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Performance of aerated submerged biofilm reactor packed with local scoria for carbon and nitrogen removal from municipal wastewater

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HIGHLIGHTS

- A single anaerobic/aerobic biofilm reactor is better than the aerobic reactor.
- Effluent recycling in single anaerobic/aerobic reactor enhances TN removal.
- Effluent recycle in the aerobic submerged biofilm reactor enhances ammonification.
- The system produces sludge with good settling properties.
- An average sludge production in the reactor was 0.145 g TSS/g COD removed.

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ABSTRACT

An up-flow submerged biofilm reactor packed with scoria was evaluated for municipal wastewater treatment. The reactor was operated two cycles (with and without effluent recycle) as single aerobic reactor at hydraulic loading rate (HLR) of 3.5–4.0 L/L/day and four cycles (with and without effluent recycle) as anaerobic/aerobic reactor at two HLR (3.5 and 5.2 L/L/day). Results indicated better removal efficiency in case of anaerobic/aerobic cycles especially for ammonia and total nitrogen. Effluent recycling in the aerobic reactor enhanced ammonification with significant reduction in ammonia and nitrogen removal, while in case of single anaerobic/aerobic reactor the effluent recycling improved ammonia and nitrogen removal and kept nitrate concentration in the final effluent below 10 mg N/L. The reactor produced good settled sludge with sludge volume index (SVI) of 46–74 ml/g for aerobic cycles and 18–50 ml/g for anaerobic/aerobic cycles. The average sludge production was 0.145 g TSS/g COD removed.

1. Introduction

In Saudi Arabia many areas still lack sanitation systems for effective treatment of domestic wastewater. The estimated numbers of populations that have no access to sewerage networks is 55% (Ministry of Economy and Planning, 2007) which is still high compared to other countries in the region. In 2010, the estimated total amount of domestic wastewater disposed of in private onsite treatment units was 1250 million m^3/year which is more than the total of 1185 million m^3 collected municipal wastewater in sewer pipelines all over the country (Al-Saud, 2010). Even some of the existing municipal sewage treatment facilities need rehabilitation and upgrading to meet the strict Saudi standard. Saudi National Water Company is planning to spend around USD $24.8 billion allocated budget in wastewater section. This investment aims to increase wastewater network coverage to 100%, up from the current coverage level of 45% (Abderrahman, 2010). The KSA has specific characteristics related to the horizontal distribution of the population throughout the country, which makes it difficult and expensive to build central wastewater treatment facilities with very long sewer networks. Decentralized facilities may cost less and become very prominent solution for many regions in the kingdom. There are many types of decentralized units that can be used as a treatment solution for municipal wastewater. However, many of these treatment technologies in need for skilled personnel, which is a challenge for many decision-makers in developing countries. In many developing countries, decision makers are looking for treatment technology that is simple in operation and able to produce treated effluent complied with the reuse standards. In Saudi Arabia, treatment performance of up-flow submerged biofilm reactor has not been investigated yet.

It has been proven by many researches that the submerged biofilm systems including those with fixed and suspended carriers are

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very effective and efficient in organic carbon and nitrogen removal by means of the attached growth biofilm, which exhibits lots of advantages as compared with activated sludge process such as stability and long retention time of microorganisms which enable removal of recalcitrant pollutants (Guo et al., 2009), much higher biomass content in terms of MLSS and MLVSS (Müller, 1998), much less surplus biomass or sludge with good settling properties (Rahimi et al., 2011). The good settling properties in the submerged biofilm is attributed to the longer solid retention time of the biomass with abundant amount and various species of metazoa, protozoa, bacteria and fungi and operation at low hydraulic retention time which results in less system footprint (Gongalves et al., 1998). However, the continuous flow submerged biofilm systems have been proved by many studies to be only efficient in nitrogen removal, the ammonia removal by nitrification in particular.

The submerged biofilm reactors with single or different ecological zones, is less expensive than the moving bed biofilm reactor. The moving bed biofilm reactor needs high energy input to keep the moving media suspended and in continuous circulation within the reactor. The minimum air flow rate to keep the media in suspension was estimated to be 5 LPM in 6 L membrane coupled moving bed biofilm reactor in case of 5% fraction while this air flow should be increased to minimum value of 9 LPM in case of 20% fraction (Lee et al., 2006). The submerged biofilm reactor is promising technology and has been used for the treatment of municipal wastewater (Xia et al., 2008; García-Mesa et al., 2010; Jin et al., 2012), industrial wastewater (Ramos et al., 2007) and dairy wastewater (Zhan et al., 2006).

In conclusion, the up-flow submerged biofilm reactor represents very robust, flexible and compact system with low sludge production and low maintenance cost. The system can be built at any scale and could be installed in existing activated sludge treatment facilities that have overload problem. Objective of this study is the application of single up-flow aerobic submerged biofilm reactor and single up-flow anaerobic/aerobic submerged biofilm reactor packed with local scoria as biofilm carrier for municipal sewage treatment.

2. Methods

2.1. Reactor configuration

To achieve the objective of this study, a lab-scale submerged biofilm reactor with 10.5 L total volume was designed and manufactured. The reactor consisted of cylindrical PVC column with 14.5 cm inner diameter, 65.0 cm total height and 63.6 cm working height. The column contains three zones: a lower zone, a middle biofilm zone, and an upper zone; the size of each zone is indicated in Fig. 1. A circular PVC plate with 14 cm diameter and containing 20 evenly distributed holes, each with a 0.5-cm diameter, was placed and fixed 3.6 cm above the bottom of the column to support the filter media in the middle zone and to enable a proper distribution of wastewater and air. The middle biofilm zone was packed with local black scoria with 0.49 void ratios which means that the water volume in the middle biofilm zone was 4.6 L while the total volume of water in the reactor is 5.78 L. Two air diffusers were mounted in the reactor; one at the bottom of the reactor and controlled by air valve 1 and the other at one third of the middle biofilm zone and controlled by air valve 2. Both valves are connected to air line coming from a compressor. During the start-up period and aerobic cycles, air valve 1 was switched on and air valve 2 was switched off while during the anaerobic/aerobic cycles the valve 1 was switched off and the valve 2 was switched on. This converts one third of the biofilm zone into anaerobic zone and the upper two thirds of the biofilm was kept aerobic. Effluent from the reactor was flowed to secondary sedimentation tank with 3.0 L total volume; see Fig. 1. Before use, the scoria was washed several times with tap water to remove fine dust and residues.

2.2. Reactor operation

To enhance biofilm growth, the reactor was inoculated with 4.36 L of return sludge from an activated sludge municipal wastewater treatment plant in Riyadh. The sludge has 10.12 g/L mixed liquor suspended solids (MLSS) and 6.84 g/L mixed liquor volatile

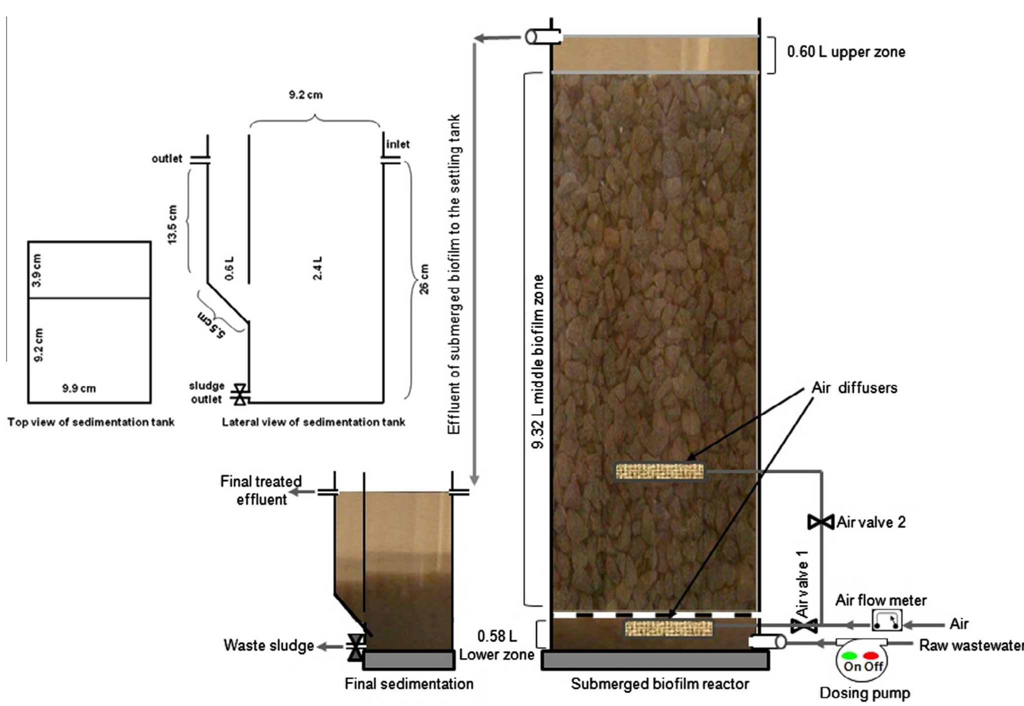

Fig. 1. Schematic diagram of the aerated submerged biofilm and secondary sedimentation unit.