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Anaerobic Treatment of Pulp and Paper Mill Wastewater Using Upflow Anaerobic Sludge Blanket Reactor (UASBR)

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ABSTRACT: The Pulp and Paper Industry is one of India oldest and core industrial sector which discharge large amount of pollutant to the environment. These Pollutant causes considerable negative effects to the ecosystem because it contains biodegradable organic material and toxic compounds. It will become a threat to ecosystem if the pollutant is not controlled before discharge. The Present study is to pulp and paper mill wastewater using upflow Anaerobic Sludge Blanket Reactor (UASBR). Upflow Anaerobic Sludge Blanket Reactor was designed depending upon Total Suspended solids and COD Removal. The typical Physiochemical and biological characteristics of hard wood/Bagasse Wastewater were studied. The maximum effluent COD removal efficiency of 87% achieved when the reactor was operated at an OLR of 0.71KgCOD/m³d.

KEYWORDS: Chemical Oxygen Demand; Upflow Anaerobic Sludge Blanket Reactor; Organic loading rate; pulp and paper mill wastewater.

I. INTRODUCTION

The Paper industry is one of the largest industries in India, consuming large amount of water, [1]. Pulp and paper are manufactured from raw materials containing cellulose fibers, generally wood, recycled paper and agricultural residues. In developing countries, about 60% of cellulose fibers originate from non wood raw materials such as bagasse cereal straw, bamboo, reeds, esparto grass, jute, flax, and sisal (Gullichsen 2000). These effluents are strongly coloured owing to the presence of lignin, resin, tannin and chlorophenolic compounds that are resistant to biodegradation. However very few studies are carried out of treating real pulp and paper mill wastewater by anaerobic digestion. Anaerobic digestion is used in treatment of waste water obtained from various wastes which coming from different industries such as sugar [4], diary [5], food processing [2]. But in case of Pulp and Paper mill wastewater, it is not used as widely as the activated sludge process [3]. Hence, pulp and paper mill wastewater needs detailed study. Therefore an attempt was made to measure the treatability performance of HUASB reactor using pulp and paper mill wastewater. In the past years, the efforts to improve water quality using modern sewage technology led to big successes in

In the past years, the enorts to improve water quarty using modern sewage technology led to big successes in industrialized countries. Here, the commonly implemented treatment systems are mostly based on a high technology level which not only requires a large amount of process energy, but is also related to high investment and operation costs. Plant operation furthermore requires highly qualified personnel that is very often not sufficiently available in developing countries. Anaerobic treatment alternative in the domestic wastewater sector is the so called UASB reactor (Upflow Anaerobic Sludge Blanket). The process is essentially based on special flow regime allowing the sewage to get into contact with a "sludge blanket" or "sludge bed" situated in the reactor, and a following 3-phase-separation of water, sludge and gas (methane). Within the sludge bed, the organic matter in the sewage is reduced by bacteria. In the Anaerobic milieu of the reactor, the methane is formed due to bacterial activity during the fermentation process, which can be utilized as energy source. In order to achieve the best performance of the reactor, several parameters such as COD (chemical oxygen demand), required retention time and others have to be taken into consideration.



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II. REPORT REVIEW

Constructed Wetland for Wastewater Treatment and Reuse: A Case Study of developing country-Atif Mustafa-2013. Treatment performance of a pilot-scale constructed wetland (CW) commissioned in a developing country was evaluated for removal efficiency of Biochemical Oxygen Demand(BOD), Chemical Oxygen Demand (COD), Total Suspended Solids(TSS), ammonia-nitrogen (NH4-N), ortho-phosphate(PO4-P), Total Coliforms(TC) and Faecal Coliforms (FC) from pretreated domestic wastewater. Monitoring of wetland influent and effluent was carried out for a period of 8 months. Treatment effectiveness was evaluated which indicated good mean removal efficiencies; BOD(50%), COD(44%), TSS(78%), NH4-N (49%), PO4-P(52%), TC(93%) and FC(98%).

Various methods involved in Wastewater Treatment to Control Water pollution-S.S. Turkar 2011. Hence various techniques were developed for purification of water. Pollution of water streams causes due to by different inorganic, organic and biological contaminates, among which pesticides are very common and introduced due to agriculture source, several usual methods of water treatment exist such as activated carbon adsorption, chemical oxidation, biological treatment. For example, activated carbon adsorption involves phase transfer of pollutants without decomposition into another pollution problem. Chemical oxidation mineralizes all organic substances and is only economically suitable for the removal of pollutants at high concentrations.

Treatment of Poultry slaughterhouse wastewater in upflow anaerobic filter under low upflow velocity-Rajakumar, R., Meenambal, T., Rajesh Banu, J., Yeom, I.T., 2011[3]. Reported about the health impacts like diarrhea, vomiting, headache, nausea, and eye irritation on children and workers due to the pulp and paper mill wastewater discharged to the environment.

Treatment of pulp and paper mill wastewater-a review –Pokhrel, D., Viraraghavan, T., -2004[7]. Reported about the effluents from the industry cause slime growth, thermal impacts, scum formation, colour problems, and deterioration of aesthetic beauty of the environment.

III. PARAMETERS TO BE CONTROLLED REGULARLY

A. PH-VALUE

The pH value in the digestion substrate is decisive for the activity of the very sensitive methogenic bacteria and therefore has to be controlled continuously. The recommended range is between pH 6.3 and pH 7.8. The utilisation of hydrogen carbonate as buffer may simplify the observation of the given range.

B. CHEMICAL OXYGEN DEMAND (COD)

Basically, anaerobic sewage treatment may be applied for low as well as for high COD-concentrations. Depending on the respective local conditions, the advantages of the anaerobic process do generally only become distinct at a concentration of >250 mg COD/l and achieve an optimum at a concentration of >400 mg COD/l. An upper limit for COD concentration in the influent sewage is not known.

C. TEMPERATURE

The anaerobic degradation process achieves its optimum at a temperature between 35-38°C. Below this range, the digestion rate decreases by about 11% for each °C temperature decreases [6].

However, given appropriate frame conditions aerobic treatment has in the past years proven to have a very high potential if ambient sewage temperatures are above 20° C. For a successful and stable microbiological degradation and the avoidances of an acidification of the process, a water temperature of atleast 15° C is necessary, although Bacterial activity can still be noticed at lower temperatures (10° C and less).

IV. METHODOLOGY

Design for treating a paper and pulp waste UASB reactor was designed depending upon (1) size and dimension of the reactor, (2) detention time, (3) reactor SRT, (4) average VSS concentration in biomass zone of the reactor, (5) methane



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gas production, (6) energy available from methane production, and (7) alkalinity requirements for a wastewater with the characteristics given below to achieve greater than 90 percent soluble COD removal.

V. **RESULT AND DISCUSSION**

The influent amount of waste water to the plant should be considerably constant. For great flow variations, e.g. due to high precipitation, a sufficiently sized buffer tank should be installed prior to the UASB to guarantee an even feeding of the reactor. Flow measurements should be part of continuous process control. They are necessary for the calculation of further process, design and operational parameters (e.g. organic charges per volume).

UASB Treatment process Design for a UASB treatment process treating an pulp and paper mill waste water

Wastewater characteristics		
Item	Unit	Value
Flow rate	m^3/d	1500
COD	g/m^3	2300
sCOD	g/m^3	2000
TSS	g/m^3	200
VSS	g/m^3	150
Alkalinity	g/m^3 as CaCo3	500
SO4	g/m^3	200
Temperature	°C	30

Design parameters and assumptions:

Y = 0.08 g VSS/g COD $K_d = 0.03 \text{ g VSS/g VSSd}$ $\mu_m = 0.25 \ g \ VSS/g \ VSSd$ $f_d = 0.15 \text{ d VSS}$ cell debris/g VSS biomass decay Methane production at $35^{\circ}c = 0.40 \text{ L CH}_4/\text{g COD}$ Reactor volume effectiveness factor = 85 %Height for gas collection = 2.5 m

Step 1:

a.

b.

Determine the reactor volume based on the design organic loading and the use of Equation

$$L = V_{n}/E$$

 $= 300 \text{ m}^3 / 0.85$

$$= 353 \text{ m}$$

Step 2: Determine the reactor dimensions

First determine the reactor cross sectional area using Eq A = Q/v based on the design superficial velocity.Use a. the upflow velocity data given in Table 3. Because the wastewater is highly soluble, select a velocity of 1.5 m/h.

 $A = Q/v = (1000 \text{ m}^3/\text{d})/[(1.5 \text{ m/h})(24 \text{ h/d})]$ $=41.6m^{2}$ $A = \pi D^2/4 = 41.6 m^2$ D = 7.28 m

Determine the reactor liquid height using b. $H_L = V_L / A$ $= 353 \text{ m}^3 / 41.6 \text{ m}^2$



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Determine the total height of the reactor using c. $H_T = H_L + H_G$ = 8.5 + 2.5= 11md. Reactor dimensions Diameter = 7.3 mHeight = 10.9 m Step 3: Determine the reactor hydraulic detention time τ $\tau = V_L / Q$ $= (353 \text{ m}^3)(24 \text{ h/d}) / (1500 \text{ m}^3/\text{d})$ = 5.65 hStep 4: Determine the reactor SRT The value of the SRT can be estimated by assuming that all the wasted bio-logical solids are in the effluent a. flow. A conservative design approach is to assume that the given effluent VSS concentration consists of biomass. Thus, the following relationship applies: $QX_e = P_{X,VSS} =$ solids wasted per day Both Q and X_e are known. The value of $P_{X,VSS}$ is given by Eq. $P_{X,VSS} = Q (Y)(S_o - S) + f_d (k_d)Q(y)(S_o - S)SRT + Q(_nb_{VSS}) - QX_e$ $1+(K_d)$ SRT $1+(K_d)$ SRT Develop the data needed to solve the above equation. b. The effluent soluble COD concentration at 90% COD removal is I. $S = (1.0-0.9)(2000 \text{ g/m}^3) = 200 \text{ g/m}^3)$ II. The effluent nbVSS concentration given that 50% of the effluent VSS is degraded is $nbVSS = 0.5 (150 \text{ g/m}^3) = 75 \text{ g/m}^3$ III. The pCOD degraded is pCOD degraded = 0.5 (2300 - 2000) $= 150 g/m^3$ Total degraded influent COD, S_o IV. $S_0 = (2000+150) \text{ g/m}^3 = 2150 \text{ g/m}^3$ Substitute the given parameter values and solve the expression given above for SRT C. $QX_e = (1500 \text{ m}^3/\text{d}) (150 \text{ g/m}^3)$ $= [(1500 \text{ m}^3/\text{d})(0.08 \text{ gVSS/g COD})(2150 - 200)\text{g/m}^3]$ [1+(0.03 gVSS/g VSS.d)SRT] + (0.15gVSS/g VSS)(0.03g VSS/g VSS.d)(1000m³/d)(0.08g VSS/gCOD)[(2150-200)g/m³]SRT [1+(0.03 gVSS/g VSS.d)SRT] $+ (1000 \text{ m}^3/\text{d})(75 \text{ g/m}^3)$ 225000 g/d= 234000/[1+(0.03)SRT]+1053SRT/[1+(0.03)SRT]+112500 SRT= 52 days Step 5: Estimate the effluent soluble COD at an SRT of 52 days at 30°c using Eq.and the given coefficients. $S = K_s[1+(K_d)SRT]$ $\overline{SRT}(Y_k-K_d)-1$ $K = \mu_m/y = (0.25 \text{ gVSS/g VSS.d})/(0.08 \text{ gVSS/g COD})$ =3.125gCOD/gVSS.d S = (360 mg/L)[1 + (0.03 g/g.d)]/[(52d)[(0.08 g/g)(3.125 g/g.d) - (0.03 g/g.d)] - 1]

= 88.3 mg/L

= 8.5 m



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Step 6: Determine if the computed SRT value is adequate. The fraction of the influent $_{s}COD$ in effluent = (88.3 mg/L)/(2000 mg/L)

$$= 0.044 = 4.4\%$$
S

Because 4.4% is less than 10% (specified in problem statement), the process SRT is adequate. Step 7: Determine the average X_{TSS} concentration in biomass zone of the reactor.

a. The value of the X_{TSS} can be estimated by using Eq.

$$SRT = \frac{V(X_{TSS})}{(Q - Q_w)X_e + Q_wX_R}$$

Because it was assumed that all the wasted solids are in the effluent flow, the term $Q_w = 0$ and the value of X_{TSS} can be estimated as follows:

$$SRT = VX_{TSS} \qquad \text{and} \quad X_{TSS} = QX_e SRT$$

b. Solve for the value of X_{TSS} , with the volume V equal to the effective volume, V_n .

$$X_{TSS} = \frac{(1500 \text{ m}^3/\text{d}) (150 \text{ g/m}^3)(52\text{d})(1\text{Kg}/10^3 \text{ g})}{200 \text{ m}^3}$$

 $= 39.0 \text{ Kg/m}^3$

The computed value is within the range of solids concentration values given earlier for the UASB process. Step 8: Determine the methane gas production and energy produced.

a. Determine the COD degraded.

 $COD = (2150 - 200) \text{ g/m}^3 = 1950 \text{ g/m}^3$

b. Determine the COD removed with sulfate as the electron acceptor. From sec. 10-3.0.67 g COD removed/g SO4 reduced

$$COD_{SR} = 0.90(200 \text{ g } SO_4 / \text{m}^3)(0.67 \text{ gCOD/g } SO_4)$$
$$= 120.6 \text{ g/m}^3$$

c. Determine the COD used by methanogenic bacteria.

$$COD_{MB} = (1950-120.6)g/m^3 (1500m^3/d)$$

$$= 2,744,100 \text{ g/d}$$

- d. Determine the methane production rate. Methane production at $20^{\circ}a = (0.40 \text{ J}/a)$
- Methane production at $30^{\circ}c = (0.40 \text{ L/g}) (273.15+30)$ (273.15+35) = 0.3935 L/gAmount of CH₄ produced /d = 0.3935 L/g(2,744,100gCOD/d) $= 1079.80 \text{ m}^3\text{/d}$ Total gas volume produced = 65 % of methane = 1079.80/0.65 $= 1661.2 \text{ m}^3\text{/d}$ Step 10: Energy produced from methane

a. Density at $35^{\circ}c = 0.6346 \text{ g/L}$ Methane density at $30^{\circ}c = 0.6346(273.15+35)/(273.15+30)$

b. Energy produced
$$= 0.6451$$

 $= 1079803 * 0.6451 * 50.1$

Step 11: Alkalinity requirements Alkalinity required = (1800 -500) = 1300 mg/L as CaCO₃ Daily addition = 1300 * 1500 *1

$$= 1950 \text{ Kg/d as } \text{CaCO}_3$$



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V. CONCLUSION

A laboratory-scale UASB reactor made of all-glass cylindrical columns with an inside diameter 7.3m and overall height 10.9m fabricated for this study. The reactor consists of 8.5m depth liquid portion at the bottom, 25cm packing depth provided above the liquid zone, and top 10cm for gas collection. Hoods are provided at top and bottom of the reactor for gas venting and probable sludge accumulation, respectively; along with three different sampling ports at appropriate locations. Good quality PVC tubing was provided for the influent flow and gas collection. Show the design features and dimensions of the UASB reactor used in the study.

REFERENCES

- [1] Balakrishnan, K., "India pulp and paper pollution control", NewDelhi report, 1999.
- Badroldin, N.A., Latiff, A.A., Karim, A.T., Fulazzaky, M.A., "Palm oil mill effluent (POME) treatment using Hybrid Upflow Anaerobic Sludge Blanket reactors; Impact on COD removal and organic loading rates ",Engineering post graduate conference (EPC),2008.
- [3] Rajakumar, R., Meenambal, T., Rajesh Banu, J., Yeom, I.T., "Treatment of poultry slaughterhouse waste water in Up flow Anaerobic filter under low Upflow velocity", Int. J. Environ.sci.Tech., 8 (1),pp.149-158,2011.
- [4] Mohamed, M., Matayum, M., Lim, T.S., "Chlorinated organics in tropical hardwood kraft pulp and paper mill effluents an their elimination in an activated sludge treatment system", pertanika 2(3), pp.387-394, 1989.
- [5] Nemerow, N.L., Dasgupta, A., "Industrial and hazardous waste management ", New York: Van Nostrand Reinhold; 1991.
- [6] Alaerts, G.J. et al.: Feasibillity of anaerobic sewage treatment in sanitation strategies in developing countries. IHE Report series 20, Delft, The Netherlands, 1990.
- [7] Pokhrel, D., Vikraghavan, T., "Treatment of pulp and paper mill wastewater a review" Science of the Total Environment 333,pp,37-58,2004.
 [8] Thompson, G., Swain, J., Kay, M., Forster, C.F., "The treatment of pulp and paper mill effluent: A review", Biores Technol 77, pp.275-
- [8] Thompson, G., Swain, J., Kay, M., Forster, C.F., "The treatment of pulp and paper mill effluent: A review", Biores. Technol 77, pp.275-286,2001.

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