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TREATMENT FEASIBILITY OF THE BLEACHING EFFLUENT OBTAINED FROM NSSC PULP AND PAPER MILL IN A UASB REACTOR

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ABSTRACT

UASB reactors R-I and R-II each with an effective volume of 6.0liters were used to study the treatability of actual bleaching effluent obtained from NSSC pulp and paper mill at mesophilic temperature and neutral pH. Methanol as a source of an easily biodegradable substance along with an activated carbon of effective size 1.5-2.5mm was added to the reactor R-I to evaluate its efficiency. It was observed that corresponding to an OLR of 2.14kg-COD/m^3-day the overall COD removal efficiency of the reactors R-I and R-II was 83% and 64%, respectively. And the AOX removal efficiency was noticed as 71% and 49% for reactor R-I and R-II, respectively. During the study it was observed that the treatability efficiency of reactor R-I was comparatively better but the amount of its biogas production was slightly lower. The average biogas gas production in reactors R-I and R-II during the course of study was observed as 0.19L/g-COD$_{removed}$ and 0.32L/g-COD$_{removed}$, respectively, with mean methane composition of 58-60% in both the reactors. The results of this study suggest that the use of methanol and an activated carbon in a UASB reactor to biodegrade the bleaching effluent of NSSC pulp and paper mill at mesophilic temperature and neutral pH reactor is a feasible and viable technique.

Keywords: *UASB reactor, Activated carbon, Bleaching effluent, COD, AOX*

INTRODUCTION

The pulp and paper mills are considered to be one of the major sources of pollution around the globe, posing enormous threat to the environment by generating highly polluted effluent. The bleaching part of the mills discharges the most toxic types of effluent containing AOX (Absorbable Organic Halides), which are formed as a result of the chemical combination between chlorine that comes from the bleaching section with the lignin residual of the pulping effluent[1]. AOX are highly harmful because most members of this family are bioaccumulative and carcinogenic in nature.

Various physical, chemical and biological techniques have been tried to reduce the level of AOX in the bleaching effluent. Since the physical and chemical processes are highly expensive in terms of their costs, therefore, the biological treatment processes are mostly preferred. Among the biological techniques, the anaerobic technologies are considered more viable option, especially for the developing countries because of its minimum energy and nutrients requirement[2]. The use of anaerobic technology is consider as relatively simple and inexpensive, and can be employed for a verity of industrial and domestic wastes treatment including the effluent of pulp and paper mill[3].

Today more than fifty anaerobic treatment systems are working around the world for the treatment of pulp and paper mills effluent[4]. Although they are highly acknowledged for their treatability performance[5], but very little work has been reported so far for the use of UASB reactor particularly for the removal of AOX from NSSC pulp and paper mills effluent, which is a common pulping method being practiced in Pakistan[6]. Furthermore, the existing anaerobic technologies are just able to reduce the AOX concentration to about 40-60%[7,8].

It was reported that the treatability performance of UASB reactor could be improved by adding an additional source of an easily biodegradable substances to the reactor[9], like by adding methanol the removal efficiency of the chlorophenolic wastes (member of the AOX family) in UASB reactor has been observed to improve[10], and by the use of an activated carbon with the digested sludge in UASB reactor improves its performance [unpublished data]. Therefore, this study was designed to further enhance the

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treatability efficiency of UASB reactor for the reduction of COD and AOX concentrations using actual effluent from the bleaching section of the local nearby NSSC pulp and paper mill. The main objective of the study was to investigate the treatability performance of UASB reactor in the presence of methanol and activated carbon.

MATERIAL AND METHODOLOGY

UASB reactors (namely R-I and R-II) used were made of acryl resin material, each with an effective volume of 6.0liters. Water jackets were provided around the reactors to maintain a constant mesophilic temperature. A mixing device (turbine shape, 1.5"x3.0") and a gas separator system were also provided in both the reactors[11]. A systematic diagram of the UASB reactor is shown in the Figure 1.0.

The UASB reactor R-I was filled with granular activated carbon (effective size; 1.5-2.5mm) to the total depth of 5 inches [unpublished data].

Substrate and Nutrients

Actual wastewater sludge was used in the study obtained from the bleaching section of a local NSSC pulp and paper mill. The wastewater characteristics data of the bleaching effluent obtained from the analysis of local NSSC pulp and paper mill effluent are given in the Table 1.0.

Methanol was added to the feeding solution of reactor R-I to equalize its COD concentration to that with the actual effluent, by first diluting the same effluent with mineral water. The ratio of methanol to actual effluent in the feeding solution to reactor R-I was kept around 1:5 during the course of study[12]. But for reactor R-II the actual effluent without methanol was used as a feeding solution.

Nitrogen and Phosphorous were added to the feeding solution of both the reactors R-I and R-II in the form of $(NH_4)SO_4$ and KH_2PO_4, respectively, in accordance with the C:N:P ratio of 350:5:1. And $MgSO_4.7H_2O$ was also added to both the reactors in the concentration of 0.1g/L[13].

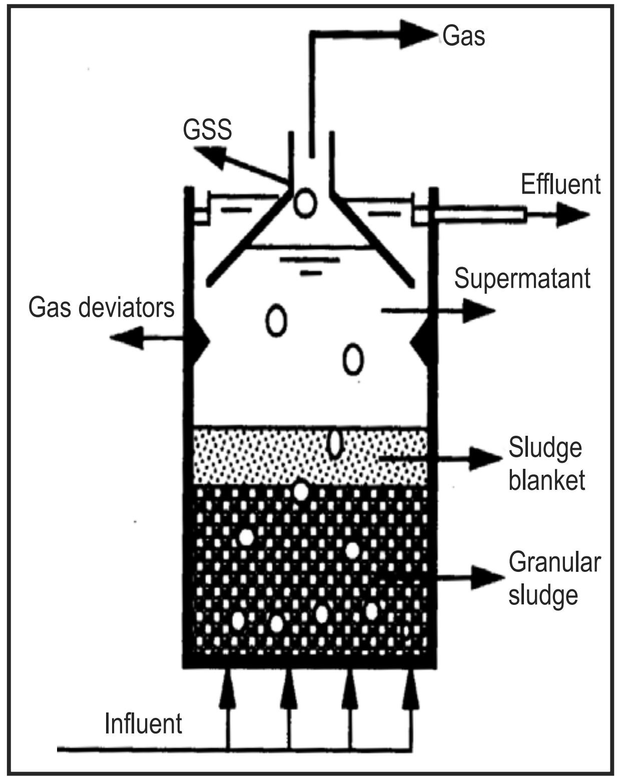

Figure 1.0: Systematic Diagram of UASB Reactor

Seeded Sludge

A digested sludge fully acclimatized with the bleaching effluent in the laboratory for about 20 days were added to both the reactors for the start-up. The concentration of MLSS and VSS of the seeded sludge observed were 84.28g/l and 59.63g/L, respectively.

Experimental Analysis

pH, temperature, COD, AOX etc of the effluent and effluent of the reactor were analyzed regularly.

Table 1.0: Wastewater Characteristics of the Bleaching Effluent from NSSC Pulp and Paper Mill

Parameters	Concentration	Parameters	Concentration
pH	7.8-8.3	Total Solids, TS (mg/L)	4310
Color (units)	1873	Total Volatile Solids, TVS(mg/L)	1475
COD (mg/L)	3215	Total Dissolved Solids, TDS(mg/L)	2324
AOX (mg/L)	39.80	Total Suspended Solids, TSS(mg/L)	1142

Total gas production was monitored twice a week using standard NaCl solution. All type of analysis was carried out by the Standard Methods[14].

RESULT AND DISCUSSION

Start-Up of the Reactors

The reactors were operated as per the given guidelines of UASB reactor[15]. Since, the pH and temperature are the two most important and principle operational parameters of the anaerobic digestion, therefore, an extreme care was taken for their control during the course of study period. As the neutral pH is considered to be the most suitable range for the microbial activities during the anaerobic digestion[13], thus the pH of both the reactors were maintained around neutral by adding an external buffer solution in the form of 0.03M $NaHCO_3$ to the feed solution after few days of operation when a drastically drop of pH was observed in these reactors. Time course of pH during the study period of the reactors is shown in the Figure 2.0.

The initial pH of both the reactors was almost neutral at the start of the study but a decreasing trend was observed later on and by the end of 3rd week, the pH of the reactors R-I and R-II was dropped to 4.87 and 4.99, respectively. It normally happens under anaerobic conditions due to the accumulation of excess volatile fatty acids within the system, but it could be control by adding an external buffer solution to the feed solution of the reactors. In this study 0.03M $NaHCO_3$ was used as a source of an external buffer to bring the pH toward neutral[2]. The average pH of both the reactors R-I and R-II due to the addition of buffering solution was later on observed as 7.02 and 7.17, respectively.

For anaerobic digestion the mesophilic range of temperature is considered as an optimum and most suitable range[16] because at lower temperature (Psychrophilic range) the microbial activity becomes quite slow[17,18,19] while at higher temperature (thermophilic range) a number of potential problems arises, e.g. high endogenous death rate[16,20]. Therefore, in this study the temperature of the both the reactors were kept constant at about 30-32°C by using an external heating devices (water jackets).

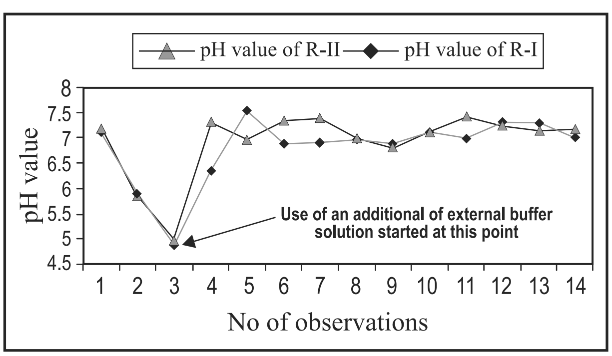

Figure 2.0: Time course of pH during the study period

Both the reactors R-I and R-II were started up simultaneously, and in order to avoid organic shocks to the reactors the organic loading rate (OLR) was gradually increased, starting from 0.15kg-COD/m^3-day to 3.24kg-COD/m^3-day, and the hydraulic retention time (HRT) was gradually decreased from 70hrs to 10hrs. Time course of OLR and HRT during the study period is shown in the Figure 3.0.

Treatability Performance of the Reactors

The OLR and HRT are the important design parameters of wastewater treatment system that determine the capital cost, and establish the engineering and economic feasibility of it. During this study the effects of OLR and HRT on the removal efficiency of COD and AOX concentrations in the reactors were thoroughly observed and relevant data obtained during the course of study period are plotted as shown in the Figures 4.0 and 5.0.

The data indicates that the treatment efficiency of the reactors R-I and R-II are greatly influenced by the OLR and HRT. The lower OLR and higher HRT seem to be quite favorable conditions for achieving higher treatment performance under anaerobic conditions in both the reactors R-I and R-II in terms of COD and AOX removal, and vice-versa. It was noticed that for every increase in OLR or decrease in the

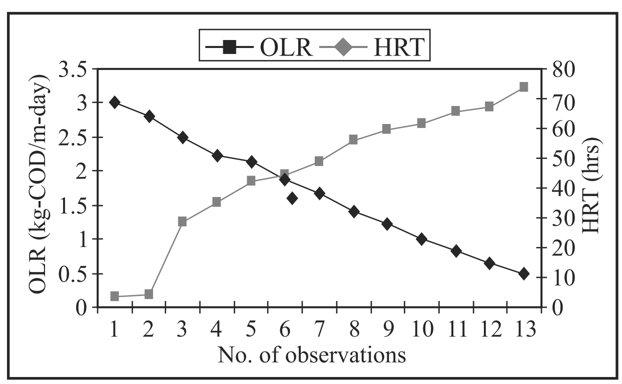

Figure 3.0: Time course of OLR and HRT during the study period

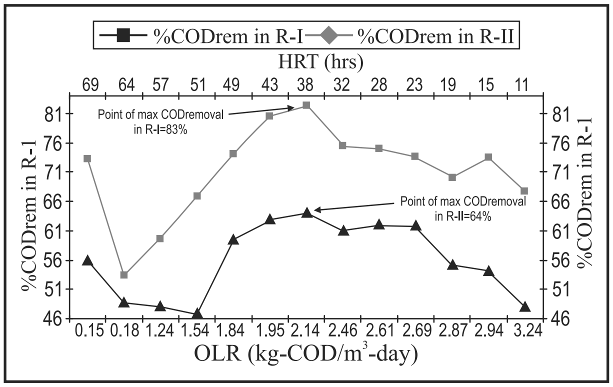

Figure 4.0: Effects of ORL and HRT on the COD removal efficiency of R-I and R-II

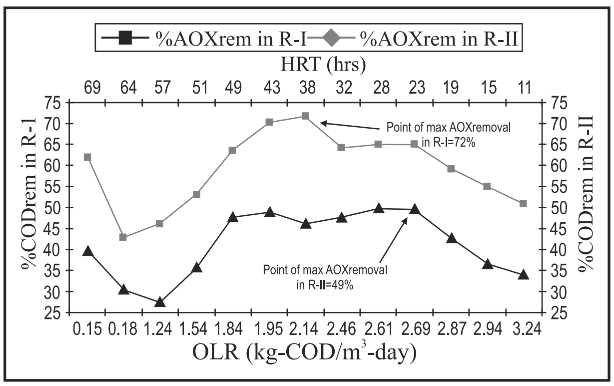

Figure 5.0: Effects of ORL and HRT on the AOX removal efficiency of R-I and R-II

HRT there was an abrupt decrease in the treatability performance of reactors R-I and R-II. This might be due to sudden shocks of heavy organic load or due to excessive accumulation of organic acids within the systems.

The data indicates that corresponding to the OLR of 2.14kg-COD/m^3-day and HRT of 38hrs the overall COD removal in reactors R-I and R-II was 83% and 64%, respectively. Also the AOX removal in reactors R-I and R-II corresponding to same conditions were noticed to be 71% and 49%, respectively. Throughout the study it was observed that the reactor R-I (with an activated carbon) gives comparatively better treatment efficiency than the reactor R-II (without an activated carbon), which indicates that the addition of an activated carbon to UASB reactor enhances its treatability performance.

The previous studies shows that the anaerobic digestion in combination with other treatment systems like aerobic, membrane filtration etc is able to remove 40-65% AOX[21,22,23,24], but if only it is used than merely 42-45% AOX could be removed[7]. Like it was reported that 40-65% of AOX could be removed from the bleaching effluent of pulp and paper mill under anaerobic conditions[9]. But the present study seems to be more reliable and gives better treatment efficiency of COD and AOX. It is because of the new strategy modified to work under anaerobic conditions in a UASB reactor where methanol as sources of an easily biodegradable substance was added to the feeding solution and by using an activated carbon with the digested sludge.

Production of biogas

Minute gas bubbles were noticed during the initial weeks of the study period, but due to low gas pressure significant amount of gas could not be collected till the 3rd week. A proper gas collection system consisting of saturated NaCl solution was installed to the reactors R-I and R-II. The data obtained pertaining to the biogas generation and methane composition during the course of study period is illustrated in the Figure 6.0 and 7.0.

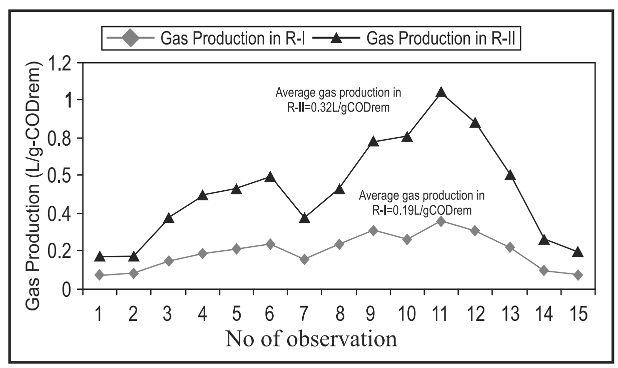

Figure 6.0: Time course of gas production during the study period

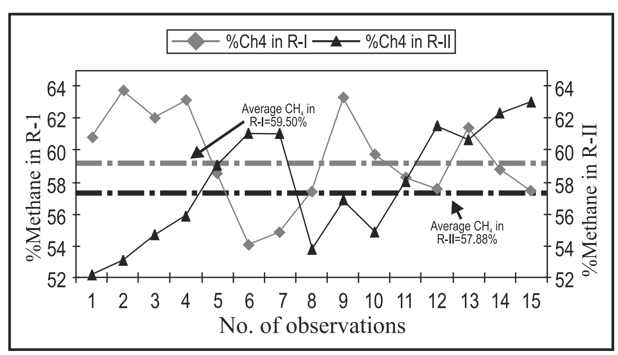

Figure 7.0: Methane composition during the course of study in R-I and R-II

It was observed that the two design parameters i.e., the OLR and HRT have an important role on the amount of biogas production under normal conditions of pH and temperature. The amount of biogas generation is directly related to the amount of feeding solution to the reactor, and the HRT plays a significant role in controlling the rate of biogas production if it is reduced. Like it was observed that there was a prominent reduction in the amount of biogas production in both the reactors R-I and R-II in the last weeks of the study period when the HRT was relatively low (below 20hrs), because the lower HRT promotes the washout of sludge from the reactor, and hence the amount of biogas production decreases by design.

Under optimum conditions the average amount of biogas gas production in the reactors R-I and R-II observed was 0.19L/g-$COD_{removed}$ and 0.32L/g-$COD_{removed}$, respectively. And the average methane composition was slightly different for both the reactors R-I and R-II, i.e. 60% and 58%, respectively. Comparatively the reactor R-I gives lesser amount of biogas generation that is because of the low mixing of substrate and biomass due to the presence of an activated carbon within the system due to which the sludge particles has become more dense. The overall gas production in both the reactors remained lower than the theoretical value of 0.35L/g-$COD_{removed}$ which might be due to the presence of recalcitrant material within the sludge used during this study[25]. Comparison between the biogas productions under anaerobic condition for similar wastes is given in the Table 2.0.

CONCLUSION AND RECOMMANDATIONS

By using methanol as an easily biodegradable substance in the presences of an activated carbon with the digested sludge to UASB reactor seems to be an extremely viable practice for the treatability of bleaching effluent from NSSC pulp and paper mill. Specifically the COD removal efficiency can be enhanced from 64% to 83% and the AOX removal from 49% to 71%, at an OLR of 2.14kg-COD/m^3-day. The optimum HRT for the design of UASB reactor to treat such wastes under mesophilic range of temperature and neutral pH is 38hrs.

The presence of an activated carbon in UASB reactor reduces the mixing of biomass and substrate, and consequently effects the formation of the biogas. The gas production would decrease from 0.32L/g-$COD_{removed}$ to 0.19L/g-$COD_{removed}$ by using an activated carbon within the reactor. But the average methane composition of biogas remains between 58-60%, either by using an activated carbon within the system or not.

A detail study is essential to identify the exact behavior of the bleaching effluent under an aerobic condition in the presence of an activated carbon. Cost analysis for the design of the UASB reactor

Table 2.0: Comparison of the biogas productions using similar substrate

Substrate	Operational Parameters	Biogas Production	Reference
Methanol	—	0.30L/g-$COD_{removed}$	[13]
Synthetic Wastes (chlorophenol + methanol)	OLR = 6.25kg-TOC/L.d HRT = 12-48hrs	0.13L/g-$COD_{removed}$ CH_4 = 60%	[10]
NSSC Pulping Effluent	OLR = 2.75kg-COD/m^3d HRT = 38hrs	0.17m^3/kg-COD_{rem}-d CH_4 = 61%	[25]
NSSC Pulping Effluent (with methanol)	OLR = 2.1 kg-COD/m^3d HRT = 44hrs	0.31L-CH_4/g-COD_{rem}.d	[12]
Synthetic Chlorophenolic Wastes (with methanol + activated carbon)	OLR = 6.5g-TOC/L-d HRT = 18-20hrs	0.17 L/g-$COD_{removed}$ CH_4 = 60-62%	Unpublished data
Bleaching Effluent (with methanol + activated carbon)	OLR = 2.14kg-COD/m^3-d HRT = 38hrs	0.19L/g-$COD_{removed}$ CH_4 = 60%	This study

needs to be evaluated on mega scale if an activated carbon is used in it.

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REFERENCES

1. *Savant D.V., R. Abdul-Rahman, D.R. Ranadi, 2005. Anaerobic digestion of absorbable organic halides (AOX) from pulp and paper industry wastewater. Bioresource Technology, 30:30-40*
2. *Bhatti, Z.I. Furukawa, K. Fujita, M., 1996. Feasibility of methanolic wastes treatment in UASB rectors. Water Research, 30: 2559-2568.*
3. *Lettinga, G., Velsen, L.V., Zeeuw, W.D, Hobma, S.W. and Klapwijk, A., 1980. Use of UASB reactor for biological wastewater treatment, especially for anaerobic treatment. Biotechnology and Bioengineering, Vol. 22: 699-734.*
4. *Bajpai, P., 2000. Microbial degradation of pollutants in pulp mill effluent. Adv. Appl. Microbiol. 48: 9-134.*
5. *Schellinkhout A., 1993. UASB technology for sewage treatment: experience with a full scale plant and its applicability in Egypt. Water Sci. Technol.* ***27:****9, 173–180.*
6. *Environmental Report Draft, March 1999. Environmental Technology Programme for Industries, Pak-EPA Pakistan.*
7. *Fitzsimons, R. Ek, M., Eriksson, K.E.L., 1990. Anaerobic dechlorination/degradation of chlorinated organic compounds of different molecular masses in bleach plant effluent. Environ. Sci. technol. 29: 1744-1748*
8. *Ferguson, J.F., Dalentoft, E., 1991. Investigation of anaerobic removal and degradation of organic chlorine from Kraft bleaching wastewater. Water Sci. Technol. 24, 241-250.*
9. *Scholz-Muramatsu, H., Neumann, A., MeBmer, M., Moore, E., Diekert, G., 1995. Isolation and characterization of Dehalospirillum mutivorans gen. non.sp.nov, a tetrachloroethene utilizing, strictly anaerobic bacterium. Arch. Microbiol. 163: 48-56.*
10. *Arshad Ali, Hashim Nisar Hashmi, 2008. "Feasibility of Co-Treatment of Chlorophenol with Methanolic Wastes, using UASB Reactor" Proceedings of 1st International Conference on Role of Chemistry for Environmental Preservation (RCEP2008) Lahore, Pakistan.*
11. *Arshad Ali, Hashim Nisar Hashmi, Rabia Haroon, 2008. "Treatment Feasibility of Low-Strength Domestic Effluent using UASB Reactor" Proceedings of 1st International Conference on Role of Chemistry for Environmental Preservation (RCEP2008) Lahore, Pakistan.*
12. *Arshad Ali, Hashim Nisar Hashmi, 2010. "Effects of Methanol on the Treatability of Black Liquor in UASB Reactor", 6th (Vol 6) of HYDRO Nepal Journal.*
13. *Bhatti, Z.I., 1995. Studies on the biological treatment of methanolic waste in UASB reactor, PhD Thesis, Osaka University, Japan.*
14. *APHA, AWWA, and WEF, 1995. Standard Methods for the examination of water and wastewater, 19th edition, Washington DC*
15. *Lettinga, G., Pol, L.W.H. Weigant, W.M., Dezeeuw, W.J., Rinzema, A., Grin, P.C., Roersma, R.E., and Homba, S.W, 1984. High rate anaerobic wastewater treatment using the UASB reactor under a wide range of temperature conditions. Jr. of Fermentation of Bioeng, JFBIEX, 70(2):119-127.*
16. *Henze, M., P. Harremoes, 1993. Anaerobic treatment of wastewater in fixed film reactor – A literature review. Water Sci. Technol., 15: 1-101.*
17. *Switzenbaum, M.S., W.J. Jewell, 1980. Anaerobic attached-film expanded-bed reactor treatment. Journal water Poll. Control Fed., 52: 1953-1965.*
18. *Kannady, K.J., van den Berg, 1982. Stability and performance of anaerobic fixed film reactors during hydraulic overloading at 10-35°C. Water Research, 16: 1391-1398.*

19. Grin, P., R. Roersma, G. Lettinga, 1985. Anaerobic treatment of raw domestic sewage in UASB reactors at temperature from 9-20°C. Proc. seminar/workshop on anaerobic treatment of sewage, Amherst, Massachusetts, University of Massachusetts.

20. Buhr, H.O., J.F. Andrews, 1977. The thermophillic anaerobic digestion process Water Research, 11: 129-143.

21. Lee, E.G.H., Crowe, M.F., Stutz, H., 1993. Pilot study of sequential anaerobic/aerobic biological process for dechlorination of whole mill kraft effluent. CPPA Ann. Meeting 1993 Montreal, Canada 79 (A), 53-60.

22. Hall, E.R., Onysko, K.A., Parker, W.J., 1995. Enhancement of bleach kraft organochloride removal by coupling membrane filtration and anaerobic treatment. Environ. Technol. 16: 115-126.

23. Francis, D.W., Turner, P.A., Wearing, J.T., 1997. AOX reductions of kraft bleach plant effluent by chemical pre-treatment, pilot-scale trials. Water Res. 31:10, 2397-2404

24. Tezel, U., Guven, E., Erguder, T.H., Demirer, G.N., 2001. Sequential (anaerobic/aerobic) biological treatment of Dalaman, SEKA pulp and paper industry effluent. Waste Manage. 21: 717-724.

25. Arshad Ali, Hashim Nisar Hashmi, Inthikhab Ahmad Querashi, Athar Saeed, 2009. "Treatment feasibility of NSSC pulping effluent using UASB reactor" 5th (Vol 5) of HYDRO Nepal Journal.