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Potential of using biological aerated filter as a post treatment for municipal wastewater

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ABSTRACT

The main objective of this study was to assess and evaluate the performance of a packed bed up flow anaerobic sludge blanket reactor (P-UASB) followed by a biological aerated filter (BAF) for the treatment of municipal wastewater for reuse. The integrated pilot plant treatment system consisted of a UASB reactor packed with non-woven polyester fabric (NWPF) followed by BAF unit then inclined plate settler. The P-UASB was operated at two different organic loading rates (OLR) namely; 1.54 and 2.07 kg COD/m^3/day with a corresponding HRT of 6 and 4 h. The results revealed that the system achieved sustainable and satisfactory reductions in total COD, BOD_5 and TSS. Their corresponding residual values were 37.30 mgO_2/l, 16.23 mgO_2/l and 10.38 mg/l with average percentage removals of 89, 92 and 95%, respectively. Increasing the OLR from 1.54 to 2.07 kg COD/m^3/day had a slight effect on the performance of the treatment system. Also, removal of 5 logs of total coliform, 4 logs of fecal coliform and 4 logs of fecal streptococci were obtained. Moreover, the treatment system had a small foot print, cost effective and can treat the wastewater of low to medium strength and produced an effluent suitable for reuse in unrestricted irrigation.

1. Introduction

Water is considered one of the most vital human resources which have economic, social, political and environmental importance throughout the world. In Egypt, the water sector suffers from scarcity as well as deterioration of water quality due to the disposal of untreated municipal wastewater into surface water especially in rural areas. This dilemma makes developing new affordable and appropriate technologies for municipal wastewater treatment an urgent need. Among the promising wastewater treatment technologies is using packed bed up-flow anaerobic sludge blanket (P-UASB). This technique promotes a good contact between the inflow wastewater and the microorganisms at high concentration and consequently high organic matter removal at short retention time (Lettinga, 2008; Khan et al., 2011). However, the P-UASB is still a primary treatment and a post treatment is required to achieve a good quality effluent amenable for wastewater reuse (Abou-Elela et al., 2013a,c).

There are numerous post treatment systems such as activated sludge process (ASP), fluidized bed reactors (FBR), trickling filter (TF), aerated lagoons, oxidation ponds and constructed wetlands (Abou-Elela and Hellal, 2012; Abou-Elela et al., 2013b; Cristina et al., 2015). One of the post treatment technologies after the anaerobic treatment is the attached biomass processes such as the biological aerated filters (BAF). Since the solids are entrapped into the BAF filter, the settling phase is no more required and consequently the associated problems described above in the conventional activated sludge process can be avoided. The BAF represents one of the most economical upgrading technology, flexible, provides small foot print and it can be used at various stages of treatment (Hansen et al., 2007). Also, the use of media within BAF provides a large surface area for the development of biomass. The media also allows the reactor to act as a deep, submerged filter and to incorporate suspended solids removal (Mendoza-Espinoza and Stephenston, 1999). The most studied packing materials are stones, clay, schist, polyethylene, polystyrene and even wasted plastic materials (Osorio and Hontoria, 2002). Recently non-woven polyester fabric (NWPF) was used and proved to be a very effective biomedia (Abou-Elela et al., 2013a,c).

The main objective of the present study was to evaluate the performance of the P-UASB reactor followed by BAF unit packed with NWPF for the removal of organic, inorganic as well as pathogenic contaminants. Furthermore, to investigate the suitability of the treated wastewater for reuse in rural area and/or small communities.

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Table 1
Operating conditions of the treatment system.

Reactors	Operating conditions					
	P-UASB		BAF		IPS	
	1st Load	2nd Load	1st Load	2nd Load	1st Load	2nd Load
Dimensions (cm)	114 × 102 × 191		93 × 78 × 130		60 × 60 × 150	
HRT (h)	6	4	3.2	2.13	1.49	1.04
Temperature (°C)	15–42	15–42	15–42	15–42	15–42	15–42
Up-flow velocity (m/h)	0.25	0.376	0.40	0.575	–	–
Flow rate (m^3/d)	7	10	7	10	7	10
Dissolved oxygen (mg/l)	–	–	3–5	3–5	–	–
OLR (kg COD/m^3/day)	1.54	2.07	0.9	1.56	0.6	0.88
Packing material	Rolled NWPF		Rolled + plates NWPF		–	–
Surface area m^2/m^3	2000	2000	–	–	–	–

2. Materials and methods

2.1. Description of the integrated treatment system

The pilot plant treatment system consists of a UASB reactor packed with NWPF. The anaerobically treated effluent was subjected to post treatment using BAF unit. An inclined plate settler (IPS) was used after the BAF unit to sustain any biomass washed out from the BAF as well as to enhance the quality of the treated effluent. The dimensions and operating conditions of the treatment train are shown in Table 1. NWPF was used as a packing material in both UASB and BAF. The configuration of NWPF in the UASB was similar to that used by (Abou-Elela et al., 2013a). However, in BAF unit, the NWPF was arranged in vertical plates at a distance of 5 cm apart from each other and were fixed at a distance of 10 cm from the bottom of the reactor. The void spaces between every two successive plates were filled with rolled NWPF to increase the surface area for microorganism's propagation. The system was operated and installed at a nearby wastewater treatment plant, North Cairo. The screened sewage was continuously pumped to the UASB reactor using a submerged pump.

2.2. Launching the treatment system

The P-UASB reactor was seeded with anaerobically primary digested sludge. The seeded sludge has a concentration of 46.51 g/l for TSS and 25.82 g/l for VSS. In addition, the BAF reactor was seeded with activated sludge from a nearby wastewater treatment plant (WWTP). The sludge has a concentration of 8.5 g/l for TSS and 1.42 g/l for VSS. The start-up period of the treatment system took about 2–3 months until it reached the steady state condition.

2.3. Physico-chemical and biological analysis

Physico-chemical analysis and bacteriological analysis were measured according to (APHA, 2012) and (Engelbrecht and Lalchandani, 1977).

3. Results and discussion

3.1. Characterization of feeding wastewater to the treatment system

Characterization of the influent wastewater to the treatment system indicated that the average values of total and soluble COD were 341.8 and 119.0 mgO_2/l, respectively. The average BOD_5 and TSS were 206.7 mgO_2/l and 172.4 mg/l, respectively. Biological examination of raw wastewater indicated that total coliform counts ranged from 2.0×10^6 to 4.6×10^7 MPN/100 ml with an average value of 1.5×10^7 MPN/100 ml. The fecal coliform concentrations were ranged from 1.5×10^6 to 2.3×10^6 MPN/100 ml with an average value of 1.93×10^6 MPN/100 ml.

3.2. Efficiency of P-UASB

The results obtained from the P-UASB operated at an average organic loading rate of 1.54 kg COD/m^3/day and HRT of 6 h, revealed that the system achieved sustainable and satisfactory reductions in the TCOD, BOD_5 and TSS. Their corresponding percentage removal values were 58.5, 66.6 and 77.14%, respectively. In addition, 2 logs of pathogens were removed as indicated by total coliform. The results obtained proved the advantage of using the innovative packing material (NWPF) in the P-UASB when low strength wastewater was used. The NWPF has pleated and rough surface, which can retain more biomass rather than the plain surface due to its high surface area (2000 m^2/m^3), large pore size (43.8 μm) and low density. All that enhances the strong adhesion of microbial biomass onto the packing media, promoting the effective physical entrapment/adsorption and subsequent bonding (chemical/electrostatic and Van der waals forces) between biomass and media which led to immobilization of attached biomass (Sanchez et al., 1994). SEM micrographs show the entrapment of microorganisms on the surface of NWPF, while still some void spaces avilable. These results are in agreement with (Uemura et al., 2002; Abou-Elela et al., 2013a) which indicated that the packing media in P-UASB serves as a filter preventing bacteria washout and also providing a large surface area for faster biofilm development and improve the methanogenesis.

3.3. Retained biomass in P-UASB

Sludge analysis indicated that the sludge yield coefficient in the P-UASB reactor was 0.342 kg SS/kg COD removed per day. The attached biomass on the surface of NWPF in the P-UASB reactor operated at an average OLR of 1.54 kg COD/m^3/day was 67.34 SS g/l and 28.19 VSS g/l.

3.4. Post treatment-using BAF

To improve the quality of the anaerobically treated effluent, the biological aerated filter was used as a post treatment after the P-UASB. The system was operated at a retention time of 3.2 h, a flow rate of 7 m^3/day and OLR 0.9 kg COD/m^3/day. The recorded results in (Fig. 1(a–c)) indicated that great removal of organic and inorganic pollutants have been achieved. Average removal rates of TCOD, SCOD, BOD_5 and TSS were 87, 80, 89 and 91%, respectively. The average residual values were 45.52 mgO_2/l TCOD, 26.92 mgO_2/l SCOD, 21.92 mgO_2/l BOD_5 and 17.77 mg/l TSS. The use of packing media (NWPF) in the BAF provides a large surface area per