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Fecal coliform removal from the effluent of UASB reactor through diffused aeration

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ABSTRACT

Although UASB systems treating municipal wastewater generally remove fecal coliform (FC) by ~ one order of magnitude, the effluent still contains concentrations higher than the WHO standard for unrestricted irrigation. In this study, the effect of continuous diffused aeration on the removal of FC was examined. The diffused aeration system was operated at different hydraulic retention times (60, 30 and 15 min) and dissolved oxygen (DO) concentrations (5–6 and 1–2 mg/l). The removal of FC was affected by the applied HRT and DO. Optimum results were obtained at HRT and DO equal to 60 min and 5–6 mg/l respectively, with FC removal of approximately 2 log (97%). The mechanisms responsible for FC die-off were the pH and oxidation reduction potential (ORP) of the medium.

Keywords: Diffused aeration; Municipal wastewater; Dissolved oxygen; ORP; Fecal coliform removal; UASB

1. Introduction

Reclaimed water from sewage treatment processes is a reliable alternative for irrigation [1–5]. Since 1980, the use of high rate up-flow anaerobic sludge blanket (UASB) reactor for sewage treatment gained wide popularity throughout the world due to its great advantages over conventional aerobic treatment processes [1]. However, the UASB reactor hardly produces effluent of suitable quality for disposal especially concerning microbial pathogens. Fecal coliform (FC) removal efficiencies have been reported in UASB reactors to be, only one order of magnitude [6,7]. Therefore, a post-treatment step is usually required to achieve the desired disposal standards, to protect the receiving water bodies and to reuse for restricted or/and unrestricted irrigation.

Recently, different post-treatment systems for UASB reactors have been investigated at laboratory and pilot scale, such as the rotating biological contractor (RBC), the down-flow hanging sponge (DHS), trickling filters and biological aerated filters [8]. However, none of these methods achieved high efficiency in terms of the removal of pathogens. Other studies reported that coliforms removal depends on a variety of factors such as pH, dissolved oxygen (DO), oxidation reduction potential (ORP) and hydraulic retention time (HRT) [9–11]. Indeed, the removal rate of *E.coli* was significantly higher at DO concentration between 3.3 to 8.7 mg/l,

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corresponding to those of a normal water course (7.6–8.0 mg/l), compared to lower values. Present study, investigated the effect of continuous aeration on pathogens removal from UASB reactor effluent.

2. Methods

2.1. Reactor configuration

The UASB reactor was constructed of perspex with a working volume of 45 l (20 cm diameter and 1.5 m high). A gas–liquid-solids–separator (GLSS) was installed on the top of the reactor.

The aeration tank was constructed of plexiglass with a variable volume of 6 to 2 l, depending upon experimental HRT. The aeration control system provided through six symmetrical fine pore diffusers located at the bottom of the system fed with an air pump (Fig. 1).

2.2. Reactor operation

The sewage used for the study was obtained from local pumping station. The UASB reactor was operated at an HRT of 8 h regularly for more than 12 mon. The effluent from the UASB reactor was aerated continuously at different HRT and DO concentrations. Initially, the aeration HRT was maintained at 60 min, then subsequently decreased to 30 min and finally to 15 min. The continuous diffused aeration system was operated for a period of more than 4 mon under ambient temperature conditions. The experimental work was planned into six different modes of operation (Table 1).

2.3. Physiochemical and bacteriological analysis

Samples from influent and effluent of diffused aeration tank were analyzed for pH, ORP, turbidity, biological oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), sulfide and fecal coliform (FC) according to Standard Method [19]. FC was measured using the Most Probable Number method (MPN),

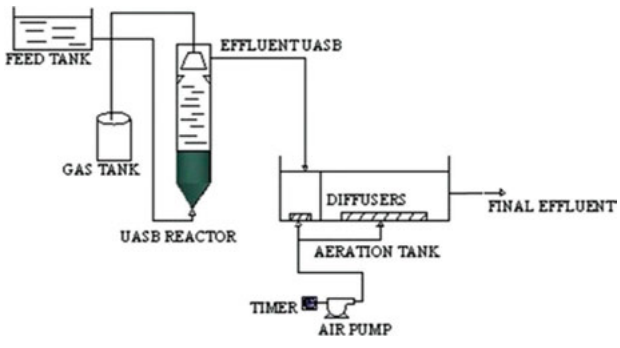

Fig. 1. Schematic representation of the UASB-diffused aeration system.

Table 1
Operating conditions of the flash aeration system

Mode of study	HRT (min)	DO (mg/l)
I	60	5.0–6.0
II	60	1.0–2.0
III	30	5.0–6.0
IV	30	1.0–2.0
V	15	5.0–6.0
VI	15	1.0–2.0

where samples were suitably diluted using sterile deionized water before inoculation using A1 broth at an incubation temperature of 35 ± 0.5°C for 48 h.

3. Results and discussion

In Table 2 different physiochemical and microbial parameters at the influent and effluent of the diffused aeration tank are presented as a function of the HRT and the DO concentration. The effect of each different parameter on fecal coliform removal is following discussed.

Table 2
Summary statistics from six operational modes

Mode	Samples/ efficiency	pH	ORP (mV)	FC (MPN/100 ml)
I	In DAS	7.4	–73	2.10E + 05
	Eff DAS	8.5	289	7.05E + 03
	% removal	–	–	**97**
II	In DAS	7.2	–39	1.96E + 06
	Eff DAS	7.7	194	8.22E + 05
	% removal	–	–	**58**
III	In DAS	7.4	–135	4.27E + 04
	Eff DAS	8.0	226	1.31E + 04
	% removal	–	–	**69**
IV	In DAS	7.3	–118	5.21E + 04
	Eff DAS	7.5	99	3.54E + 04
	% removal	–	–	**32**
V	In DAS	7.2	–125	4.30E + 03
	Eff DAS	7.8	–27	2.20E + 03
	% removal	–	–	**49**
VI	In DAS	7.1	–97	1.44E + 05
	Eff DAS	7.3	–61	1.32E + 05
	% removal	–	–	**8**

InDAS: Influent to Diffused Aeration System (UASB reactor effluent)**; Eff DAS:** Effluent from Diffused Aeration System.

3.1. Effect of HRT and DO

The effect of aeration on the removal of FC at different HRTs (60, 30 and 15 min) and DO concentrations (5.0–6.0 and 1.0–2.0 mg/l) presented in Table 2. From the observations, it inferred that an increase in FC removal with the increase in HRT occurred, similar to the results of previous studies [10].

The maximum FC removal efficiency (97%) was observed for operational mode I-highest HRT and DO, while the lowest one (only 5%) for operational mode VI-lowest DO and HRT. Moreover, in all operational modes a higher FC removal was observed for the 5–6 mg/l DO concentration, 97%, 68% and 48% for operational mode I, III and V, respectively. This observation can be partially explained by the fact that fecal coliform die-off accelerates at very high DO, especially at super saturation conditions [12].

3.2. Mechanisms for FC removal

3.2.1. Effect of pH on FC removal

The pH values at the diffused aeration tank and the corresponding FC removal is given in Fig. 2. An increase in UASB effluent pH was observed after the aeration process. This pH increase was caused by volatile organic compounds (VOC) and CO_2 purging from the aqueous phase due to aeration.

The effects of pH on FC removal were significantly correlated, within the operational range of 7.2–8.9. It was observed that fecal coliforms removal rate increased up to 94% with increasing pH above 8.5. These findings are concomitant to the observations of Davies-Colley et al. which found that inactivation of fecal coliforms and *E.coli* increased strongly if pH approached 8.5 or above it [13].

It has also been reported that fecal coliforms were adversely affected by high DO and increased pH [14,17]. Under starvation conditions FC die-off rapidly as the pH increased above 8.5 (from 8.5–8.75 to pH 9.0).

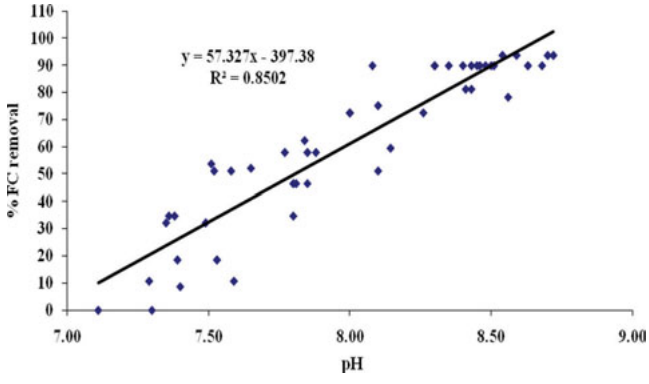

Fig. 2. Variation of % FC removal with pH.

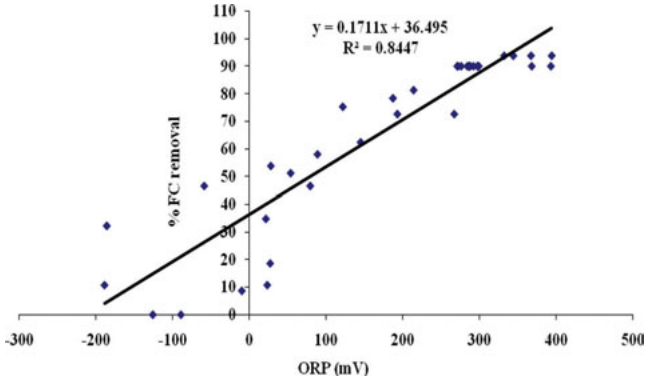

Fig. 3. Variation of % FC with ORP.

Complete removal of *E.coli* was reported for pH values above 10.4, however, similar pH influence on FC removal rate was observed for lower pH values [15,16].

3.2.2. Effect of oxidation reduction potential

The effect of ORP on FC removal is shown in Fig. 3, where at higher ORP values (300 to 400 mV) the removal of FC was significantly higher. Similar results were observed by other researchers, where the microbial life span was observed to be inversely proportional to ORP [9,11,18].

4. Statistical evaluation by paired two samples means t-test

In order to determine whether the observed correlation between two sets of experimental data were significant, data were subjected to paired two sample mean t-test. Results obtained from the statistical analysis of data are summarized in Table 3.

The results obtained from paired t-test between FC percentage removal and the different physic-chemical variables (pH, ORP) indicates that the critical value of t obtained from the t- distribution table at 5% probability level is lower than the value of t-stat in each case.

Table 3
Results of paired t-test: two samples for means between pH, ORP and % FC removal

% FC removal Data paired	Variables	
	pH	ORP
Degree of freedom (df)	48	35
Pearson correlation (R)	0.92	0.80
t-statistic	13.1	2.5
t-critical	2.0	2.0
P	≤0.05	

It shows that the chances of error in drawing out conclusions are less than 5%. Therefore, null hypothesis is rejected. Thus, it can be concluded that a real and significant correlation exist between the obtained experimental data for FC percentage removal and physico-chemical variables.

5. Conclusions

- The highest fecal coliform removal (97%) was observed at 60 min. HRT with DO level of 5–6 mg/l.
- Accordingly, the removal of FC was maximum when the pH was between 8.0–8.6 and the ORP greater than 250 mV.
- The results indicate that the removal rate depend on pH and ORP. The removal rates depended on these factors with correlation coefficients of 0.4–0.8 for FC at significant levels of 95% ($p \leq 0.001$).

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References

[1] T.C. Chang, S.J. You and S.H. Chuang, Evaluation for the Reclamation Potential of High-Tech Industrial Wastewater Effluent Treated with Different Membrane Processes, Environ. Eng. Sci., 24 (2007) 762–8.
[2] R.J. Chiou, T.C. Chang and C.F. Ouyang, Aspects of Municipal Wastewater Reclamation and Reuse for Future Water Resource Shortages in Taiwan, Water Sci. Technol., 55 (2007) 397–405.
[3] B. Jimenez, C. Maya and G. Salgado, The Elimination of Helminth ova, Faecal coliforms, Salmonella and Protozoan cysts by Various Physicochemical Processes in Wastewater and Sludge, Water Sci. Technol., 43 (2001) 179–82.
[4] B. Jimenez and A. Chavez, Low Cost Technology for Reliable Use of Mexico City's Wastewater for Agricultural Irrigation, Environ. Technol., 9 (2002) 95–108.
[5] T.M. Scott, M.R. McLaughlin, V.J. Harwood, V. Chivukula, A. Levine and A. Gennaccaro, Reduction of Pathogens, Indicator Bacteria, and Alternative Indicators by Wastewater Treatment and Reclamation Processes, Wat. Sci. Tech. Water Supply, 3 (2003) 247–52.
[6] M. Von Sperling, C.A.L. Chernicharo, A.M.E. Soares and A.M. Zerbini, Coliforms and Helminth Eggs Removal in a combined UASB Reactor–Baffled Pond System in Brazil: Performance Evaluation and Mathematical Modeling, Wat. Sci. Tech., 45(10) (2002) 237–242.
[7] M. Von Sperling and L.C.A.M. Mascarenhas, Performance of Very Shallow Ponds Treating Effluents from UASB Reactors, Wat. Sci. Tech., 51(12) (2005) 83–90.
[8] Khan and Abid Ali, (2011), Post Treatment of Effluent of UASB Reactor Treating Sewage, PhD Thesis would be submitted in December, IIT Roorkee, India.
[9] J.W. Klock, Survival of Coliforms Bacteria in Wastewater Treatment Lagoons, J. Wat. Poll. Cont. Fed., 43 (1971) 2071–2083.
[10] H.E. Maynard, S.K. Ouki and S.C. Williams, Tertiary Lagoons: A Review of Removal Mechanisms and Performance, Wat. Res., 33(1) (1999) 1–13.
[11] N.M. Parhad and N.V. Rao, Effect of pH on Survival of E. coli., J. Wat. Pollut. Contr. Fed., 46(5) (1974) 149–161.
[12] R.F. Feachem, D.J. Bradley, H. Garelick and D.D. Mara (1983), Sanitation and Disease Health Aspects of Excreta and Wastewater Management, World Bank Studies in Water Supply and Sanitation 3, John Wiley & Sons: Chichester (UK).
[13] R.J. Davies-Colley, A.M. Donnison, D.J. Speed, C.M. Ross and J.W. Nagels, Inactivation of Fecal Indicator Microorganisms in Waste Stabilization Ponds: Interactions of Environmental Factors with Sunlight, Wat. Res., 33(5) (1999) 1220–1230.
[14] B. El Hamouri, Kh. Khallayoune, K. Bouzoubaa, N. Rhallabi and M. Chalabi, High Rate Algal Pond Performances in Fecal Coliforms and Helminth Egg Removals, Wat. Res., 28 (1994) 171–174.
[15] N.M. Parhad and N.U. Rao, The Effect of Algal Growth on the Survival of E. coli in Sewage, Indian J. Environ. Hlth., 14(2) (1972) 131–139.
[16] M. Troussellier, P. Legendre and B. Baleux, Modeling of the Evolution of Bacterial Densities in an Eutrophic ecosystem (sewage lagoons), Microbial. Ecol., 12 (1986) 355–379.
[17] R.M. Maier, I.L. Pepper and C.P. Gerba (2000), A Textbook of Environmental Microbiology Academic Press, Elsevier, US.
[18] C. Polprasert, M.G. Dissanayake and N.C. Thanh, Bacterial Die-Off Kinetics In Waste Stabilization Ponds, Journal of Water Pollution Control Federation, 55 (1983) 285–296.
[19] APHA, AWWA, WEF, 1998, *Standards Methods for the Examination of Water and Wastewater*, 20th edition, American Public Health Association, American Water Works Association and Water Environmental Federation, Washington, DC.