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Disinfection of wastewater: Comparative evaluation of chlorination and DHS-biotower

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Abstract: *The present study reports the onsite evaluation of two pilot scale disinfection units. One of the pilot plants is based on chlorination, and other is based on fixed film aerobic process (biotower). Evaluation study consisted of onsite monitoring of COD, BOD_5 and TSS and fecal coliform over a period of three months. Samples were collected from the inlet and outlet of the pilot plants. These pilot plants were evaluated so as to have an appropriate disinfection technology for the treatment of the effluents from upflow anaerobic sludge blanket reactor (UASBR) based sewage treatment plants which could meet the biological quality standards. All the influents samples collected from both the pilot plants contained fecal coliform ranging from 10^5 to 10^6 MPN/100 ml. The results show that the fecal coliform removal is up to 98.2% and 100% for biotower and chlorination, respectively. Both, the chlorination and down hanging sponge-biotower (DHS-biotower) improved the quality of effluent from the UASBR in terms of COD, BOD_5 and TSS. Though chlorination performed better compared to the DHS-biotower, however, it has additional risk associated with the formation of trihalomethanes (THMs).*

Key words: *Chlorination, Disinfection, Fecal coliforms, Municipal wastewater and UASB, Biotower*
PDF file of full length paper is available with author

Introduction

The direct disposal of treated or untreated municipal sewage into surface water bodies has deteriorated the water quality of major rivers of India (Kumari *et al.*, 2006). The presence of disease causing pathogens in the effluents discharged by sewage treatment plants (STPs) affects the microbiological quality causing considerable threat to public health. It is also known that the most widespread contamination of water is from human wastes which causes diseases and is ultimately responsible for killing more than 3 million people in a year (World Bank, 1992; Indra and Sivaji, 2006; Krishnan *et al.*, 2007). The conventional municipal sewage treatment plants, which generally do not include disinfection process, reduce fecal microorganism densities by 1-3 orders (Miescer and Cabelli, 1982; George *et al.*, 2002; Zaimoglu, 2006). The treatment of such wastewaters by adequate processes is essential to avoid the problem of waterborne diseases to human beings. Thus, it is required to disinfect wastewater effluents prior to final disposal. Chlorination is the most common method used worldwide for the disinfection of pathogens from wastewater before discharge into receiving streams, rivers or oceans (Haas and Engelbrecht, 1980; Lazarova *et al.*, 1999). The status of disinfection of wastewater in India and most of other developing countries is essentially very different, where it still as a concept does not exist at large. A number of issues like selection of treatment process, risk associated with the presence of pathogens, and applicability of indicator microorganisms to represent pathogenicity of wastewater *etc.* is yet to be fully established.

In a developing country like India, sanitary and hygiene conditions are unsafe due to the lack of sufficient wastewater collection, treatment and disposal facilities life-threatening for urban residents and deteriorate the overall environmental quality of the urban area at large. According to study by Laxmi *et al.* (1997) almost all surface water sources in India are contaminated and unfit for human consumption. Only some of the existing wastewater treatment plants work and of those even fewer meet discharge standards (Arceivala, 1997). Till recently, the reduction of microbial pollution in wastewater treatment has not been a priority in India. However, the standard for fecal coliforms in the effluent from sewage treatment plants are 1000 MPN /100 ml (desirable) and 10, 000 MPN/100 ml (permissible). Nevertheless, STPs in India do not practice disinfection process. Moreover, many STPs, along the river Yamuna are based on upflow anaerobic sludge blanket reactor (UASBR) technology. It is found that these plants could reduce the organic pollution load, but the biological quality of the treated wastewater effluent did not improve and the water quality in the river remained unfit for reuse (Uemura *et al.*, 2002). Thus, it becomes essential to ascertain an appropriate technology, so as to improve the water quality as well as to meet the standards for fecal coliform in the receiving water bodies.

The present work is aimed to study the pilot plants that have been constructed at different UASBR based STPs to evaluate various disinfection processes. In this study, the disinfectant action of chlorination and down hanging sponge (DHS) biotower against the indicator microorganism (fecal coliforms) has been observed. Besides, effect of chlorination and DHS-biotower on the physicochemical parameters like chemical oxygen demand (COD), biochemical oxygen demand (BOD_5 at 20°C) and total suspended solids (TSS) have also been evaluated.

Materials and Methods

Pilot plant set-up: The pilot scale disinfection units located at two different UASBR based STPs have been selected for this study. One of these pilot plants has been constructed after 27 MLD UASBR based STP, Noida (Uttar Pradesh, India) and is based on chlorination using calcium hypochlorite (either slurry form or liquid high test hypochlorite, HTH) with a capacity of 2 million liter per day (MLD). The other 1 MLD DHS-biotower pilot plant, developed by Prof. H. Harada (Machdar *et al.*, 1997), is based on fixed film aerobic process and has been constructed after 40 MLD UASBR based STP, Karnal (Haryana, India). These STPs, based on UASBR technology, consists of preliminary treatment (Screen and Grit Chamber), UASBR and final polishing pond (Fig. 1).

A schematic diagram of the pilot plants at Noida and Karnal is presented in Fig. 2 and 3 respectively. The chlorination unit of 2 MLD consists of a sump, mixing unit and baffled contact chamber (3m x 7m) and a specific dose of chlorine was mixed with a separate pipe. The 1 MLD DHS-biotower based on fixed film aerobic process consists of a sump and reactor having plastic rectangular sheets onto which triangular prism polyurethane foams were tiled. Raw sewage after UASBR treatment was supplied to the chlorination unit and DHS-biotower.

In case of chlorination unit, initially the bleaching powder was used as a disinfectant from day 1 to day 48 and later on it was found that there was no residual chlorine in the bleaching powder, so the bleaching powder was replaced with calcium hypochlorite as disinfectant after 48th day. The dose of disinfectant was 5 mgl^{-1} from day 1 to day 16 and was increased to 20 mgl^{-1} from day 20. The contact time for the reaction between wastewater and disinfectant was 30 min throughout the study.

Collection of wastewater samples: The wastewater samples were collected from the inlet and outlet of the pilot plants over a period of three months for the evaluation of the fecal coliforms along with other parameters like COD, BOD_5 and TSS. The samples after chlorination unit were dechlorinated with sodium sulphite to stop the action of residual disinfectant. Samples were immediately transported to the laboratory in an icebox. The microbial analysis for fecal coliforms was carried out within 4 hr of sample collection. Rest of the sample was preserved in the refrigerator. Other physico-chemical parameters, *i.e.*, COD, BOD_5 and TSS were determined as per standard methods (APHA, 1998).

Enumeration of fecal coliforms: The fecal coliforms were enumerated using multiple-tube fermentation technique to obtain MPN as per standard methods (APHA, 1998). For the enumeration, samples were suitably diluted using sterile deionized water before inoculation in appropriate medium. The A1 broth was used for the growth of the fecal coliforms. Five tubes for three different dilutions (10, 1 and 0.1) were taken and microorganisms were recovered at the discriminating temperature of 44.5^{o}C for 24 hr. For 10 ml sample, the double strength of broth is used. Media for bacterial analyses were obtained from Difco laboratories. All the sample dilutions were assayed in triplicate.

Results and Discussion

Reduction of fecal coliform: To achieve good disinfection, the contact time and dose are extremely important. A longer contact time is required for complete disinfection to occur. As per Lindsay (2004), a contact time of 30 minutes is a minimum, and if the dose remains constant, the contact time may necessitated to be increased at low temperatures or higher pH to obtain the same level of disinfection. Typical chlorine doses for municipal wastewater disinfection are about 5-20 mgl^{-1} with a contact time of 30 to 60 min (Lazarova *et al.*, 1999). During this study, 5 and 20 mgl^{-1} of disinfectant doses for a fixed contact time of 30 min was applied. It was observed that a dose of 20 mgl^{-1} was very effective for the reduction in indicator microorganism (fecal coliforms). Initially when a dose of 5 mgl^{-1} was used, the reduction in fecal coliforms count was less than 90%. It may be attributed to the fact that the minimum dose required for the killing of microorganism was not sufficient as there was high chlorine demand due to the presence of high concentration of organic matter and suspended solids in the UASBR effluent. The average fecal coliforms count was reduced from 3.58×10^5 ($\pm 1.02 \times 10^5$) MPN/100ml to nil at a dose of 20 mgl^{-1} and 30 min contact time (Fig. 4a). Thus the results shows that almost 100% removal of fecal coliforms has been observed after chlorination; however at certain days *i.e.*, from day 7 to day 14 and from day 44 to day 53 (Fig. 4a), the number of fecal coliforms present in the wastewater effluent after disinfection was increased. It could be explained on the basis of type of chemical used for the chlorination. During this period, bleaching powder was used. Later on it was found that the chemical used at the plant does not have any residual chlorine. Chlorination was switched to the fortified brand of the calcium hypochlorite, high test hypochlorite (HTH). It indicated that chlorination was very effective in the removal of fecal coliforms if the regular operation and maintenance (O and M) is ensured.

The DHS-biotower system was composed of polyurethane material as the packed media to which microorganisms attach and as the porous media for solids retention (Tawfik *et al.*, 2006a). A post treatment unit based on DHS-biotower was installed as pilot plant at 40 MLD STP Karnal to improve the microbiological quality of UASBR effluent. Fig. 4b presents the fecal coliforms concentration in inlet and outlet of DHS-biotower. Removal of bacteria in such fixed film reactors is directly related to the bacterial count of the sewage and at low-rate loadings to the surface area of the filter medium. The average fecal coliforms count was reduced from 3.01×10^6 ($\pm 7.67 \times 10^5$) MPN/100 ml to 4.68×10^4 ($\pm 2.57 \times 10^4$) MPN/100 ml in DHS-biotower. The fecal coliform removal efficiency of biotower is very high with an average removal of 98.24%. Uemura *et al.* (2002) have also reported similar results. Fixed film reactors are extremely effective in removing pathogenic bacteria with normal removal efficiencies of >95% (Pike, 1975; Lessard and Bihan, 2003).

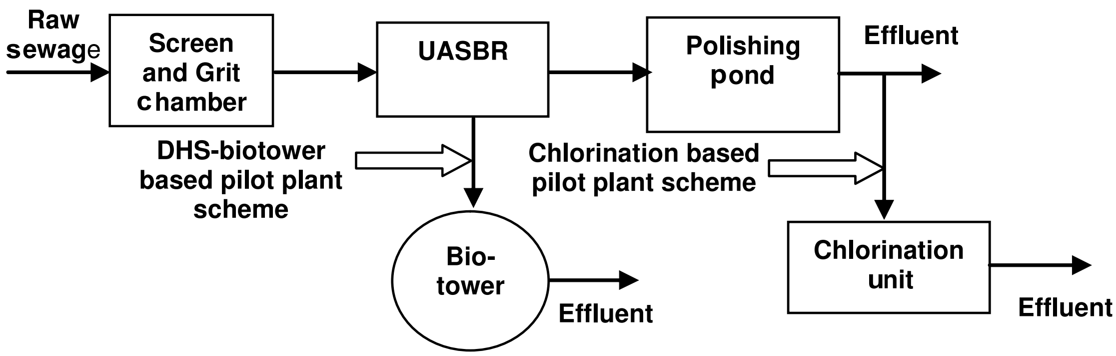

Fig. 1: Schematic diagram of the pilot plants specifying the location of the influents to the plants

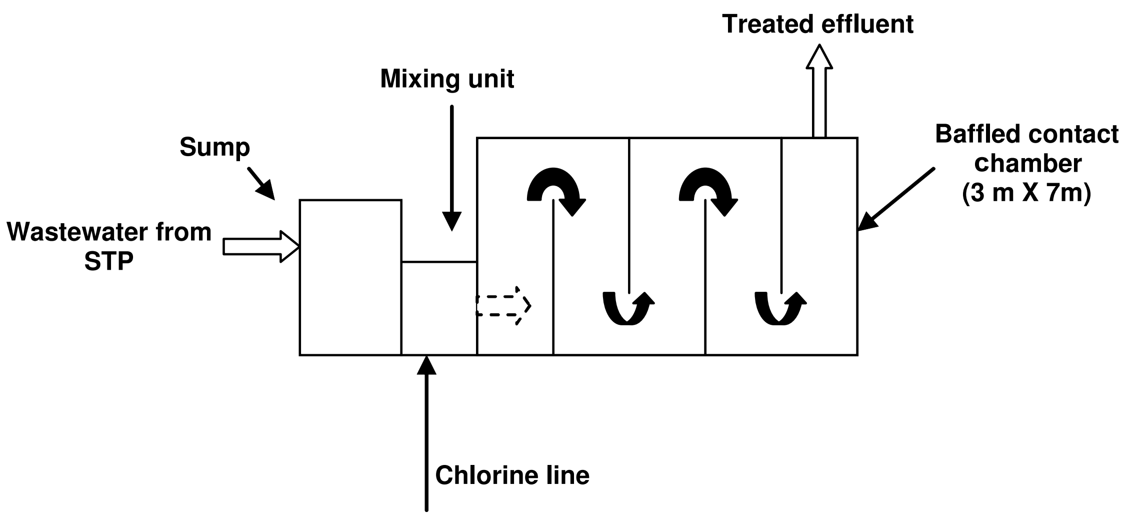

Fig. 2: Schematic flow diagram of chlorination unit pilot plant (2 MLD) at Noida

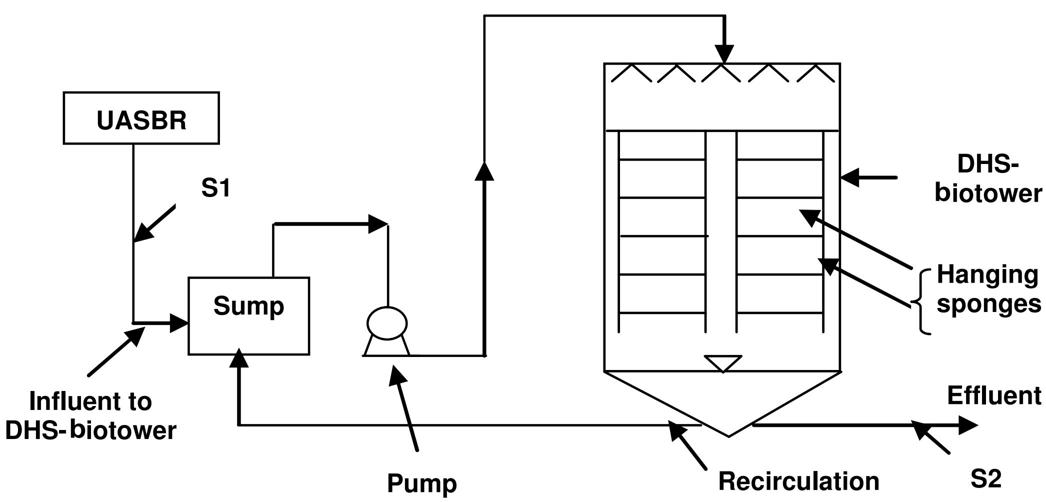

Fig. 3: Schematic flow diagram of DHS-biotower (1 MLD) pilot plant at Karnal

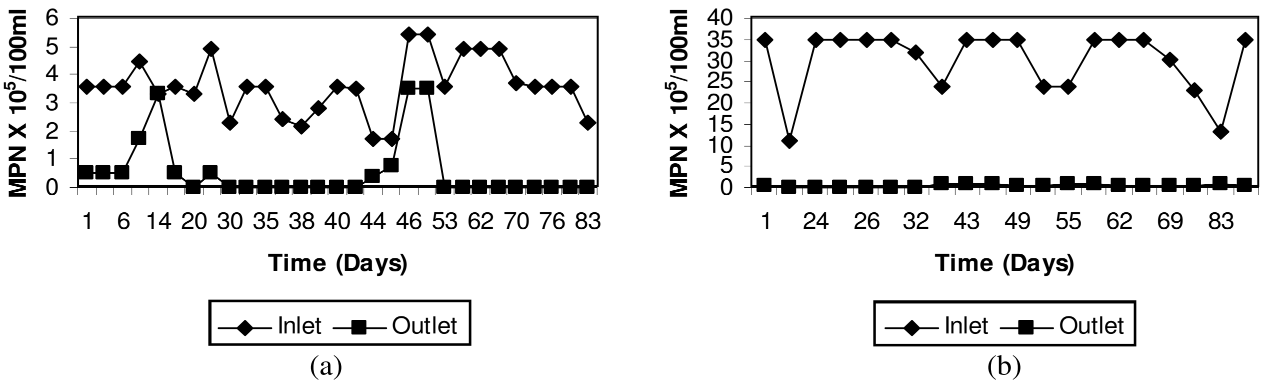

Fig. 4: Fecal coliforms count in inlet and outlet with time (a) Chlorination unit (b) DHS-biotower

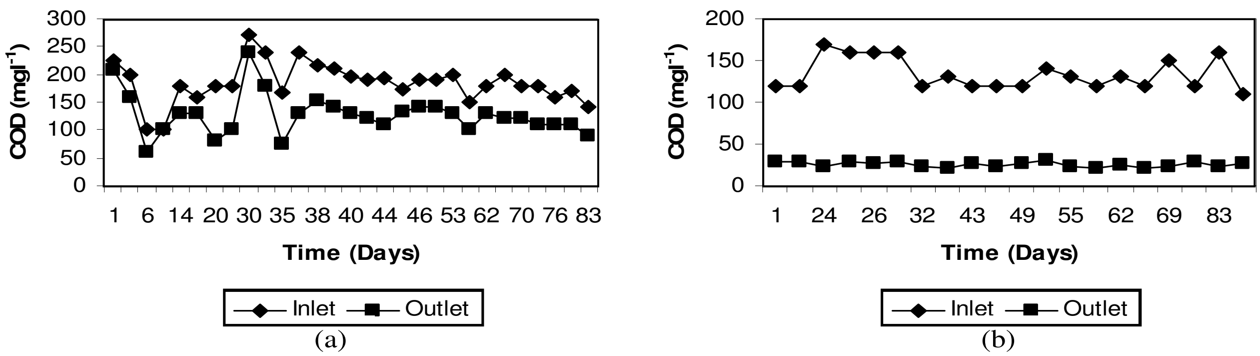

Fig. 5: COD concentration in inlet and outlet with time (a) Chlorination unit (b) BHS-biotower

The fecal coliforms removal with the chlorination could be attributed to change in membrane permeability of micro-organism or impaired enzymatic activity (Venkobachar *et al.*, 1977; Roller, 1980; Straub *et al.*, 1995). Fecal coliforms removal observed with the biotower could be attributed to the exposure to aerobic conditions in which oxygen acts as a toxicant to the fecal coliforms. The removal mechanism of fecal coliform in the DHS system has been attributed to the adsorption process, followed by predation whereas, die-off and sedimentation process is a relatively minor removal mechanism in the DHS system (Tawfik *et al.*, 2006 b). It has been observed that the chlorination was better option as compared to DHS-biotower in terms of fecal coliforms removal.

Effect on physico-chemical parameters: The disinfection efficiency is highly influenced due to the presence of suspended solids and soluble organic compounds. Disinfection of wastewater, with high suspended solids, using chlorine would be imperfect, as chlorine can not effectively penetrate solids to kill entrapped bacteria (Narkis *et al.*, 1995).

The amount of chlorine (dose) required depends upon a number of parameters like number of bacteria, pH of the wastewater, temperature and turbidity. The pH of the influent to the chlorination unit varied from 7.4 to 7.8. The influent organic loading to chlorination unit fluctuated greatly. The COD of the influent varied between 100 and 270 mgl^{-1} whereas; the BOD_5 varied between 42 and 80 mgl^{-1}. Figs. 5a and 6a present the concentration of COD and BOD_5 in the inlet and outlet of the chlorination unit respectively. Thus, COD and BOD_5 removal varied greatly during the time course due to the fluctuation in influent organic loading. The average COD was reduced from 185 ± 36.4 mgl^{-1} to 127 ± 37.2 mgl^{-1} in the chlorination unit. Whereas, the average BOD_5 was reduced from 57.1 ± 10.6 mgl^{-1} to 32.1 ± 11.5 mgl^{-1} in the chlorination unit. Thus, indicating that the average removal of COD and BOD_5 was 31.50% and 44.52% respectively. Fig. 7a shows the trend of TSS in the chlorination unit. TSS concentration in the inlet of chlorination unit varied between 36 and 88 mgl^{-1}. Suspended solids after chlorination were reduced more than 35% when hypochlorite was used as a disinfectant (53rd day to 83rd day), however, when bleaching powder was used as disinfectant, TSS were found to be increased in the effluent. The TSS concentration in effluent was varied between 40 and 93 mgl^{-1} when bleaching powder was used.

Though chlorination could remove fecal coliforms very effectively but it has a disadvantage of generating toxic disinfection by-products (DBP). During chlorination, naturally occurring organic compounds such as chlorophenols, trihalomethanes (THMs) and haloacetic acid (HAAs) are formed (Gunten *et al.*, 2001). These DBPs have been found as human carcinogens and harmful for the

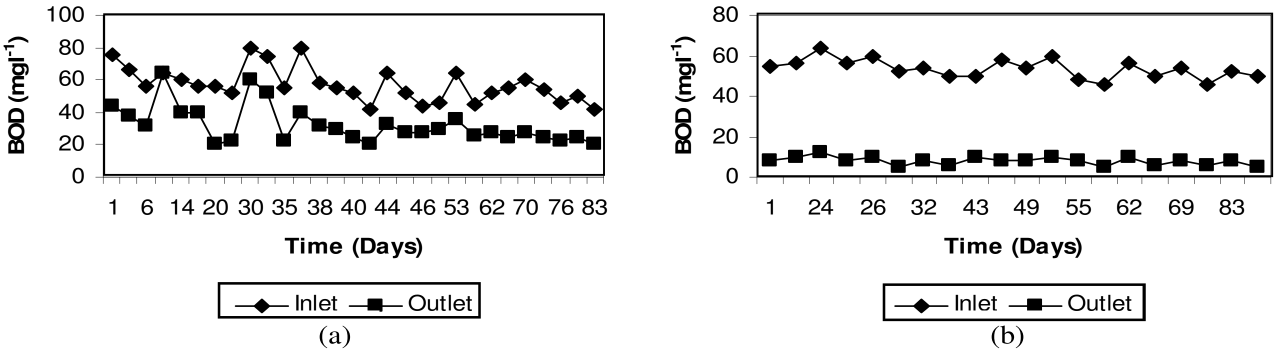

Fig. 6: BOD concentration in inlet and outlet with time (a) Chlorination unit (b) DHS-biotower

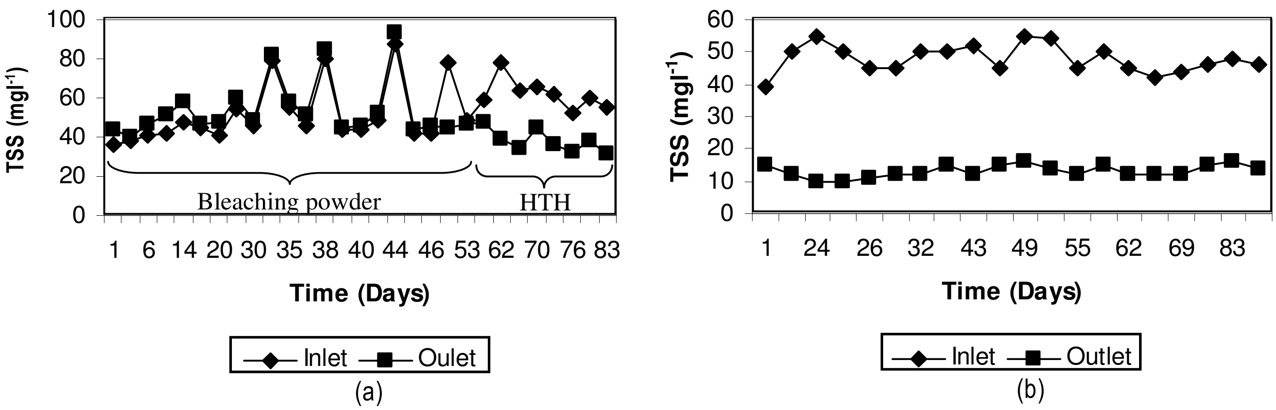

Fig. 7: TSS concentration in inlet and outlet with time (a) Chlorination unit (b) DHS-biotower

environment even at low concentrations, less than 0.1 mgl^{-1} (Szal *et al.*, 1991; Lazarova *et al.*, 1999). The cost of chlorine disinfection systems is dependent on the manufacturer, the site, the capacity of the plant, and characteristics of the wastewater to be disinfected.

The DHS-biotower gave an excellent performance with respect to the removal of the organics. The influent COD (Fig. 5b) to the DHS-biotower varied between 110 and 170 mgl^{-1} whereas, the BOD_5 (Fig. 6b) varied between 46 and 64 mgl^{-1}. The average COD was reduced from 134 ± 18.75 mgl^{-1} to 12.9 ± 7.95 mgl^{-1} in the DHS-biotower. Whereas, the average BOD_5 was reduced from 53.55 ± 4.77 mgl^{-1} to 7.95 ± 1.98 mgl^{-1}. Thus overall average removal of the COD and BOD_5 in DHS-biotower was 80.72% and 85.27% respectively. Uemura *et al.* (2002) observed similar results for effluent organic quality of the biotower. Fig. 7b shows the TSS concentration in the inlet and outlet of DHS-biotower. The Influent TSS to the DHS-biotower varied between 39 and 55 mgl^{-1}. The average TSS reduction was 47.80 ± 4.32 mgl^{-1} to 13.1 ± 1.91 mgl^{-1} in the DHS-biotower. Results show that more than 72 % suspended solids could be removed by biotower. Machdar *et al.*, (1997) also observed similar results for TSS removal in the whole combined system (UASB+ biotower) accomplishing about 67-76% TSS removal.

Both, the chlorination and DHS-biotower improved the quality of the effluent from the UASBR in terms of parameters like fecal coliforms, BOD_5, COD and TSS. However, DHS-biotower based process if employed singly may not achieve the desired levels of fecal coliform in the final effluent from the STP. Biotower could produce a superior effluent quality in terms of COD and BOD_5 as compared to chlorination. As the COD levels in the influent to the chlorination were high, the dose of the disinfectant required for the complete removal of the fecal coliforms was high. The potential for the DBPs would be high in such a case, which could be harmful to human health. While in case of biotower, there is no such problem of formation of the DBPs. Thus to remove the fecal coliforms completely a post treatment unit is required, which can efficiently improve the physico-chemical as well as biological quality of wastewater so as to meet the standards.

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