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Feasibility of Utilizing Moving Bed Biofilm Reactor to Upgrade and Retrofit Municipal Wastewater Treatment Plants

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ABSTRACT: In this study, feasibility of upgrading and retrofitting municipal wastewater treatment plants was investigated at laboratory scale using Moving Bed Biofilm Reactor (MBBR) process. For this purpose, an aerobic pilot was operated for nearly one year in different conditions, in which a moving bed carrier with a specific biofilm surface area of 500 m^2/m^3 and a filling rate of 60% was utilized. System efficiency in removal of BOD_5 and COD was examined at different hydraulic retention times (HRTs) of 1, 1.5, 2, 2.5, 3 and 4 h. The obtained results indicated high ability of the system to tolerate organic loading and to remain stable at a high food to microorganism (F/M) ratio. The system produced effluents with good quality at low HRTs and led to an average BOD_5 removal efficiency of nearly 88% during the operational period. The Organic Loading Rate (OLR) applied to the system had a range of 0.73-3.48 $kgBOD_5/m^3$.day and 2.43-11.6 $gBOD_5/m^2$.day, at which the reactor showed a good performance and stability. In general, it was concluded that (MBBR) can be an excellent alternative for upgrading and optimizing municipal wastewater treatment plants

Key words:MBBR,Optimization, Sewage, Biomass, Carrier

INTRODUCTION

Wastewater treatment is essential to safeguard human health and environment (Borghei et al. 2008; Mokhtari Azar 2011; Zinatizadeh *et al.,* 2007; Sarparastzadeh *et al.,* 2007; Rajakumar and Meenambal, 2008; Mtethiwa *et al.,* 2008; Rajasimman and Karthikeyan, 2009; Al-Malack, 2010; Akbarpour Toloti and Mehrdadi, 2011;). Accordingly, more attention should be given to improvement of wastewater treatment process as well as upgrading and retrofitting treatment plants (Kimura et al. 2008; Safari *et al.,* 2011; Sekman *et al.,* 2011; Oyoo *et al.,* 2011; Onodera *et al.,* 2012; Hatamoto *et al.,* 2012; Aguilar-Lopez *et al.,* 2013; Nasrabadi *et al.,* 2013; Khan and Faheem, 2013). It should be also noted that operation and maintenance cost of wastewater treatment plants is much more than roads. (Tandukar *et al.,* 2007). Therefore, upgrading and retrofitting wastewater treatment plants are of high importance, and nowadays are done to meet various objectives such as increasing effluents quality, water reuse (Brepols et al. 2008), removal of wastewater nutrients (Münch *et al.,* 2000), and increasing the capacity of wastewater treatment plants (Nandy *et al.,* 2002). In general, there are different methods for biological wastewater treatment. The most important systems are activated sludge, aerated lagoon in suspended growth, bio-filters and Rotating Biological Contactors (RBC) in attached-growth (Tchobanoglous *et al.,* 2004). Some disadvantages have been reported for these systems including sludge bulking and rising (Kotay *et al.,* 2011), foaming (Petrovski *et al.,* 2011), excess sludge generation (Hassani *et al.,* 2011), operational problems, poor performance in removing nutrients from wastewater, clogging, ponding, etc. (Tchobanoglous *et al.,* 2004). Yet, the biofilm system is more qualified than suspended growth systems due to the presence of a carrier with high specific surface, formation of bio-film and more flexible and compact reactor. These

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systems are more resistant to organic shock and toxic substances. In addition, treatment efficiency has a little relation to sludge settling (Jahren *et al.*, 2002, Rodgers *et al.*, 2003). Extensive researches have concentrated on these systems (Andreottola et al. 2000, Ferrai et al. 2010, Wang et al. 2006; Jamal Khan et al. 2011). One of biofilm processes innovated in Norway in late 1980's and early 1990's is Moving Bed Biofilm Reactor (MBBR). The main goal of developing MBBR was to initiate a process with a high concentration of microbial bio-mass operating towards improving the conditions of suspended and attached-growth systems (Rusten et al. 2006; Li et al. 2011). This process uses the entire volume of the reactor for the growth of biomass. It is a self-cleaning system and does not need any back-wash (Chen et al. 2007; Salvetti et al. 2006; Dupla et al. 2006). The aim of this study is to evaluate the application of MBBR systems in order to optimize, upgrade, and increase the capacity of municipal wastewater treatment plants

MATERIALS & METHODS

In order to conduct this study, a pilot plant was constructed and installed in the municipal WWTP of Shahrak Ghods located on the western part of Tehran, the capital of Iran, into which wastewater of nearly 500,000 people enters. The pilot plant was exploited for a period of one year. The effluents of grit removal and primary sedimentation were fed to prevent the pilot plant and pumps from being damaged. The pilot was built in rectangular-cubic shape with an equal length and width of 30 cm, a height of 100 cm as well as an effective volume of 60 L, and it was made of Plexiglas. The system was aerated by four air stones placed at the bottom of the pilot. The effective depth of the wastewater was 70 cm, and suspended carrier filled 60% of the pilot volume. The aeration pump with a capacity of 250 L/h supplied the air required. The used carrier was Kaldnes whose specifications have been briefly provided in Table 1. As shown in Table 1, the surface area of the carrier is 500 m^2/m^3. Considering the filling ratio, the surface area will be reduced to 300 m^2/m^3. A mesh screen with holes of 5 mm in diameter was installed on top of the pilot to trap carrier in the system. The schematic design of the pilot is illustrated in Fig.1.

To start up the reactor, approximately half of it was filled by the return sludge of Shahrak Ghods WWTP. Initially, for biomass to be able to penetrate fully into the carriers, the reactor operated in batch mode for a period of 5 days in a way that its aeration would switch off once every 8 h for 1 h to settle the sludge completely. Then, the valves mounted at the reactor height discharged half of the effluents. After being discharged, the wastewater re-entered into the system and then the system aerated for 8 h. After this phase, operation of the pilot was changed to the continuous mode. In this phase, which lasted for 25 days, the sludge was regularly returned to the reactor. After a period of approximately one month, the biofilms were clearly observed on the carriers and the line of returning sludge was stopped. Pilot influent was set by a dosing pump

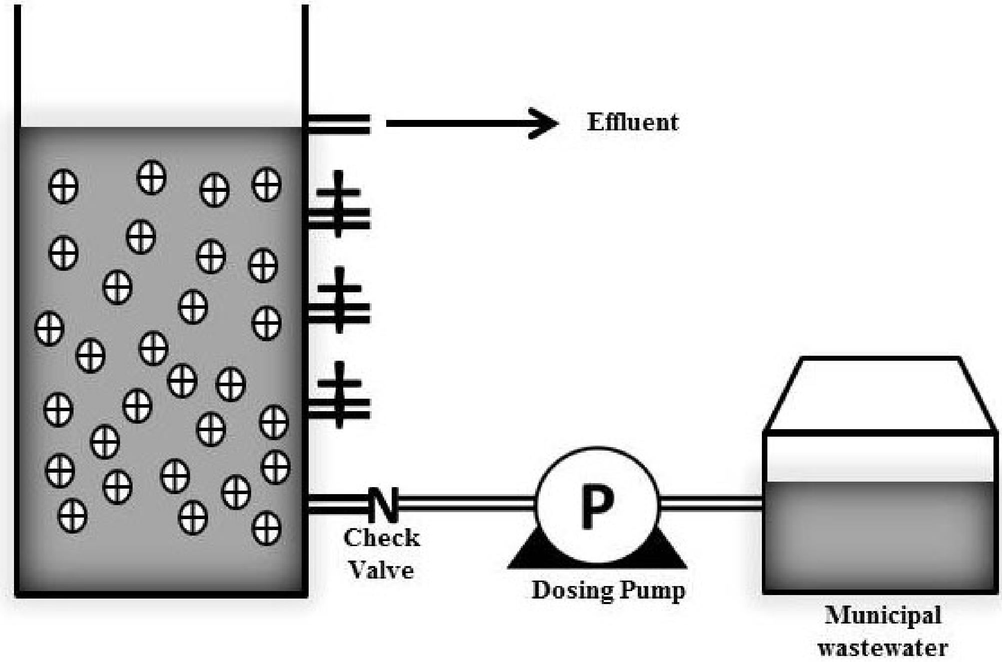

Fig. 1. a schematic diagram of the pilot plant MBBR reactor

(Etatron-Italy). Following the steps taken to start up the pilot and form the biofilms, the influent discharge was gradually increased in order to reach the maximum OLR. Accordingly, each stage of influent was increased with intervals of 5 days to protect the system against the shocks. This trend continued until the pilot HRT was regulated on an hourly basis.

The entire sampling and analytical tests were taken according to the Standard Method Handbook (APHA 1998). The Biochemical Oxygen Demand (BOD_5), Mixed Liquor Suspended Solids (MLSS) and Mixed Liquor Volatile Suspended Solids (MLVSS) were determined by Method No. 5210 D (Respirometric Method), Method No. 2540 D (Solids Dried at 103–105°C) and Method No. 2540 E (Fixed and Volatile Solids Ignited at 550 °C), respectively. The Chemical Oxygen Demand (COD) values were assessed by utilizing the Colorimetric Method with HACH Spectrophotometer (DR 5000 USA) and the Thermal Reactor (DRB 200, USA), and vials for influents and effluents were evaluated as 0-1500 ppm and 0-150 ppm, respectively. The temperature and pH of the reactor were measured with the WTW Table pH Meter (model 720, Germany), and the dissolved oxygen (DO) with the portable WTW DO Meter (oxi 340i, Germany).

RESULTS & DISCUSSION

Table 2 demonstrates average, maximum and minimum amounts of COD, BOD_5, temperature, pH, MLSS and MLVSS. The pilot operation and the related tests lasted for approximately one year. The research was conducted in two stages: the first one included the pilot start up, forming biofilms and achieving steady state conditions in a period of 60 days, and the second one was experimental stage in which the OLR applied to the system was changed. The second stage was conducted in six phases, each of which lasted for 55 days. Accordingly, after forming bio-film, passing through the reactor start up step and reaching a stable condition, the reactor was run with the maximum OLR and flow rate (60 LPH) in the first phase. In the subsequent phases, the OLR applied to the system was reduced to examine the impact of changes in F/M ratio and HRT on the pilot and operational conditions by reducing the influent flow rate. As shown in Table 2, HRT changes from 1 to 4 h as influent flow rate varies between 15-60 L/h. The maximum organic load applied to the reactor in the first phase was 3.19 $kgBOD_5/m^3$.day and 6.33 $kgCOD/m^3$.day on average. In this phase, the reactor efficiencies in removal of BOD_5 and COD were respectively 79.91% and 70.48% on average. During the 55 days that the first phase was being completed on the pilot, white foams arising from detergents were observed on the surface of the system every so often, which indicated that the HRT was not adequate. This problem was solved by increasing the HRT in the next phases.

As illustrated in Table 2, by reducing the organic load applied to the system, efficiency is evidently boosted, which is due to the more adequate HRT of the system. Minimum organic loads of 0.81 $kgBOD_5/m^3$.day and 1.58 $kgCOD/m^3$.dayon average were applied to the reactor in the sixth phase. In this phase, the reactor efficiencies for removal of BOD_5 and COD were respectively 94.64% and 92.30% on average. As Table 2 suggests, the pH of the reactor was almost in the neutral range (i.e. 7-8) and there was no significant relationship between the pH and changes occurred in the reactor during the six phases of the study.

In general, Table 2 reveals extremely high efficiency of the MBBR in eliminating biodegradable materials so that with the HRT of 1 h, nearly 80% BOD_5 removal efficiency was recorded for the system. Such a high degree of capability is due to excessive production of active biomass by the system, taking up both the entire volume of the reactor for treatment, and high specific surface area of the carriers. The amounts of BOD_5, COD and organic load imposed on overall surface of the carrier during the operation period are shown in Figs 1 and 2 in detail. Fig. 3 demonstrates the range of available biomass in the system. As can be seen in this fig, a relatively slight reduction was observed in cell mass of the reactor as it was approached to the last phase of the pilot operation. Accordingly, MLSS and MLVSS levels reached from their maximum amounts of 3,027 and 2,268 mg/L to their lowest amounts of 1,848 and 1,029 mg/L, respectively. This reduction in biomass is due to the reduction of organic loading applied to the system and consequently reduced synthesis of the cell mass. In systems using attached-growth to treat wastewater, OLR is an important designing and operational parameter, while in systems with suspended-growth, such as activated sludge, F/M is one of critical operational parameters. The ratio called process factor, has a considerable impact on the process and makes the operation more complex. Therefore, if the system is operated with low F/M, there is a risk of bulking and growing filamentous bacteria. Besides, at operational condition of high F/M, sedimentation of sludge is not done properly, and consequently, the effluents quality will not be desirable (Tchobanoglous *et al.*, 2004). Figs 5 and 6 show that the parameters (OLR and F/M) entered the system during the operation, and specify their impact on removal efficiency of organic matter. The F/M rate entering a common activated sludge system is approximately 0.2 to 0.5 $kgBOD_5/kgMLVSS$.day. The

MLSS in such systems usually varies between 1,500 to 3,000 mg/L, which ensures BOD removal efficiency within the range of 85-95% with HRT of 3-5 h. The common organic load reported in this process is 0.3 to 1.6 kgBOD_5/m^3.day (WEF 2010). What is clearly seen in Fig. 4 is that the MBBR can tolerate much greater range of F/M than the activated sludge. According to the results attained, maximum F/M applied to the system was 1.88 kgBOD_5/KgMLVSS.day which was reached to 0.5 kgBOD_5/kgMLVSS.day at its lowest rate. This occurs while the acceptable average value reported for a common activated sludge process is equal to 0.5 kgBOD_5/kgMLVSS.day (0.2 to 0.6). It should be noted that these changes did not cause any particular difficulty during the operation of the system in terms of the quality of sludge settling and effluents. According to the results of Fig. 5, in the HRT of 1.5 h and higher, BOD removal efficiency was above 80%. As the fig. 4 suggests, the amount of the system MLSS at this HRT was 2,700 mg/L and gradually, with the HRT decreasing, it was averagely reached to 2,000 mg/L in its lowest state. All the amounts were within the range listed for a common activated sludge. Based on the results illustrated in Fig. 6, the maximum OLR

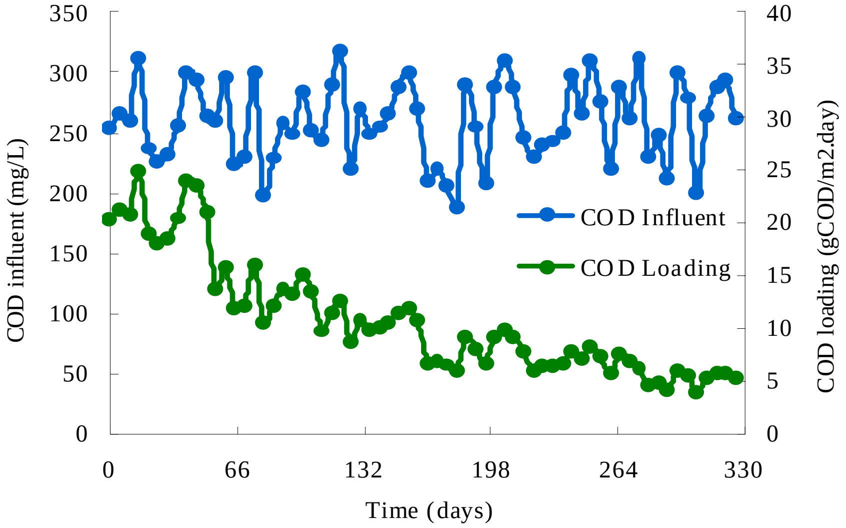

Fig. 2. COD concentration and COD loading at different operational times

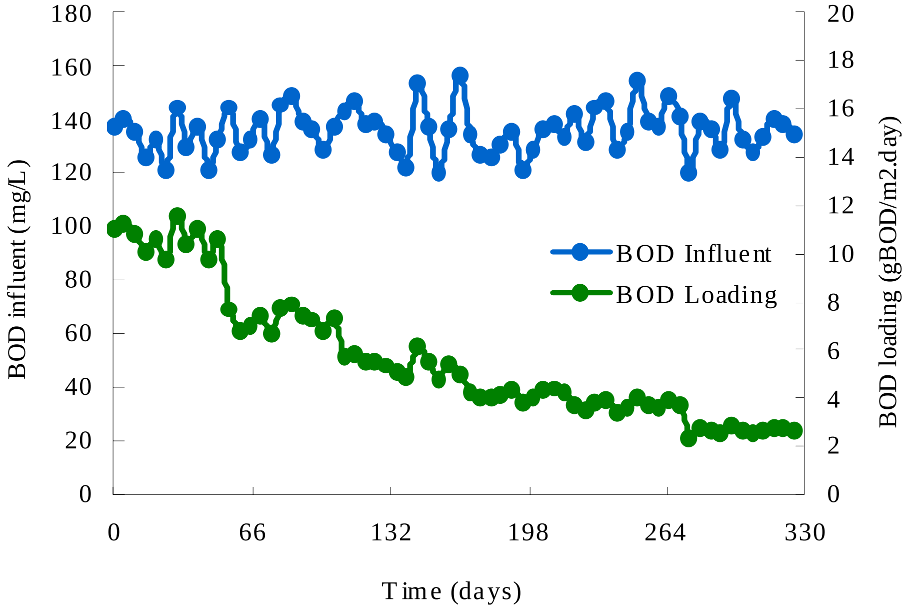

Fig. 3. influent BOD concentration and BOD loading rate at different operational times

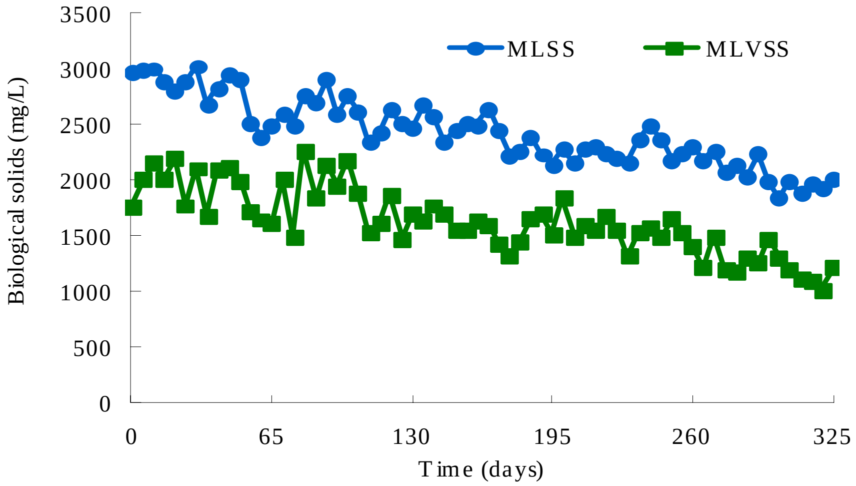

Fig. 4. variations of Biological solids during different operational times

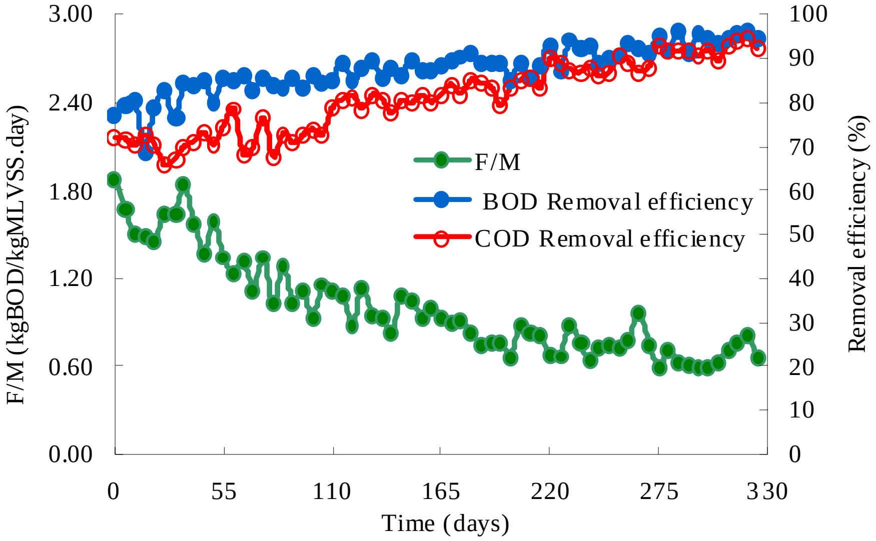

Fig. 5. variations of Food to Microorganism Ratio and organic removal efficiency at different conditions

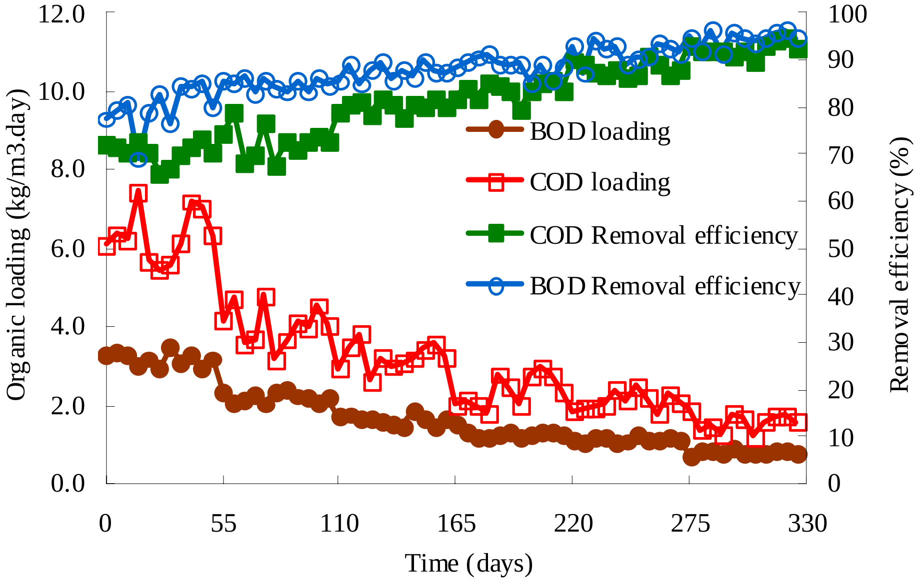

Fig. 6. BOD and COD loading applied to the system in different operational period and system removal efficiency

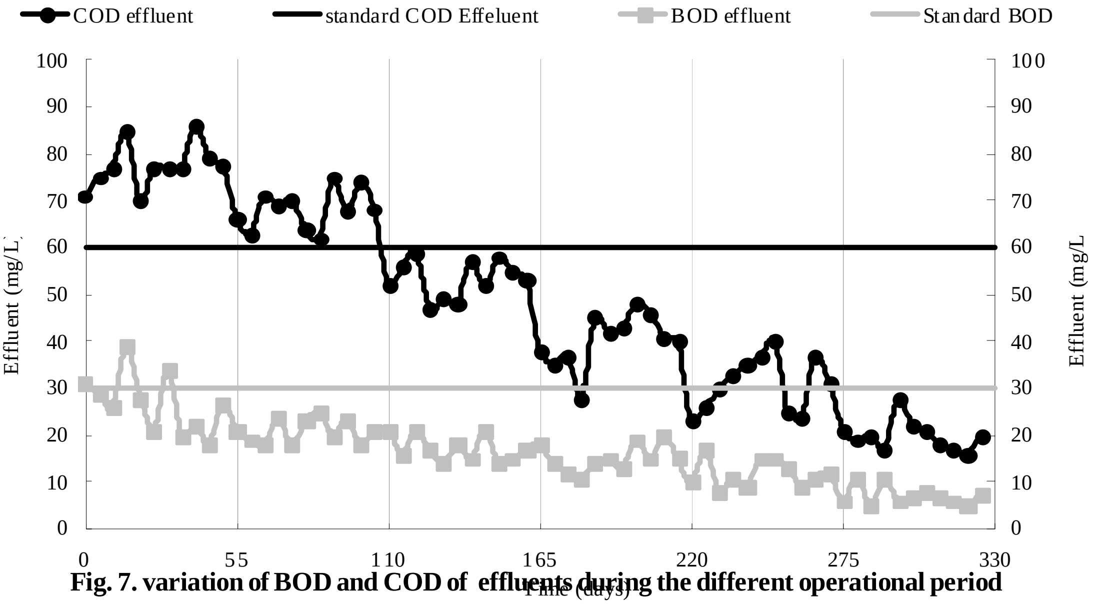

Fig. 7. variation of BOD and COD of effluents during the different operational period

The Kaldnes plastic media characteristics	
Type	K_1
Nominal diameter (mm)	9.1
Nominal length (mm)	7.2
Bulk density (kg/ m^3)	150
Specific biofilm surface area (m^2/m^3)	500
Filling rate (%)	60
Material	Polyethylene (PEHD)

Table 2 . Stable performance results obtained under various experimental conditions

Phase		HRT	Q	COD R.E	OLR	BOD$_5$ R.E	OLR	MLSS	MLVSS	T	pH
	Ave	1.0	60	70.48	6.33	79.91	3.19	2908	1998	19.91	7.59
P1	Max	1.0	60	73.13	7.46	85.25	3.48	3027	2196	23.80	7.89
	Min	1.0	60	66.08	5.45	69.05	2.93	2689	1693	16.40	7.23
	Ave	1.5	40	75.10	4.05	84.84	2.20	2626	1894	20.96	7.65
P2	Max	1.5	40	78.72	4.80	86.47	2.38	2910	2268	24.70	7.96
	Min	1.5	40	67.84	3.18	82.98	2.03	2396	1506	16.50	7.36
	Ave	2.0	30	79.19	3.24	87.45	1.64	2498	1647	21.71	7.51
P3	Max	2.0	30	81.78	3.82	89.86	1.85	2679	1879	24.90	7.89
	Min	2.0	30	77.65	2.64	84.89	1.45	2344	1478	18.30	7.29
	Ave	2.5	24	83.49	2.37	88.75	1.29	2311	1566	20.36	7.54
P4	Max	2.5	24	85.71	2.98	91.27	1.51	2650	1843	24.20	7.98
	Min	2.5	24	79.43	1.81	85.27	1.17	2147	1337	16.90	7.08
	Ave	3.0	20	88.23	2.10	91.63	1.13	2278	1502	19.86	7.57
P5	Max	3.0	20	90.94	2.48	94.48	1.24	2494	1681	23.60	7.92
	Min	3.0	20	86.09	1.77	87.12	1.03	2169	1226	16.80	7.12
	Ave	4.0	15	92.30	1.58	94.64	0.81	2016	1223	20.33	7.54
P6	Max	4.0	15	94.54	1.87	96.40	0.89	2246	1480	24.80	7.98
	Min	4.0	15	89.50	1.20	91.47	0.73	1848	1029	15.90	7.23

[1] Hydraulic retention time (h): MLSS (mg/L): MLVSS (mg/L) : T, temperature (°C) : Q : LPH

[2] COD Removal efficiency (%)

[3] Organic loading rate (kgCOD/m^3.day)

[4] COD Removal efficiency (%)

[5] Organic loading rate (kgBOD$_5$/m^3.day)

applied to the reactor was equal to 3.48 kgBOD$_5$/m^3.day. The value reached to 0.73 kgBOD$_5$/m^3.day at its minimum amount. This range is much greater than the current loading range for the activated sludge process. This demonstrates high ability of the process in tolerating the organic load.

Regarding the issues discussed above, it can be concluded that MBBR not only endures a higher organic load, but also, with a lower HRT (approximately less than half the time required) can have the same efficiency of conventional activated sludge. Comparison of organic load bearing of the system with that of attached-growth process confirms the above. The organic load recommended for the standard trickling filter is 0.07 to 0.22 kgBOD5/m3.day. In these circumstances, BOD removal efficiency has been reported to be equal to 80-90%. The mentioned Organic load amount is tantamount to 0.36 to 1.2 kgBOD5/m3.day for Activated Bio-Filter (ABF) (Tchobanoglous et al. 2004). Hiras et al. (2004) utilized RBC system for treatment of municipal wastewater. They reported that the RBC in loading range of 38-182 gCOD/m^2.day showed an average efficiency of 82%. However, such efficiency can be obtained at HRT of 16.5 h (Hiras et al. 2004). Initially, it seems that the system accepts a higher organic load than the amount achieved in this study (2.43-11.6 gBOD$_5$/m^2.day). However, regarding the HRT, it was revealed that the main reason for the lower capacity of tolerating ORL is the high specific surface of the MBBR carriers in comparison to that of RBC. As a result, the MBBR has the capacity of performing treatment operations in a shorter period compared to the RBC system. In terms of wastewater quality, according to Iranian environmental regulations, effluents standards for BOD$_5$ and COD are 30 mg/L and 60 mg/L, respectively. Except in special cases, EPA considers acceptable effluents BOD$_5$ limit of less than 30 mg/L for discharges (USEPA 2004).

Fig. 7 illustrates the system discharge rate in all phases of operation. Two lines are plotted in the figure parallel with the X axis, one on 60 and the other on 30. These lines show the acceptable standards for COD and BOD$_5$. At HRT of 2 h or more, the MBBR effluents will be absolutely within the standard range of COD. As indicated in Figure 7, the effluents’ BOD is below the recommended standards in all phases, except for two points, which is negligible. This means that in all loadings applied, MBBR could reduce biodegradable materials to desirable standards. In this respect, if the desirable HRT of the process is considered 2 h, the aeration tank volume will specifically be less than older systems such as activated sludge, trickling filter, RBCs, etc. Thus, the present wastewater treatment plants can be easily upgraded. Despite the enormous benefits, some disadvantages have also been reported for MBBR. Relatively expensive and bulky carries can be mentioned as the main defects of this system. This means that a predetermined space must be assigned to storage carriers during repairs (WEF 2010). Throughout the operational phase, after growing the biofilm within the carriers, the carriers spun freely and easily in the system. Consequently, they spread throughout the reactor volume in a perfectly homogeneous way, whereas with such aeration, dissolved oxygen of 2 to 3 mg/L was provided.

During the operating phase, no problems pertinent to sludge-bulking and rising were observed and the sludge settling was performed properly. The carriers never endured clogging and whenever the cellular biomass within the carriers increased, it would be ripped off by the air bubbles and the contents of the reactor could be observed very clearly. No unpleasant odor was released from the system during the one-year period. The effluent was always very clear and seemed acceptable in terms of physical specifications.

In reviewing previous, relevant literature, interesting contents can be extracted. For example, Andreotolla et al. (2000) compared a MBBR system in which 70% of the volume was filled with FLOCOR-RMP carriers (with specific surface area of approximately 160 m^2/m^3) with an activated sludge system for treatment of municipal wastewater and with an average influent COD of 231 mg/L. At HRTs of 3-7 h, they reported an average COD removal efficiency of 76% for the MBBR (Andreottola et al. 2000). Obviously, the results of the current study are different from their study achievements. This is due to the differences in the type of carriers used as well as its specific surface area. Wang et al. (2006) also studied a MBBR system, which was filled with domestic wastewater to the amount of 50% with spherical shaped carriers, made of polyethylene (with specific surface area of 320 m^2/m^3). The influent COD range was 145–432 mg/L and the average COD removal efficiency for HRT of 6 h was reported to be 77.1% (Wang et al. 2006). As it can be noted, the results are incompatible with those of our study. This difference is due to the type of carriers and its restricted specific surface area. Therefore, it can be stated that the type of the selected carriers has a crucial impact on the system and its consequent results. Ferrai et al. (2010) performed a research with cylindrical shaped polyethylene carriers manufactured by Biomaster. Their results were similar to those of ours, so that with an average HRT of 1.5 h, they reported an average COD removal of 82% (Ferrai et al. 2010). The results of this study imply that MBBR advantages to construct new WWTPs allow designers to reduce the cost of initial investment. It provides the possibility of upgrading old WWTPs being on-stream by adding carriers and minor modifications. In this way, their capacity will be boosted and better effluents quality can be achieved.

CONCLUSION

MBBR is not F/M-parameter-sensitive. It can fully maintain its stability in organic loads several times higher than conventional systems such as activated sludge, trickling filters, RBCs, ABF, etc. This is considered a very important advantage of the process. Compared to the old conventional processes, this system requires less HRT to reduce wastewater organic load to the optimal level. This can lead to reduced volume of aeration tank. Therefore, MBBR can be used to increase the capacity of WWTPs and upgrade them to improve effluents quality. Furthermore, by combining this system with anoxic and anaerobic systems (in remaining aeration tank) the output nutrient rate can be reduced to an acceptable level. Thus, the current WWTPs can be upgraded. The specific surface of the carriers is a crucial parameter. When selecting carriers, enough attention should be paid to choose the appropriate specific area in order to reduce the required time for treatment process and consequently reduce ase ocess and consequently,a alan tu matn vojud dare moshkel dashtam.the treatment costs. MBBR does not have common problems such as sludge bulking and rising, foaming, poor sludge settling, carriers clogging and the need for backwashing with regard to the operational characteristics. Strong resistance to impact and no need to return the sludge make the system much easier to operate. Considering the effluents quality, with HRT of 2 h, the system meets the standards of Iran and EPA in elimination of organic materials.

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REFERENCES

Aguilar-López, R. , López-Pérez, P. A. , Peña-Caballero, V. and Maya-Yescas, R. (2013). Regulation of an Activate Sludge Wastwater Plant VIA Robust Active Control Design. Int. J. Environ. Res., **7 (1)**, 61-68.

Akbarpour Toloti, A. and Mehrdadi, N. (2011). Wastewater Treatment from Antibiotics Plant. Int. J. Environ. Res., **5 (1)**, 241-246.

Al-Malack, M. H. (2010). Effect of Sludge Initial Depth on the Fate of Pathogens in Sand Drying Beds in the Eastern Province of Saudi Arabia. Int. J. Environ. Res., **4 (4)**, 825-836.

Andreottola, G., Foladori, P., Ragazzi M. and Tatàno, F. (2000). Experimental comparison between MBBR and activated sludge system for the treatment of municipal wastewater. Water science and technology, **41 (4-5)**, 375–382.

APHA, (1998). Standard Methods for the Examination of Water and Wastewater. 20th Ed., APHA, AWWA, WPCF, American Public Health Association, Washington, DC, USA.

Borghei, S. M., Sharbatmaleki, M., Pourrezaie, P. and Borghei, G. (2008). Kinetics of organic removal in fixed-bed aerobic biological reactor. Bioresource technology, **99 (5)**, 1118-1124.

Brepols, Ch., Dorgeloh, E., Frechen, F.-B., Fuchs, W., Haider, S., Joss, A., de Korte, K., Ruiken, Ch., Schier, W., van der Roest, H., Wett, M. and Wozniak, Th. (2008). Upgrading and retrofitting of municipal wastewater treatment plants by means of membrane bioreactor (MBR) technology. Desalination, **231 (1-3)**, 20–26.

Chen, S., Sun, D. and Chung, J. S. (2007). Treatment of pesticide wastewater by moving-bed biofilm reactor combined with Fenton-coagulation pretreatment. Journal of hazardous materials, **144 (1-2)**, 577-584.

Dupla, M., Comeau, Y., Parent, S., Villemur, R. and Jolicoeur, M. (2006). Design optimization of a self-cleaning moving-bed bioreactor for seawater denitrification. Water research, **40 (2)**, 249-258.

Ferrai, M., Guglielmi, G. and Andreottola, G. (2010). Modelling respirometric tests for the assessment of kinetic and stoichiometric parameters on MBBR biofilm for municipal wastewater treatment. Environmental Modelling & Software, **25 (5)**, 626-632.

Hassani, A. H., Nejaei, A. and Torabian, A. (2011). Excess Sludge Minimization in Conventional Activated Sludge Pilot Plant by Three Chemical Matters. International Journal of Environmental Research, **5 (4)**, 981-988.

Hatamoto, M., Nagai, H., Sato, S., Takahashi, M., Kawakami, S., Choeisai, P. K., Syutsubo, S., Ohashi, A. and Yamaguchi. T. (2012). Rubber and Methane Recovery from Deproteinized Natural Rubber Wastewater by Coagulation

Pre-treatment and Anaerobic Treatment. Int. J. Environ. Res., **6 (3)**, 577-584.

Hiras, D. N., Manariotis, I. D. and Grigoropoulos, S. G. (2004). Organic and nitrogen removal in a two-stage rotating biological contactor treating municipal wastewater. Bioresource technology, **93 (1)**, 91-98.

Jahren, S. J., Rintala, J. A. and Odegaard, H. (2002). Aerobic moving bed biofilm reactor treating thermomechanical pulping whitewater under thermophilic conditions. Water research, **36 (4)**, 1067-1075.

Jamal Khan, S., Ilyas, S., Javid, S., Visvanathan, C. and Jegatheesan, V. (2011). Performance of suspended and attached growth MBR systems in treating high strength synthetic wastewater. Bioresource technology, **102 (9)**, 5331-5336.

Khan, M. A. and Faheem, S. M. (2013). Monitoring Bacterial Diversity in a full-scale Municipal Wastewater Treatment plant in Dubai by Fluorescence in situ hybridization Technique.Int. J. Environ. Res., **7 (2)**, 479-484.

Kimura, K., Nishisako, R., Miyoshi, T., Shimada, R. and Watanabe, Y. (2008). Baffled membrane bioreactor (BMBR) for efficient nutrient removal from municipal wastewater. Water research, **42 (3)**, 625-632.

Kotay, S. M., Datta, T., Choi, J. and Goel, R. (2011). Biocontrol of biomass bulking caused by Haliscomenobacter hydrossis using a newly isolated lytic bacteriophage. Water research, **45 (2)**, 694-704.

Li, H. Q., Han, H. J., Du, M. A. and Wang, W. (2011). Removal of phenols, thiocyanate and ammonium from coal gasification wastewater using moving bed biofilm reactor. Bioresource technology, **102 (7)**, 4667-4673.

Mtethiwa, A. H., Munyenyembe, A., Jere, W. and Nyali, E. (2008). Efficiency of oxidation ponds in wastewater treatment. Int. J. Environ. Res., **2 (2)**, 149-152.

Mokhtari Azar, A., Ghadirpour Jelogir, A., Nabi Bidhendi, G. R. and Zaredar, N. (2011). Examination of the operator and compensator tank role in urban wastewater treatment using activated sludge method. Environmental monitoring and assessment, **175 (1-4)**, 651-659.

Münch, E.V., Barr, K., Watts, S. and Keller, J. (2000). Suspended carrier technology allows upgrading high-rate activated sludge plants for nitrogen removal via process intensification. Water science and technology, **41 (4-5)**, 5-12.

Nandy, T., Kaul, S. N. and Shastry, S. (2002). Upgrading a paper industry effluent treatment plant for capacity expansion with recourse to recycling effluent. Resources, Conservation and Recycling, **34 (3)**, 209-228.

Onodera, T., Sase, S., Choeisai, P., Yoochatchaval, W., Sumino, H., Yamaguchi, T., Ebie, Y., Xu, K., Tomioka, N., Mizuochi, M. and Syutsubo, K. (2012). Evaluation of Process Performance and Sludge Properties of an up-flow staged Sludge Blanket (USSB) reactor for Treatment of Molasses Wastewater. Int. J. Environ. Res., **6 (4)**, 1015-1024.

Oyoo, R., Leemans, R. and Mol, A. P. J. (2011). Future Projections of Urban Waste Flows aand their Impacts in African Metropolises Cities. Int. J. Environ. Res., **5 (3)**, 705-724.

Petrovski, S., Dyson, Z. A., Quill, E. S., McIlroy, S. J., Tillett, D. and Seviour, R. J. (2011). An examination of the mechanisms for stable foam formation in activated sludge systems. Water research, **45 (5)**, 2146-2154.

Rajakumar, R. and Meenambal, T. (2008). Comparative Study on Start – Up Performance of HUASB and AF Reactors Treating Poultry Slaughterhouse Wastewater. Int. J. Environ. Res., **2 (4)**, 401-410.

Rajasimman, M. and Karthikeyan, C. (2009). Optimization studies in an Inverse Fluidized Bed Bioreactor for Starch Wastewater Treatment. Int. J. Environ. Res., **3 (4)**, 569-574.

Rusten, B., Eikebrokk, B., Ulgenes, Y. and Lygren, E. (2006). Design and operations of the Kaldnes moving bed biofilm reactors. Aquacultural Engineering, **34 (3)**, 322-331.

Rodgers, M., Zhan, X. M. and Gallagher, B. (2003). A pilot plant study using a vertically moving biofilm process to treat municipal wastewater. Bioresource technology, **89 (2)**, 139-143.

Sekman, E., Top, S., Uslu, E., Varank, G. and Bilgili, M. S. (2011). Treatment of Oily Wastewater From Port Waste Reception Facilities by Electrocoagulation. (2011). Int. J. Environ. Res., **5 (4)**, 1079-1086.

Safari, E., Jalili Ghazizade, M. Shokouh, A. and Nabi Bidhendi, Gh. R. (2011). Anaerobic Removal of COD from High Strength Fresh and Partially Stabilized Leachates and Application of Multi stage Kinetic Model. Int. J. Environ. Res., **5 (2)**, 255-270.

Salvetti, R., Azzellino, A., Canziani, R. and Bonomo, L. (2006). Effects of temperature on tertiary nitrification in moving-bed biofilm reactors. Water research, **40 (15)**, 2981-2993.

Sarparastzadeh, H., Saeedi, M., Naeimpoor, F. and Aminzadeh, B. (2007). Pretreatment of Municipal Wastewater by Enhanced. Chemical Coagulation. Int. J. Environ. Res., **1 (2)**, 104-113.

Tandukar, M., Ohashi, A. and Harada, H. (2007). Performance comparison of a pilot-scale UASB and DHS system and activated sludge process for the treatment of municipal wastewater. Water research, **41 (12)**, 2697-2705.

Tchobanoglous, G., Burton, F. L. and Stensel, D. H. (2004). Wastewater Engineering: Treatment Disposal and Reuse, 4th Ed. the McGraw-Hill Companies, New York, USA.

U.S. EPA, (2004). Guidelines for Water Reuse. U.S. Environmental Protection Agency and U.S. Agency for International Development, Washington, DC. EPA-625/R-04-108.

Wang, X. J., Xia, S. Q., Chen, L., Zhao, J. F., Renault, N. J., and Chovelon, J. M. (2006). Nutrients removal from municipal wastewater by chemical precipitation in a moving bed biofilm reactor. Process Biochemistry, **41 (4)**, 824-828.

Water Environment Federation (WEF). (2010). Design of Municipal Wastewater Treatment Plants, the McGraw-Hill Companies, New York, USA.

Zinatizadeh, A. A. L., Salamatinia, B., Zinatizadeh, S. L., Mohamed, A. R. and Hasnain Isa, M. (2007). Palm oil mill effluent digestion in an up-flow anaerobic sludge fixed film bioreactor. Int. J. Environ. Res., **1 (3)**, 264-271.