

Sewage Treatment using an Innovative System: DHS Bio-Tower in Combination with UASB

Rakesh Kumar Bhardwaj¹, Hariom Sharma², Vibha Bhardwaj³

¹ Department of Chemistry, Dyal Singh College, Karnal – 132001, INDIA

² PWD Water Supply & Sanitation, Water Testing Laboratory, Karnal – 132001,

³ Department of Microbiology, Kurukshetra University Kurukshetra Haryana

ABSTRACT

Water is an environmental, social and economic asset needs to be managed with the objective of conserving a common patrimony in the interests of the community at large. The sewage treatment technologies have proven to be expensive, complex and are failing to cater to the total wastewater generated. The untreated/partially treated wastewater makes its way to the water body causing immense degradation of the ecosystem and the environmental health. Some effective, advanced treatment technologies take high construction and maintenance costs, high energy consumption. Need is for sustainable wastewater treatment technologies - to locally treat the sewage and also reuse/recycle. The decentralized sewage treatment can be both electro-mechanical system that have higher energy requirement or natural systems with less or no energy requirement. Substantial efforts are being made to document, understand, and explain the science behind these issues all over the world. The DHS (Down-flow Hanging Sponge) Bio-Tower based on anammox process in combination with UASB (Upward Flow Anaerobic Sludge Blanket) is one of the economically attractive system for sewage treatment & well suited for tropical and subtropical countries. The DHS Bio reactors employing different sizes of sponge media exhibit excellent performance in removal of BOD, COD and ammonium nitrogen, at a fixed hydraulic retention time. Wastewater is trickled from the top of the reactor and allowed to flows vertically down through the reactor containing microorganisms retained both inside and outside of the sponge media. The results of investigations show that smaller sponge media produced better removal efficiencies may be due to better oxygen uptake in the stream flowing down through reactor.

1. INTRODUCTION

Urbanization is forcing policy makers to examine the availability of food, water and energy resources. The uncontrolled growth in urban areas has made planning and expansion of water and sewage systems very difficult and expensive[1]. Carbonate and bicarbonate being originated from microbial decomposition of organic matter and alkalinity from industries a major concern that lead to precipitation of sludge, deposition of scales and causes caustic embrittlement. The pollution load

is characterized by high color content, suspended solids, nutrients and toxic substances such as heavy metals and chlorinated organic compounds. Furthermore, human exposure to toxic chemicals, pharmaceuticals and trace organic contaminants, antibiotic resistant microorganisms, and natural toxins such as those created through harmful algal blooms is increasing through increased reliance on both groundwater and surface freshwater[2]. Triclosan, (5-chloro-2 (2, 4-dichlorophenoxy) phenol), is a chlorinated diphenyl ether has been widely used as a general antibacterial agent in various commercial products such as cosmetics, antiseptic soaps, washing-up liquid, plastic, kitchenware and toys etc., resistant to degradation[3] and toxic to aquatic life and natural water purifier algae & phytoplankton [4]. Wastewater containing huge amount of nitrogenous compounds can't be released to the surface water as it has ecological impacts and affect human health [5].

Chemical, Physicochemical and biological methods are broadly used for treatment of wastewater loaded with highly concentrated NH_4^+ - N. In considering the criterion like cost-benefit analysis, requirement of energy and chemical doses, familiarity with operational procedures, and environmental sustainability, a particular treatment for a specific pollutant is usually selected [6]. A number of conventional treatment technologies have been considered for treatment of wastewater contaminated with organic substances. Commercial activated carbon is regarded as an effective material for controlling the organic load. However due to its high cost and 10-15% loss during regeneration, unconventional adsorbents like fly ash, peat, lignite, wood, saw dust etc. have been used for the removal of refractory materials,[7] for varying degree of success. The Up-flow Anaerobic Sludge Blanket (UASB) reactor has been favored as one the most suitable sewage treatment process in developing countries because of their low energy use, easy maintenance, and cost effectiveness. However, when using UASB reactors to treat solely municipal sewage, it is relatively difficult to produce good quality effluent. The installation of an appropriate post treatment process is necessary after UASB treatment[8-12]

The DHS process uses polyurethane sponge as media to retain biomass. Wastewater is trickled from the top of the reactor and purified by microorganisms retained both inside and outside of the sponge media as the wastewater flows vertically down through the reactor. As the sponge media in DHS reactors are not submerged in wastewater but hang freely in the air, oxygen is dissolved into the wastewater. Therefore there is no need for external aeration or any other energy inputs. Furthermore, in DHS reactors, a large amount of activated sludge grow both inside and outside of the sponge media so that an ecosystem with an extremely long food chain can be established, resulting in minimization of excess sludge production. It has performed superbly in removing COD, BOD, ammonium nitrogen, and fecal coliform (F. coli) .

2. MATERIALS AND METHODS

The wastewater samples were collected in the cleaned polythene bottles from DHS *Bio-Tower reactor* Sewage Treatment Plant (STP) Karnal, Haryana, India. The same sampling protocol was employed for each measurement in a routine manner for 30 weeks in continuation covering seasons of year 2012-13. The pH was measured using the Lab India pH. The samples were analyzed for the BOD and COD as per the manufactures manuals for calibrations of the apparatus and operations. For the measurements of BOD, the BOD bottles of capacity 300 ml and the incubator was provided with a temperature control of $\pm 0.5^{\circ}\text{C}$. The estimation of suspended solids was carried out by measuring the weight of residue retained on the glass fiber filter (Whatman Grade 934 AH) in the known volume of the samples. All the mass measurements were performed on an electronic balance (Citizen) with least count 1 mg. All measurements were carried out at $25 \pm 1^{\circ}\text{C}$ using a thermostat provided with electronic relay and stirrer. The samples were stored in refrigerator before analyzing and the reagents used in the estimation were of AR grade.

3. RESULTS AND DISCUSSIONS

Sewage is the wastewater released by residence and small scale industries in a community. It consists of more than 99 % water with only less than 1 % of dissolved and suspended solid material. The waste water generated from some of the cities of Haryana & being drained to Yamuna River has been reported in Table No. 1.

Table No 1 : The Volume of waste water being drained to Yamuna River.

Cities of Haryana State along Yamuna Rivers	Population As per 2011 census	Total Waste water (MLD)	Treatment Unit	Treated waste (MLD)
Yamunanagar	216628*	> 70	One	40
Karnal	286,974*	> 66	TWO	48
Panipat	294150*	> 80	Two	50
Sonepat	277053*	> 72	One	40
Delhi	11007835*	> 4000	Three	2400

* www.census2011.co.in/census

The average of the experimental data for water parameters *viz.* BOD, COD, ORP, TSS, VSS, pH, nitrogen and ammonia measured over thirty weeks in the sewage of Karnal city have been tabulated in Table 2 and are graphically represented in Figure 1-5. Quantization in all observations was made by standard addition method[13].

Table 2. The measured average values of 180 days for water parameters in sewage

Sr No.	Parameter	Before Treatment (in sewage)	After UASB Treatment	After UASB + DHS Treatment
1	BOD (mg/L)	189	62	11
2	COD (mg/L)	490	180	36
3	Nitrogen (mg/L)	48.2	36.4	19.5
4	Ammonium (mg/L)	33.2	37.6	14.3
5	TSS (ppm)	293	153	9
6	VSS (ppm)	252	122	5
7	ORP (V)	-264	-266	-87
8	pH	7.2	7.1	7.9

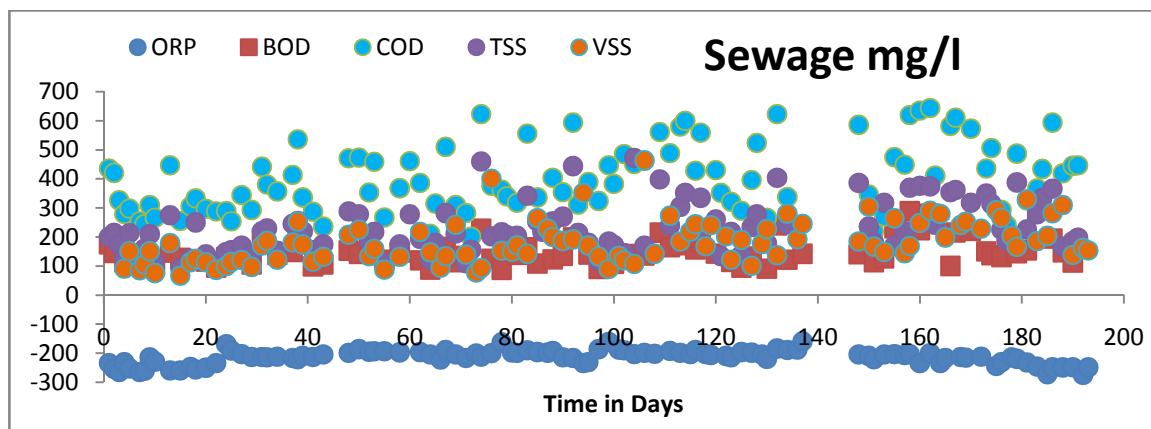


Figure 1 - Variation of BOD, COD, TSS, VSS and ORP in waste water with time

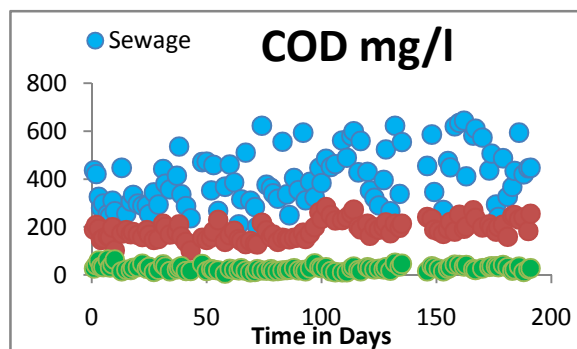
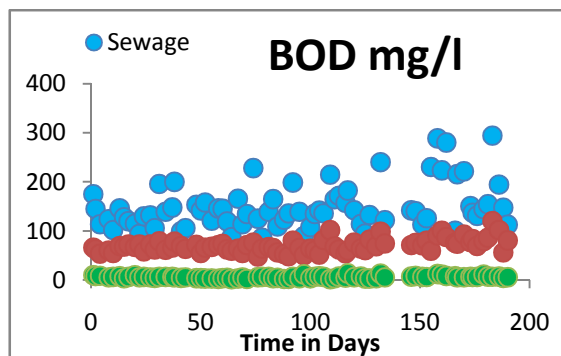


Figure 2 Variation of BOD with time. Figure 3 -Variation of COD with time

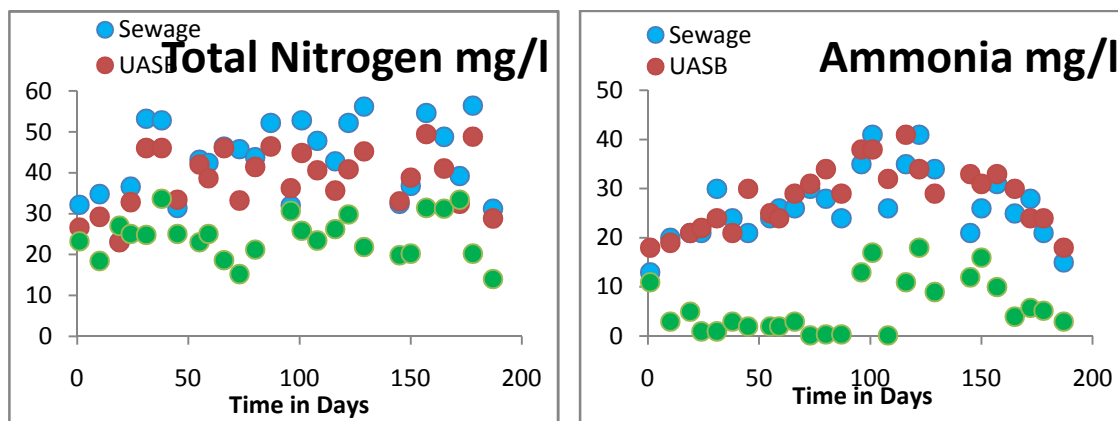
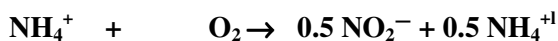


Figure 4 Variation of Total Nitrogen with time **Figure 5** Variation of Ammonia with time.

The Figures 1–5 shows the variation of studied parameters over the study period is not regular but at random. The studied parameters as a whole have increased with alarming rate. The averaged values of BOD : 189 (mg/L); COD: 490 (mg/L) and pH as 7.2. The cloudiness of sewage is caused by suspended particles. The measured average value of TSS: 293 ppm while, the VSS : 252 ppm. The ORP (oxidation reduction potential) is a measure of energy potential. Table 2 reflect the average values of ORP as -264 V. Sign is an indicator weather the reaction takes place in anaerobic(if negative) or aerobic(if positive). Many industrial plants discharge heavy metals and volatile organic chemicals (VOCs) directly into streams or inject them into the aquifer.

The anaerobic treatment is considered as a pre-treatment technique and has been applied in developing countries including India, replacing the more costly activated sludge processes. The application of combined partial nitrification–ANAMMOX process have represented significant advances in the field of biological removal of the nitrogen pollution to the treatment of high ammonia nitrogen content waste water and will lead to substantial savings of energy and resources[14]. Under anoxic conditions NH_4^+ is oxidized to gaseous N_2 using nitrite (NO_2^-) as electron acceptor with the production of NO_3^- that saves oxygen and organic matter requirements compared with conventional nitrification/denitrification process[15]. An autotrophic bacteria belonging to *Planctomycetales* carry out the anammox reaction[16].



DHS Bio-Tower at Karnal: Conventional wastewater treatment plants have not been designed for nitrogen removal and many plants do not meet the current discharge limits. The combination of

UASB as pretreatment unit and Down-flow Hanging Sponge (DHS) *Bio-Tower* reactor as a post treatment unit for sewage treatment system is shown in Figure 6. The DHS is basically a contact process in which water pass over or through biomass growing on a fixed media of polyurethane contained in the reactor. The media acts as a gas–solids separator that helps to provide uniform flow through reactor, improves contact between the waste constituents and biomass, resulting in longer retention time.

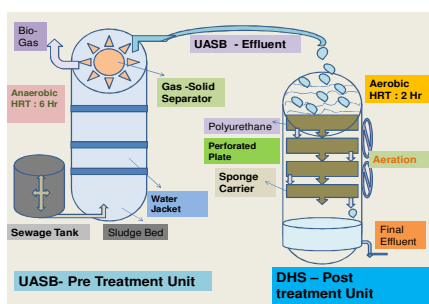


Figure –6. Schematic diagram of UASB with DHS sewage treatment

The results in the Figure 3 and 4 reflect the performance of the bio-reactor and advocate the high substrate removal efficiencies. There is a tremendous decrease in the measured values of water parameters i.e. 97 % in BOD (181 mg/L to 8 mg/L); 94% in COD (486 mg/L to 32 mg/L); nitrogen (48.2 mg/L to 18.1 mg/L) and the level of ammonia 31.2 mg/L to 13.7 mg/L in the samples collected from DHS Bio-Tower reactor at Karnal. The decrease in total nitrogen and ammonia as shown in Figures 5 & 6 may be due to the possible Anammox (anaerobic oxidation of ammonia). Anammox offers the possibility of replacing nitrification and denitrification for removing ammonia nitrogen from wastewater with partial nitrification via anammox bacterial reaction. Ammonia is oxidized by two pathways: firstly ammonia is oxidized to nitrite by hydroxylamine which is oxidized to nitrate by hydroxylamine oxidoreductase; Secondly ammonia and nitrite are anaerobically converted to nitrogen gas. According to our experience, even simple maintenance and operation tasks like the exchange of disinfectant containers are not performed adequately in some developing countries. Therefore, a secondary treatment process that can perform adequate disinfection on its own would be very useful as a sewerage treatment process in such countries.

4. CONCLUSIONS

The study indicates that the increasing proportions of the human population in the urban areas of many countries are associated with the production of large volumes of waste-water that must be treated before discharge in to a recipient in a sustainable manner. To achieve ecological wastewater treatment standards a closed-loop treatment system is the need of hour. Now a day's most of the

systems under operation are “disposal-based linear system”. These traditional linear treatment systems must be transformed into the cyclical treatment to promote the conservation of water and nutrient resources. It can be concluded from this study that combination of anaerobic (UASB) with aerobic (DHS) is a self-sustainable sewage treatment and a better alternate to other conventional treatment system.

5. ACKNOWLEDGEMENT

Authors thank Dr. H. Harada, Professor Tohoku University Japan for his expert suggestions and permission to collect the samples from 1 MLD Bio-Tower (DHS reactor) STP Karnal.

REFERENCES

- [1] Looker, N., Municipal Wastewater Management in Latin America and the Caribbean”, *R.J. Burnside International Limited, Published for Roundtable on Municipal Water for Canadian Environment Industry Association*, 1998.
- [2] Sudhira H.S. and Kumar V.S., Monitoring of lake water quality in Mysore City: Proceeding of Lake , Bangalore, India, *Indian Institute of Sciences*, , 2000 : 1-10
- [3] Adolfsson-Erici, M., Pettersson, M., Parkkonen, J. and Sturve, J. Triclosana commonly used bactericide found in human milk and the aquatic environmen, *Organohalogen Compd.*, 2000; 45 : 83 -86.
- [4] Latch, D.E., Packer, J.L., Stender, B.L., VanOverbek, J., Arnold, W.A. and McNeill, K., Aqueous Photochemistry of Triclosan: Formation of 2,4-Dichlorophenol, 2,8 DichlorodibenzoP-Dioxin, and Oligomerization Products. *Environmental Toxicology and Chemistry*, 2005; 24: 517-525.
- [5] Kelter, P.B., Grundman, J., Hage, D.S. and Carr, J.D., A Discussion of water Pollution in the United States and Mexico: with High School Laboratory Activities for analysis of lead atrazine and nitrate, *J. Chem. Educ.* 1997; 74 : 1413-1421.
- [6] Mulder, M.W., van Loosdrecht, M.C.M., Hellinga, C. and Kempen, R., Full scale application of the SHARON process for treatment of rejection water of digested sludge dewatering, IWA Conference Proceedings, Paris, France, July, 2000 : 3-7.
- [7] Pandey, K.K., Prasad, G. and Singh, V.N., Copper Removal from aqueous solution by fly ash, *Water Research*, 1985; 19 : 869-873.
- [8] Van Haandel, A.C. and Lettinga, G., Anaerobic Sewage Treatment: A Practical Guide for Regions with a Hot Climate, *John Wiley and Sons, New York* 1994.
- [9] Harada, H., Tandulkar, M., Uemura, S. and Ohashi, A., A low-cost municipal sewage treatment system with a combination of UASB and the “Fourth Generation” Down flow Hanging Sponge (DHS) reactors, *Water, Science & Technology*, 2005; 52: 323-329.
- [10] Harada, H. and Machdar, I, Combination of a UASB Reactor and a Curtain-type DHS (Downflow Hanging Sponge) Reactor as Cost-effective Sewage Treatment System for Developing Countries, *Water, Science & Technology*, 2002; 42: 83-88.
- [11] Harada, H., Tandulkar, M. and Ohashi, A., Performance comparison of a pilot-scale UASB and DHS system and activated sludge process for the treatment of municipal wastewater, *Water Research*, 2007; 132 : 166-172.
- [12] Harada, H., Tawfic, A. and Ohashi, A., Sewage treatment in a combined up-flow sludge blanket (UASB)-down flow hanging sponge (DHS) system, *Biochemical Engineering Journal*, 2006; 29 : 210-219.

- [13] Willard, H., Merritt, L. and Dean J., *Instrumental Methods for Analysis, 5th Ed. Van Nostrand, New York.* 1974.
- [14] Van Dongen, L.G., Jetten, M.S.M. and van Loosdrecht, M.C.M., *The combined Sharon/Anammox Process, A sustainable method for N-removal from sludge water, STOWA Report, IWA Publishing, London, UK.* 2001.
- [15] Strous, M., Heijnen, J.J., Kuenen, J.G. and Jetten, M.S.M., *The sequencing batch reactor as a powerful tool for the study of slowly growing anaerobic ammonium-oxidizing micro-organisms, Appl. Microbiol. Biotechnol* 1998 ; 50 : 589–596.
- [16] Schmid, M., Wachtmann, U.T, Klein, M., Strous, M., Juretschko, S., Jetten, J.W, Schleifer, K..H., and Wagner, M., *Molecular evidence for genus level diversity of bacteria capable of catalyzing anaerobic ammonium oxidation, Appl. Microbiol.* 2000; 23: 93–106.