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Original Research Paper

Treatment of Synthetic Domestic Wastewater by Integrated Aerobic/Anoxic Bioreactor (IAAB)

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ABSTRACT

An integrated aerobic/anoxic bioreactor with total liquid volume of 180 L was utilized for the treatment of synthetic domestic wastewater. Bioreactor performance was monitored by the removal of biochemical oxygen demand (BOD). Organic loadings simulating low and medium strength domestic wastewater with a BOD concentration of 110 and 235 mg/L were used to evaluate the bioreactor in stages 1 and 2 respectively. Hydraulic retention time (HRT) was varied between 12 and 7.2 days. Biomass from a sewage treatment plant was used as seed sludge. BOD removal was monitored from the aerobic, anoxic and effluent compartments of the bioreactor every two days. Results at HRT of 12 days show that the bulk of organic matter removal was prominent in the aerobic compartment with an effluent concentration of 28.7 and 30.5 mg/L at the steady states of stages 1 and 2 respectively. The anoxic compartment showed slight BOD removal with effluent concentration of 24.2 and 27.7 mg/L at the steady states of stages 1 and 2 respectively. The BOD concentration in the effluent compartment was 4.5 and 14.5 mg/L at the steady states of stages 1 and 2. BOD removal took a downtrend when HRT was decreased from 12 to 7.2 days in the aerobic and anoxic compartments, but was constant for the effluent compartment at steady state. Ammonia, nitrate, COD and MLVSS were all monitored. Ammonia, nitrate and COD removal were about 93%, 83% and 92% respectively. Growth of biomass (MLVSS) was more prominent in the aerobic compartment. This study demonstrates that an IAAB has the potential to treat wastewater.

INTRODUCTION

The consequences of the discharge of contaminated and improperly treated wastewater from various sources into the water bodies cannot be underestimated. They contain nitrogenous compounds such as ammonia, nitrate and nitrite, which cause eutrophication (Ezechi et al. 2014a). They impact toxicity to aquatic organisms which could cause methaemoglobin and subsequently death (Camargo et al. 2005). They could also result to methaemoglobinaemia in infants when high nitrate concentrated water is consumed. Nitrite, on the other hand, can form nitrosoamines in mammals and results in cancers of the digestive tract. Therefore, nutrient elimination from wastewater sources is of significant importance, not just for the protection of water bodies, but also to supplement limited fresh resources especially, in arid environments (Ezechi et al. 2012a, Ezechi 2012b, Ezechi et al. 2014b, Ezechi et al. 2015, Isa et al. 2014).

Biological treatment methods are aged long economical and well established treatment processes. Most biological wastewater treatment plants are designed with separate compartments (aerobic and anoxic) and connected through piping systems. These could increase investment costs through the use of a vast array of land. In addition, in compact or nuclear environments, where space is limited, the installation of a wastewater treatment plant becomes a challenge. Therefore, there is a dire need to develop systems that can reduce investment cost and also meet the objective of regulatory bodies.

Integration of the various biological treatment process compartments (aerobic/anoxic) is an approach to overcome the huge capital cost in wastewater treatment plants with the use of a vast array of space. It is intended to utilize a small space for operation, especially in compact and nuclear settlements. Previously, the integration process has mainly been utilized in the membrane and anaerobic biological processes in various configurations for the treatment of high strength wastewater and biogas production (Chan et al. 2012, Del Pozo & Diez 2005, Wang et al. 2005). Integrated bioreactors are smaller footprint of the conventional wastewater treatment plant and combines its individual degradation pathways into a single pathway (Chan et al. 2009). It is compact, cost effective, easy to operate and could be installed in nuclear settlements, urban cities with compact town planning and mountainous areas. However, the knowledge of the use of integrated bioreactors (aerobic/anoxic) for the nitrification/denitrification process is still at infancy.

The objective of this study is to investigate the performance of an integrated bioreactor treating synthetic low and medium strength domestic wastewater. Biochemical oxygen demand (BOD) was used as an indicator of bioreactor performance. Experiments were conducted in two stages of various organic loadings and two hydraulic retention time (HRT) of 12 and 7.2 days.

MATERIALS AND METHODS

Bioreactor configuration: The bioreactor has an oval shape consisting of three different compartments of aerobic (10 L), anoxic (20 L) and clarifier (150 L) integrated simultaneously into each other. The aerobic compartment is installed in the anoxic compartment and both compartments are installed in the clarifier. The bioreactor is configured in a pre-nitrifying fashion. Influent wastewater flows into the aerobic compartment in a downward process and moves into the coupled baffled aerobic compartment through the openings at the bottom of the aerobic compartment and subsequently moves into the anoxic compartment in an upward process. The wastewater from the anoxic compartment flows into the clarifier through the opening at the bottom of the anoxic compartment for settling. Settled wastewater flows into the effluent compartment from the clarifier. Mixed liquor recirculation (MLR) was automatically conducted into the anoxic compartment for one minute (16 times/day) to provide agitation, phase separation and mixing.

Wastewater preparation: The wastewater was a synthetic preparation simulating low and medium strength domestic wastewater. An appropriate amount of Purina Alpo substrate was daily dissolved in tap water, according to the operation HRT. Ammonia was included in the sample by addition of appropriate amount of ammonium chloride according to experimental plan. Table 1 summarizes the influent wastewater characteristics at stages 1 and 2.

Bioreactor operation: Biomass, with a mixed liquor suspended solid concentration of 3000 mg/L was collected from a sewage treatment plant and applied to the bioreactor. A masterflex peristaltic pump was used to supply the influent wastewater into the aerobic compartment at two different influent BOD concentrations of 110 and 235 mg/L at a fixed HRT of 12 days. The influence of HRT was then investigated by varying the HRT in the range of 12 and 7.2 days at a fixed BOD concentration of 235 mg/L.

Table 1: Average influent wastewater characteristics.

Parameter	Stage 1	Stage 2
pH	7.3	7.5
NH_3 (mg/L)	17.2	26.3
NO_3 (mg/L)	1.0	1.8
TSS (mg/L)	316	486
COD (mg/L)	250	500
BOD (mg/L)	110	235

. Oxygen was supplied to the aerobic compartment by means of ceramic plate diffusers placed at the bottom of the compartment in a fashion that produces rising air bubbles to every part of the compartment. Biomass was allowed an acclimation period of 20 days at a daily mixed liquor temperature of 25°C ±2. Samples were collected from the influent, aerobic, anoxic and effluent compartments every two days for the analysis. The bioreactor was considered in a steady state when near fixed values (5%) are obtained over a period of 8-10 days. BOD_5 was measured according to 21^{st} edition of the standard method number 5210 (APHA 2005). Ammonia and nitrate concentrations were measured using the colorimetric method (Nessler and cadmium reduction methods respectively). pH, DO and temperature were daily monitored concurrently using a pH meter (Session™), DO meter (YSI 550 A) and a thermometer (Thermolyne P/N MEX – 147 IMM 76 MM MCT). COD concentration was measured using colorimetric method. All the analysis were triplicated.

RESULTS AND DISCUSSION

Fig. 1 shows the removal of BOD_5 from each compartment of the bioreactor in stages 1 and 2.

BOD removal was prominent in each compartment of the bioreactor. This was evident in the way the effluent concentration attained steady state. In stage 1 (HRT 12 days), effluent BOD was below 5 mg/L at steady state but increased to about 15 mg/L in stage 2 due to increase in organic loading. BOD concentration in the aerobic and anoxic compartment was 28.7 and 24.2 mg/L in stage 1 but increased to 30.5 and 27.7 mg/L in stage 2. A slight increase in effluent concentration of all compartments was observed when BOD concentration was increased. This could be attributed to carbonaceous substrate removal, ammonia assimilation and endogenous respiration (Hamoda et al. 1996). Similar pattern of BOD removal from refinery effluent using wetland systems have been reported elsewhere (Huddleston et al. 2000).

Fig. 2 shows the BOD concentration at various HRT. BOD concentration slightly increased in the aerobic and anoxic compartment when HRT was decreased from 12 to

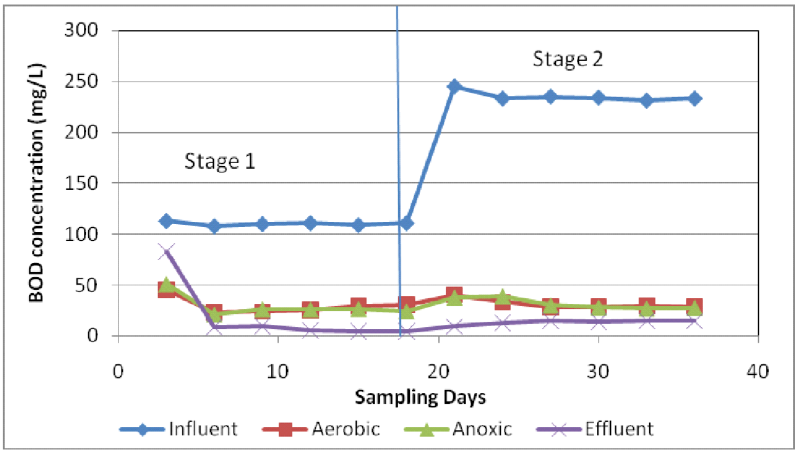

Fig. 1: BOD removal from each compartment: HRT 12 days.

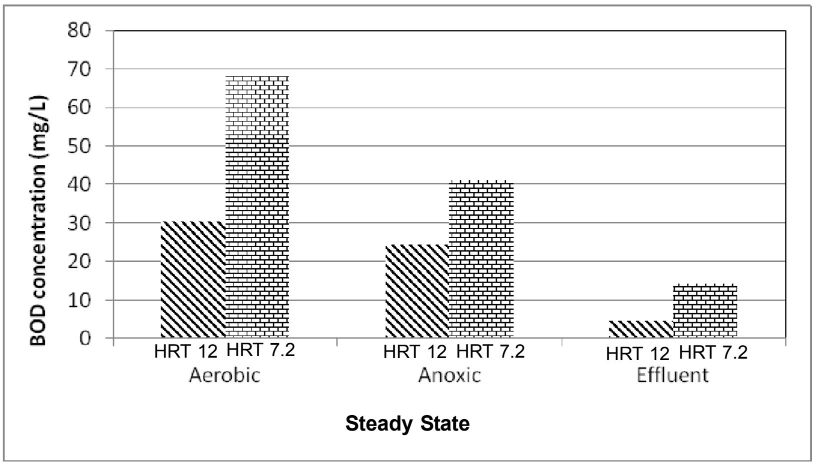

Fig. 2: Influence of HRT on BOD removal.

7.2 days. However, increase in HRT only impacted a negligible effect on the effluent compartment.

The percent BOD removal for each bioreactor compartment is presented in Fig. 3 at the various steady state conditions. It was observed that BOD simultaneously decreased from the aerobic compartment to the effluent compartment. The BOD removal of 96 % and 94 % was obtained in the effluent compartment at steady state conditions of stages 1 and 2.

The growth of microorganisms in the aerobic and anoxic compartments was monitored and presented in Fig. 4. It was observed that the biomass growth was more prominent in aerobic compartment due to substrate gradient and high substrate utilization rate. Ammonia, nitrate and COD were monitored and presented in Table 2. The bioreactor achieved effluent concentrations below the Malaysia Department of Environment (DOE) standard "A" guidelines for sewage discharge.

CONCLUSION

An integrated aerobic/anoxic bioreactor (IAAB) was investigated for the treatment of low and medium strength domestic wastewater using BOD as an indicator of bioreactor performance. It was observed that the increase in BOD concentration resulted in an increase of effluent BOD concentration. However, decrease in HRT did not significantly affect effluent BOD concentration. The growth of biomass was observed to be more prominent in the aerobic compartment due to substrate gradient and substrate utilization. Ammonia, nitrate and COD were also found to have values below the Malaysia DOE standard A guideline for sewage effluent discharge. This study therefore shows that an IAAB could

Table 2: Steady state concentrations.

Sample	Steady state stage 1 pH	NH_3 (mg/L)	NO_3 (mg/L)	COD (mg/L)	MLVSS (mg/L)	Steady state stage 2 pH	NH_3 (mg/L)	NO_3 (mg/L)	COD (mg/L)	MLVSS (mg/L)
Aerobic Compartment	7.7	2	0.8	40	3264	7.3	2.9	1.2	79	4334
Anoxic Compartment	7.5	1.5	0.3	23	3107	7.5	2.4	0.5	71	4167
Effluent Compartment	7.9	0.95	0.3	11	-	7.2	1.7	0.3	42	-

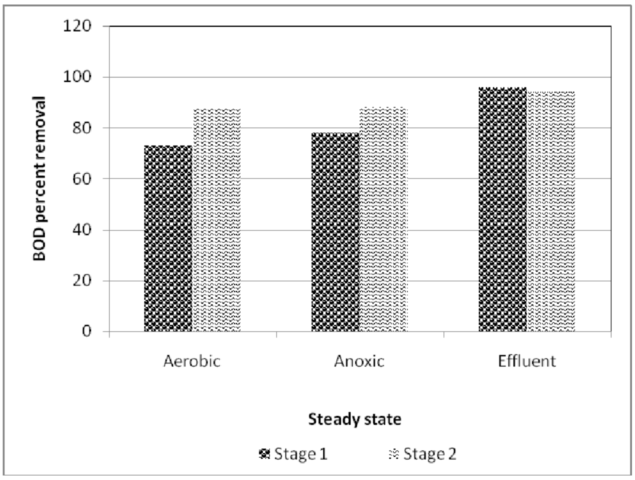

Fig. 3: Percent BOD removal from all compartment.

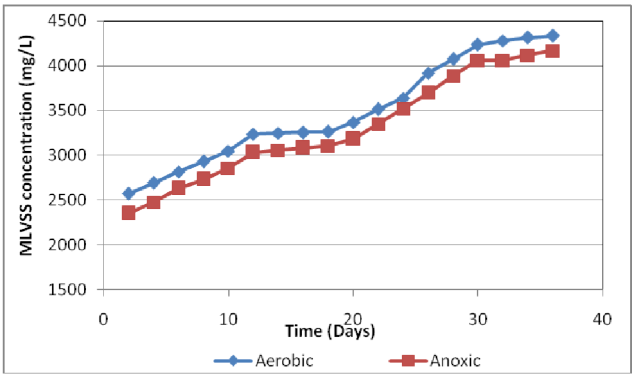

Fig. 4: MLVSS concentration.

potentially be used as a positive alternative for wastewater treatment.

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