastewater in order to make it less hazardous to humankind and nature (Punmia et al., 2003).

Biological processes are a cost-effective and environmentally sound alternative to the chemical treatment of wastewater (Borkar et al., 2013). The activated sludge and trickling filters are two common technologies utilized for the biological treatment of sewage. A moving bed biological reactor (MBBR) is a combination of these two technologies. Two forms of biomass exist in an MBBR system, involving suspended flocks and a biofilm attached to carriers. It can be operated at high organic loads and it is less sensitive to hydraulic overloading (Pal et al., 2016). It is not quite the same as activated sludge due to retained biomass, attached to media. The process has been utilized for the treatment of both municipal and industrial wastewater. Today, there are around 600 MBBRs that have been introduced in 50 unique nations all around the world. Installations are executed for different treatment purposes such as organic removal, nitrification, and denitrification for both the municipal and industrial wastewater (McQuarrie et al., 2011); (Ødegaard, 2000).

Both the suspended and attached growth processes have their advantages and disadvantages. The attached growth method has been considered as most favorable due to small footprint, minimum equipment maintenance and simpler operation in relation to the suspended growth method (Westerling, 2014). Furthermore, the attached film system has no fouling, no need for backwash, and no need to return the sludge. The biofilm has a low hydraulic decline and a high specific area. The process offers flexible design, which is highly stable and resistant to a variety of shocks (Biswas et al. 2014). Due to these reasons, the moving bed biofilm reactor has been progressing by Anoxkaldnes in Norway in the late 1980s and early 1990s (Ødegaard, 1999).

The main aim of this study is to evaluate the performance of a MBBR compact system with polyethylene media as a biofilm support carrier in terms of the organic matter and suspended solid removal, along with the nitrification and microbial growth for the medical wastewater from Al-Batool Teaching Hospital in Baquba city of Iraq.

MARERIAL AND METHODS

Full-scale system and wastewater

Experiments were done in the period from 1st January 2017 to 15th April 2017. The raw wastewater from Al-Batool hospital was used as the influent wastewater for all experimental works during this study. This work correlated with the operating continuous stages of a full-scale MBBR for the treatment of raw hospital wastewater, and then it was conducted at EEC USA packaged wastewater treatment plant with a capacity of 250 m^3/day, in the Al-Batool Teaching Hospital of Baquba city, Iraq. The system used was a packaged wastewater treatment plant that incorporates Assisted Moving Bed Biomedia, Tequatic Plus tertiary filtration (Tequatic Filter, and Ultraviolet Disinfection (UV). Figure 1 shows the schematic of EEC USA packaged MBBR system. The EEC wastewater treatment plant technology is based on assisted moving bed (AMB) process and includes two moving bed bioreactors in series, followed by an integral clarifier, all in a single, packaged plant.

Water is delivered to the MBBR via a feed pump located in the equalization tank on site to the first chamber of the system. The first chamber functions as a "roughing reactor" to shave peak wastewater loads and remove the majority of influent biological oxygen demand (BOD) from the wastewater; the second chamber is a polishing reactor designed to reach the required effluent BOD; and the third chamber is a combined clarification and settling system designed to remove total suspended solids (TSS) from the treated water to the sludge tank, as well as to recycle the residual BOD back to the first chamber for reprocessing. Each reactor was aerated via a coarse bubble air distribution, located at the bottom. High-efficiency regenerative blowers were used to supply air in order to provide oxygen to the biomass and mixing of biomedia.

The (AMB) Biomedia was a specially designed biofilm carrier element which is free floating in each of the reactors and has a large surface area effectively, 500 m^2/m^3 of media volume, on which a stable biomass can grow, combining the best characteristics of the activated sludge technology with a stable carrier element. The EEC

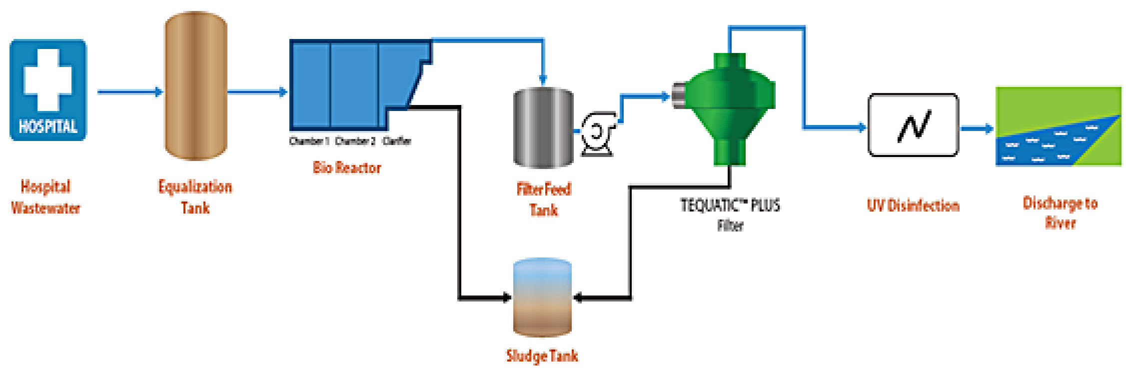

Fig. 1. The schematic of EEC USA packaged MBBR system

AMB Biomedia was made of plastic that has a long expected lifetime in water. The Biomedia was made from extruded tube cuttings with an internal cross and has 25 external low fins. The nominal dimensions are the dioamter of 12 mm and the length of 10 mm. The surface to volume ratio is approximately 850 m^2 per m^3 of Biomedia in bulk. 50% of the tank volume was occupied by elements.

Raw wastewater was obtained from the collection equalization basin of Al-Batool Teaching Hospital as influent to the system. The raw wastewater was screened with a 0.75 cm opening screener.

Operation conditions

The MBBR system operates with a flow rate of 6 m^3/hr, corresponding to a hydraulic retention time (HRT) of 4.1 hr. The mass liquor suspended solids (MLSS) was maintained within the range of 1400 ± 200 mg/L with a temperature of 18 ± 3 ^oC. The pH value was within the range of 6.8–8.2.

Analytical methods

Each analytical parameter was tested once a week. Each tested value represented the average value of three gathered samples. The analysis of TSS, MLSS and sludge volume index (SVI) were conducted using the procedures recommended by APHA, (2005). The BOD_5 was estimated with the aid of the OX Direct control system, Germany. Lovibond water testing photometer system MD200, Germany was used for testing COD. Dissolved oxygen (DO) was measured using Lovibond SensoDirect OXi200, Germany. Hanna Instruments were used for measuring the pH. The analysis of NH_4-N was measured using Potentiometric Titration Titroprocessor, MD 686, Swesra. The analysis of NO_3-N was measured using a UV-Visible Recording Spectrophotometer, MD UV- 160A- Japan.

RESULTS AND DISCUSSIONS

Typical compositions of the influent wastewater are given in Table (1). As shown in this table as well as Figures 2 and 3, in spite of the fluctuation in the influent organic load, the average effluent of BOD_5 and COD was 28.4 and 46.7 mg/l, corresponding to 79.5% and 74.5%, respectively. These outcomes are in a good agreement with (Andreottola et al., 2000; Yogita S. and Mitali J., 2015; Husham et al., 2014) which found that the BOD removal efficiency ranges between 79 to 82% and 76% of COD removal efficiency.

The effluent TSS of the MBBR system was stable within the range of 23.4 to 38 mg/l with the average value of 29.6 mg/l, corresponding to 78% removal efficiency, as shown in Figure 4. These

Table 1. Typical compositions of the influent wastewater

Items	BOD_5 (mg/l)	COD (mg/l)	PO_4 (mg/l)	NH_4_N (mg/l)	NO_3–N (mg/l)	TSS (mg/l)	O&G (mg/l)	pH (–)	EC (µS)	SO_4 (mg/l)	TDS (mg/l)
Range	84.7–260	130–305	1.6–4.3	25.8–89	0.5–6.5	105–158	7.5±3	7.8–8.1	1855±100	173±10	1048–1287
Avrage	147.2	194.6	2.8	51.3	1.73	135	7.5	8.0	1855	173	1117

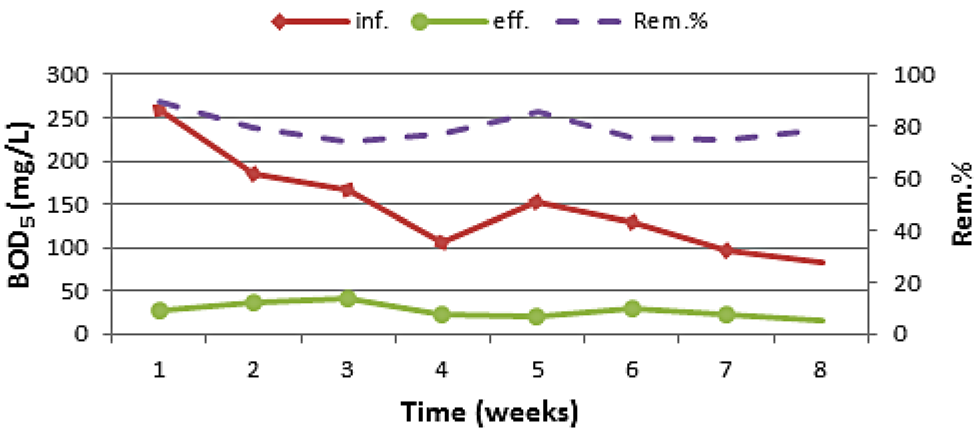

Fig. 2. Influent, effluent and removal efficiency of BOD

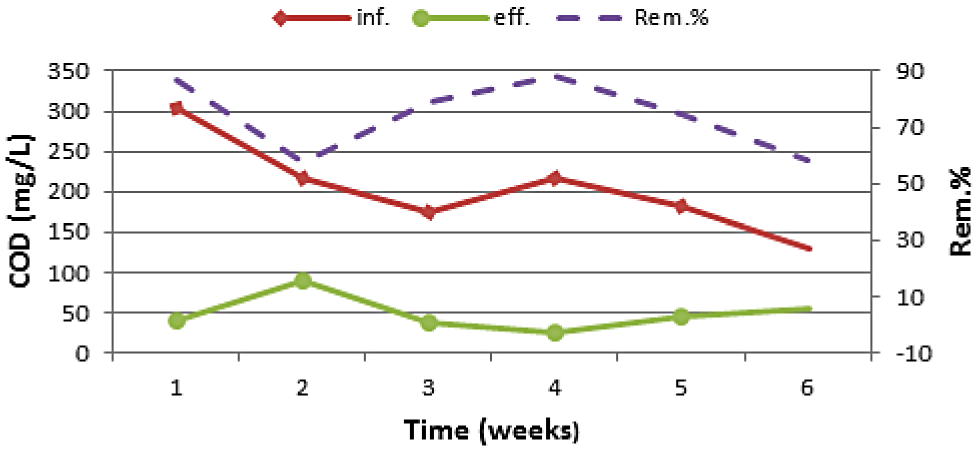

Fig. 3. Influent, effluent and removal efficiency of COD

results seems to be in an agreement with another study (Andreottola et al., 2000), which reported that the effluent TSS of the MBBR system within the range of 6–37 mg/l.

Figures 5 and 6 illustrate the influent and effluent of NH_4-N and NO_3-N as a function of time, respectively. It is clear that approximately 80% of ammonia was converted to nitrate. This indicates that a good nitrification occurs in the MBBR system. On the basis of the summation of influent and effluent nitrogen content, the nitrogen removal efficiency was only 29.4% due to the absence of anoxic zone in MBBR system. The nitrogen removal at this point was attributed to the denitrification in the anoxic zone which exists in the deep layers of the attached biofilm, in addition to the nitrogen removal by cell metabolisms.

In the MBBR strategy, that over 90% of biomass is likely caught and cultivated in the media as opposed to being suspended in the liquid (Schmidt and Schaechter, 2011). In this study, the MBBR system shows a weak formation of biomass on carriers, with only 1.93g TSS/m^2 of media, corresponding to 32% of the suspended biomass in the reactor. This finding might be due to the low organic load (0.965 kg/m^3), which leads to endogenous decay of the attached biomass. Aygun et al. (2008) found that an increase in the organic loading rate will prompt the increase in the amount of biomass attached to the carrier. Perhaps for this reason, the EEC USA packaged wastewater treatment plant, in this case, recirculates biomass to the first chamber.

Palm et al. (1980) reported that the SVI did not surpass the value of 150 mL/g, which can indicate good settling properties of the sludge. Sludge having SVI more than 150 mL/g is often categorized as bulking sludge. In this experiment, the SVI values were below 100 mL/g for all experiments, except for the second value, as shown in Figure 7. This indicates that the sludge is dense and has rapid settling characteristics.

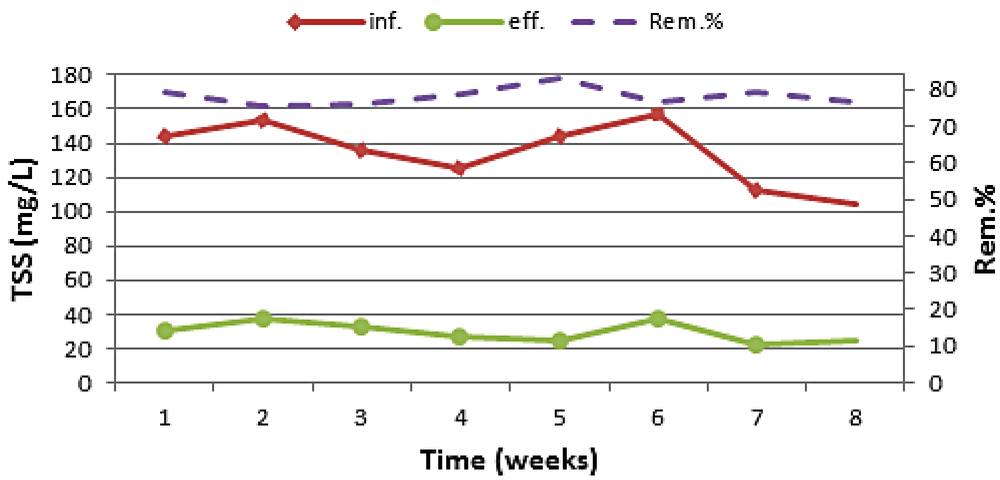

Fig. 4. Influent, effluent and removal efficiency of TSS

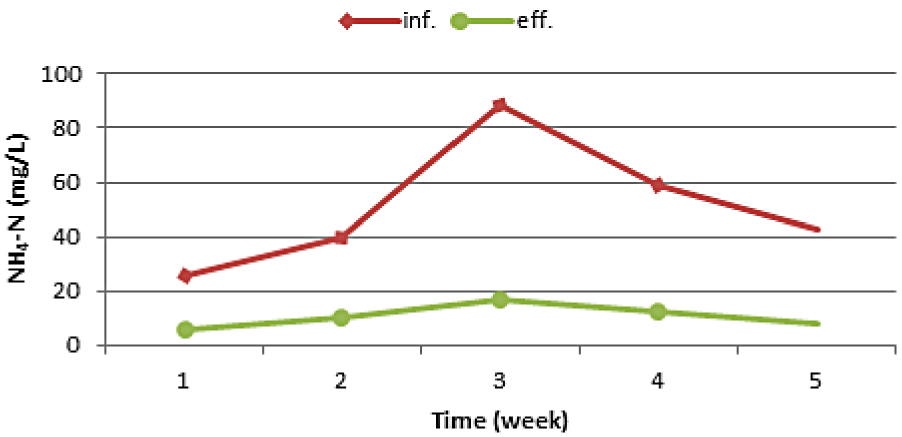

Fig. 5. Influent and effluent NH_4-N

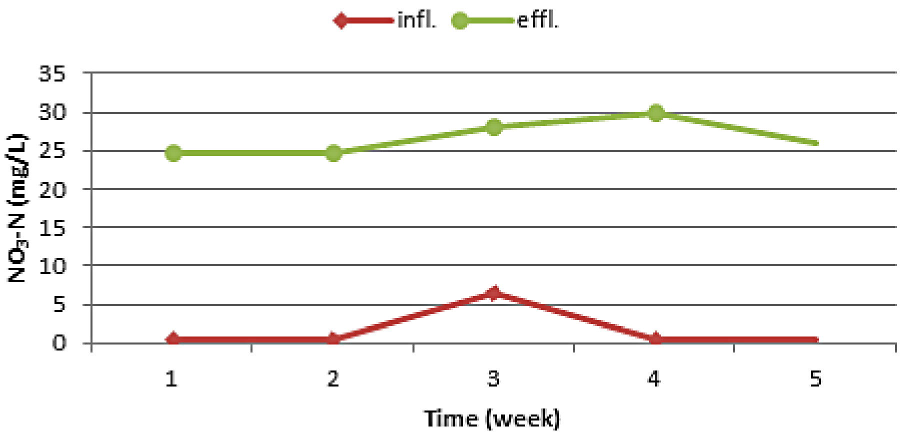

Fig. 6. Influent and effluent NO_3-N

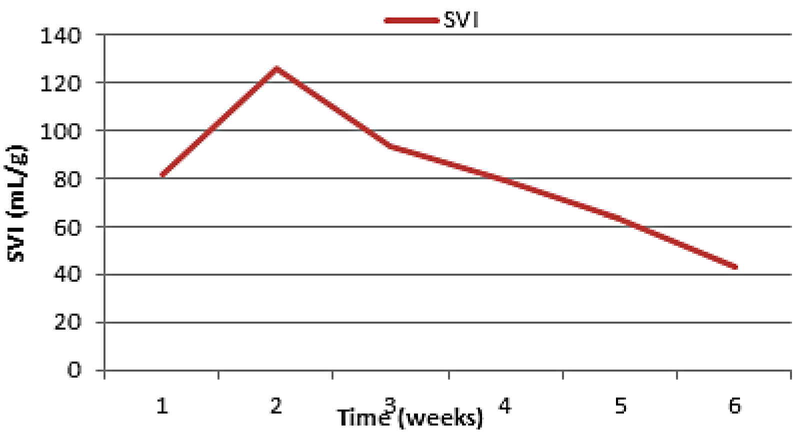

Fig. 7. The variation of SVI for MBBR experiment

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 the MBBR system was not perfect in terms of organic matter removal, compared to the activated sludge process, which might be due to the low MLSS and detachment of biomass from carriers. Nevertheless, the tested system is well suited for meeting the requirements pertaining to the limitations of rivers maintenance from pollution for effluent of organic matter and TSS.

The system shows a weak formation of biomass on carriers. The reduction in TDS was not significant. The tested system yields the sludge with good settling properties.

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