



Coliforms removal in two UASB + ASP based systems

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ABSTRACT

Two full scale up-flow anaerobic sludge blanket (UASB) reactor with activated sludge process based STPs (43 Ml d⁻¹ and 100 Ml d⁻¹ capacities) purely for municipal wastewater having two different aeration systems (surface and diffused) were continuously evaluated for one year. Total coliforms (TC) and fecal coliforms (FC) were measured along with other performance monitoring parameters in raw sewage, UASB effluents, and in final effluents. The concentration of total and fecal coliforms ranged from 9.3×10^6 to 1.2×10^{14} MPN/100 ml and 9.3×10^6 to 2.4×10^{13} MPN/100 ml respectively in raw sewage. At both the plants, it was observed that finally treated effluent still contained significant number of total coliforms (5.71×10^5 and 6.7×10^5) and fecal coliforms (3.67×10^5 and 2.2×10^5) after overall removal of 99.9%, which is still greater than the permissible limit of 1000 MPN/100 ml and needs further treatment. Seasonal variation indicated the effective removal of coliforms in raw sewage was in summer. Fecal coliforms are highly correlated with phosphorous and total coliform concentrations.

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1. Introduction

The direct treatment of sewage by up-flow anaerobic sludge blanket (UASB) reactor is an attractive and appropriate option for the developing countries like India, since it requires low energy, low initial capital cost, less land requirement, less sludge generation and most important energy generation in the form of methane gas (Lettinga, 1995; Schink, 2002). Therefore there has been a clear-cut shift in sewage treatment process from conventional aerobic process like activated sludge process (ASP) to UASB reactor based sewage treatment plants (STPs). But it is well documented in literature (Seghezze et al., 1998) that anaerobic wastewater treatment plants fail to discharge the effluents as per the effluent discharge standards (WHO 1989; CPCB 2001) mainly for biochemical oxygen demand (BOD), chemical oxygen demand (COD), pathogens and suspended solids (SS). A post-treatment method was recommended after UASB which must be aerobic (Chernicharo, 2006; Mungray and Kumar 2008), which may reduce the adverse effects of pathogens and residual organics to the aquatic environment (Seghezze et al., 1998). Concerns with water quality have increased in recent years, fecal indicators and pathogens are most responsible for water borne diseases originated from point sources discharges such as raw sewage and effluents of wastewater treatment plants (Seurinck et al., 2005).

The effectiveness of wastewater treatment systems with respect to the elimination of microbiological pollution is often measured by determining the densities of total coliforms (TC) and fecal coliforms (FC) in effluent of wastewater treatment plants. WHO has recognized coliforms (TC and FC) as the key fecal indicators (WHO, 2002). These indicators provide a total spectrum of water borne diseases; viz. TC indicates the presence of bacterial pathogens while FC indicates the presence of bacterial pathogens as well as the presence of enteric viruses through their relation with coliphages (Kazmi et al., 2008). The choice of these micro-organisms is based on two main reasons: first, it is simple and economical to determine their presence and second, this determination provides information related to the presence and behavior of the principal human pathogens present in wastewater (Molleda et al., 2008).

Conventional ASP is considered an efficient system for reducing organic and bacteriological load in comparison to UASB based system, but has some limitations. Nineteen ASP based STPs were studied by Kazmi et al. (2008) in two Indian cities. The influent concentration of TC and FC were found to be varying between log 7.0–9.0 and log 6.7–8.9 per 100 ml, respectively. In the treated effluent TC and FC values were in the range of log 4.2–7.5 and log 3.9–7.1 per 100 ml, respectively. The overall average removals of TC and FC by ASP systems were found to be log 2.2 (99.4%) and log 2.4 (99.6%), respectively. As per Metcalf and Eddy (2003), reduction of bacteria in ASP is 90–98%. Earlier studies in ASP have usually shown similar 90–99% enteric bacterial reduction (Koivunen et al., 2003). The overall efficiency of coliform removal has been reported to be 91–99% in extended aeration (EA) activated sludge process

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(Kazmi et al., 2008; Jamwal and Mittal, 2010), 92.3% in combined UASB – Polishing pond (PP) treatment (Pant and Mittal, 2007), and 98–99% in combined UASB – DHS (down-flow hanging sponge) system (Uemura et al., 2001; Tawfik et al., 2006). Two stage wetlands were also studied as a post-treatment unit for UASB by El-Khateeb et al. (2009) where coliforms were removed effectively.

Studies for the performance of ASP as a post-treatment with UASBR for coliforms removal are very limited. Only few studies (von Sperling et al., 2001; Sklyar et al., 2003; Gizgis et al., 2006) were found where wastewater was taken as a combination of Olive mill wastewater and municipal wastewater, starch industry wastewater and also municipal wastewater alone respectively but coliforms were not analyzed at all the places. In one study (Tawfik et al., 2008), the overall efficiency of TC and FC removal was reported to be 94% and 97% in combined UASB-AS (Activated Sludge) system by using a combination of dairy and domestic wastewater where domestic sewage was only 30% and total coliforms concentration in raw feed was only 5.5×10^7 MPN/100 ml.

Fate of coliforms in UASB-ASP combination purely for municipal sewage is very limited, therefore a need was felt to check the effectiveness of two UASB-ASP based STPs (43 MI d⁻¹ and 100 MI d⁻¹ capacities) purely for municipal wastewaters having two different aeration systems. Seasonal variation of pathogens is also checked. Other monitoring parameters like COD, BOD and TSS were also measured and compared with other combinations. For finding correlations between monitoring parameters with TC and FC, statistical analysis was also utilized.

2. Material and methods

Two UASB based STPs followed by activated sludge process, one at Vadodara (22° 18' 0" N, 73° 12' 1" E) of 43 MI d⁻¹ capacity, second at Surat (21° 10' 12" N, 72° 49' 48" E) of 100 MI d⁻¹ capacities, were selected for the study. At both the STPs, different types of post-treatment were used. At Vadodara, surface aeration based and at Surat, diffused aeration based units were used. Study was carried for a period of one year (May 2008–May 2009) and samples were collected on weekly basis from the following three locations from every STP (i) raw sewage, (ii) UASB effluent and (iii) final effluent. Their numbers and main characteristics are given in Table 1.

The combined UASB-ASP systems were designed to handle 200 mg l⁻¹ of influent BOD (5 day, 20 °C), 800 mg l⁻¹ COD and 400 mg l⁻¹ of influent SS for meeting the required Indian standards of 30 mg l⁻¹ of BOD, 250 mg l⁻¹ of COD and 100 mg l⁻¹ of SS in the final effluent. Sewage after preliminary treatment (removal of screenings and grit) is uniformly distributed at the bottom of UASB reactors. The UASB effluents are discharged to ASP based post-treatment units. UASB sludge is applied on filter press for dewatering. Treated sewage is discharged into river.

Table 1
UASB-ASP based STPs: dimensions and design parameters.

Parameters	Installed capacity and locations	
	43 MI d ⁻¹ Vadodara	100 MI d ⁻¹ Surat
UASB reactors		
Numbers	4	20
Dimension, L × W × D (m ³)	20 × 24 × 5.1	20 × 20 × 7.44
Effective volume of reactors (m ³)	14,680	39,200
HRT (at average flow), (h)	8–9	8–9
Post-treatment		
Numbers	2	4
Dimension, L × W × D (m ³)	52 × 26 × 4	60 × 16 × 5.5
HRT (at average flow), (h)	6	3 (designed: 5)

2.1. Analysis

The present work considers both the STPs. Grab sampling method was used for the sampling of STPs in the present study. Samples were collected from combined streams and not from individual reactors. Procedures listed in Standard methods for the examination of water and wastewater was followed for sample collection, preservation, and transportation (APHA 2005). Total coliforms and fecal coliforms were measured in samples of sewage by "Multiple-Tube Fermentation Technique" as prescribed in Standard methods for the examination of water and wastewater (APHA 2005) and reported in MPN/100 ml for sewage. Other conventional pollution parameters (COD, BOD and TSS) were also analyzed as per standard methods (APHA 2005). Dissolved oxygen (DO) and pH were measured by using different probes (HACH, USA). Nitrates, Nitrite, ammonical nitrogen, total phosphorous and *ortho* phosphorous were also analyzed according to standard methods (APHA 2005). These results were used only for statistical analysis and to find out their correlation with TC and FC.

3. Results and discussion

3.1. UASB – ASP based STPs

At both the STPs, one year data for total and fecal coliforms and fifteen weeks data for other conventional parameters are used to find range, mean and standard deviations of different parameters. Over the period of study, at both STPs, sewage temperature ranged between 20 and 34 °C, COD_T varied from 628 to 1128 mg l⁻¹, BOD_T from 195 to 269 mg l⁻¹ and TSS from 175 to 268 mg l⁻¹. Total coliforms and fecal coliforms ranged from 9.3×10^6 to 1.2×10^{14} MPN/100 ml and 9.3×10^6 to 2.4×10^{13} MPN/100 ml respectively which shows a medium quality of municipal sewage (Metcalf and Eddy, 2003). Reported average concentration in raw sewage are 1.6×10^7 MPN/100 ml in India (Pant and Mittal, 2007), range of 6.8×10^5 to 1.0×10^6 MPN/100 ml in Ghana (Auwah and Abrokwa, 2008), mean value of 1.8×10^8 MPN/100 ml at Brazil (Oliveira and von Sperling, 2008) and 4.3×10^6 MPN/100 ml by Tyagi et al. (2008). The levels of total and fecal coliforms in raw sewage were high in present investigation. This may be attributed to the increase of human activities and the decrease of domestic water consumption (El-Taweel et al., 2002; El-Khateeb et al., 2009).

Table 2 was prepared by taking average concentrations of coliforms, COD, BOD (total and particulate) and total suspended solids at three sampling points for two STPs. Similarly their percentage removals were calculated and reported for UASBR, ASP and in overall combination. Both soluble and particulate fractions were removed. For 43 MI d⁻¹ STP, influent with an average BOD value of 230 mg l⁻¹ was fed to the STP. After UASB treatment, this value reduced to 115 mg l⁻¹ and thereafter the final treatment was employed after which the total BOD value was observed to be 16 mg l⁻¹. Similar BOD concentrations were also found at 100 MI d⁻¹ STP (Table 2). COD of 879 and 727 mg l⁻¹ were fed to the STPs, these values reduced to 124 and 129 mg l⁻¹ after the treatment in UASB and in post-treatment units having overall percentage removals of 86% and 82% respectively. Similarly for TSS, final discharge values were 84 mg l⁻¹ and 94 mg l⁻¹ after the treatment in UASB and in ASP units at 43 and 100 MI d⁻¹ STPs respectively. According to the standard discharge guidelines (CPCB, 2003), 30 mg l⁻¹, 250 mg l⁻¹ and 100 mg l⁻¹ are set for BOD, COD, and TSS respectively. The final discharge concentrations satisfy the discharge guidelines.

The need of post-treatment step is clearly indicated by the removal of organics in terms of BOD and COD at both the STPs after UASB reactors. Percentage BOD and COD removal were less than 50% in UASB reactor for both 43 and 100 MI d⁻¹ plant. After the treatment in UASB, sewage entered in the post-treatment unit where it was

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