General Characteristics and Treatment of Paper Industrial Wastewater by Anaerobic Digestion

Prof. Dr. Shahshikant R. Mise[1] Ummul Khair[2]
[1]Professor [2]M.Tech. Student
[1]Department of Civil Engineering [2]Department of Environmental Engineering
[1,2]PDA College of Engineering. Kalaburagi 585102 (K.S)

Abstract— This work focuses on monitoring the general characteristics and treatment by anaerobic digestion of liquid paper wastewater under controlled conditions. The paper Wastewater is taken from Gemini graphics private limited, Kamthan. A laboratory scale models of anaerobic digester of 8L capacity, with gas collecting bottles were setup to treat Paper industrial waste water. The performance of the reactor in removing COD, Total Solids and Alkalinity were studied, with reference to different organic loading rates of 0.5, 1.0, 1.5 kg COD/m^3.d. The highest yield of alkalinity, percentage COD removal and total solid is 1123mg/L, 82.32 and 79.65% respectively.

Key words: Anaerobic Digestion, COD, Organic Loading Rates, Total Solids, Paper Wastewater, Alkalinity

I. INTRODUCTION

The pulp and paper industry is one of India's oldest and core industrial sector. The socio-economic importance of paper has its own value to the country's development as it is directly related to the industrial and economic growth of the country. Although paper has many uses, its most important contribution to modern civilization is its use as a medium to record knowledge. Paper manufacturing is a highly capital, energy and water intensive industry. It is also a highly polluting process and requires substantial investments in pollution control equipment. In India, around 905.8 million m^3 of water is consumed and around 695.7 million m^3 of wastewater is discharged annually by this sector. India's current average fresh specific water consumption of about 150 m^3/tonne of product is far above the global best specific water consumption of 28.66 m^3/tonne (for large scale wood based pulp and paper mill) and this large gap is primarily attributed to the use of obsolete technology /equipments and poor water management practices. The large water requirements and consumption by the Indian pulp and paper industries has led to water fast becoming a scarce commodity and lowering of the groundwater table and thus increased pumping costs and more importantly water shortage in many regions. Realizing the importance of water and excessive usages of water by pulp and paper sector, Central Pollution Control Board (CPCB) has taken initiative to develop the water conservation guidelines and water consumption standards and entrusted National Productivity Council to undertake the study to address these issues.[1] Instead of using the physic-chemical treatments, various biological methods can be used to treat the wastewater from the Paper industry. Biological treatment (aerobic and anaerobic type) is the most common and wide spread technique used in Paper wastewater treatment [Hunger2003]. The biological treatment method include biosorption, use of enzymes, aerobic and anaerobic treatments [Nuranand Esposito 2000].Only biotechnological solutions can be used for the reduction of COD. [1]

A. Anaerobic Digestion

Anaerobic digestion is the breakdown of organic material by a microbial population that lives in an oxygen free environment. Anaerobic means literally "Without air". When organic matter is decomposed in an anaerobic environment the bacteria produce a mixture of methane and carbon dioxide gas. Anaerobic digestion treats waste by converting putrid organic materials to carbon dioxide and methane gas. This gas is referred to as biogas. The biogas can be used to produce both electrical power and heat. The conversion of solids to biogas results in a much smaller quantity of solids that must be disposed. The organic acids including alcohols produced are further converted into methane (CH_4), hydrogen sulphide (H_2S) and carbon dioxide gas (CO_2), if methane forming bacteria are also especially present in the reactor.

B. Anaerobic Digestion (Stages)

1) Hydrolysis/liquefaction

In the first stage of hydrolysis, or liquefaction, fermentative bacteria convert the insoluble complex organic matter, such as cellulose, into soluble molecules such as sugars, amino acids and fatty acids. The complex polymeric matter is hydrolyzed to monomer, e.g., cellulose to sugars or alcohols and proteins to peptides or amino acids, by hydrolytic enzymes, (lipases, proteases, cellulases, amylases, etc.) secreted 3 by microbes. The hydrolytic activity is of significant importance in high organic waste and may become rate limiting. Some industrial operations overcome this limitation by the use of chemical reagents to enhance hydrolysis. The application of chemicals to enhance the first step has been found to result in a shorter digestion time and provide a higher methane yield. Hydrolysis/Liquefaction reactions:

Lipids → Fatty Acids
Polysaccharides → Monosaccharides
Protein → Amino Acids
Nucleic Acids → Purines & Pyrimidines

2) Acetogenesis

In the second stage, acetogenic bacteria, also known as acid formers, convert the products of the first phase to simple organic acids, carbon dioxide and hydrogen. The principal acids produced are acetic acid (CH_3COOH), propionic acid (CH_3CH_2COOH), butyric acid ($CH_3CH_2CH_2COOH$), and ethanol (C_2H_5OH). The products formed during acetogenesis are due to a number of different microbes, e.g., syntrophobacter wolinii, a propionate decomposer and sytrophomonos wolfei, a butyrate decomposer. Other acid formers are clostridium spp., peptococcus anerobus, lactobacillus, and actinomyces. An acetogenesis reaction is shown below:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

3) Methanogenesis

Finally, in the third stage methane is produced by bacteria called methane formers (also known as methanogens) in two ways: either by means of cleavage of acetic acid molecules to generate carbon dioxide and methane, or by reduction of carbon dioxide with hydrogen. Methane production is higher from reduction of carbon dioxide but limited hydrogen concentration in digesters results in that the acetate reaction is the primary producer of methane. The 4 methanogenic bacteria include methanobacterium, methanobacillus, methanococcus and methanosarcina. Methanogens can also be divided into two groups: acetate and H_2/CO_2 consumers. Methanosarcina spp. and methanothrix spp. (also, methanosaeta) are considered to be important in AD both as acetate and H_2/CO_2 consumers. The methanogenesis reactions can be expressed as follows:

$$CH_3COOH \rightarrow CH_4 + CO_2$$

(Acetic acid) (Methane) (Carbon dioxide)

$$2C_2H_5OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$$

(Ethanol)

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

(Hydrogen) (Water)

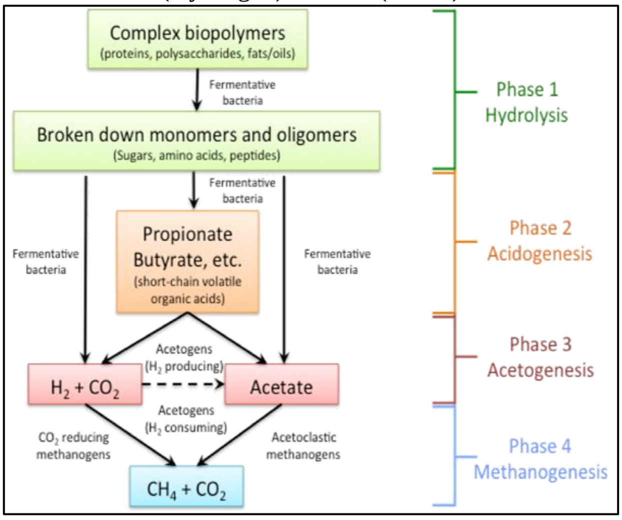

Fig. 1: Shows the whole anaerobic process.

C. *Objectives of the Study*

To determine characteristics of pulp and paper and dairy industry wastewater. To study the different stages of anaerobic digestion process. To find out efficiency of digester under optimum condition. To find out the amount of bio gas produced.To find out the efficiency of digester by blended waste. To study the effect of organic loading on the performance of anaerobic digestion process.

II. LITERATURE REVIEW

Paper is a major product of the forestry industry, and is used widely in our society. Paper products are used not only in their obvious applications in the publishing industry and for writing on, but also in a variety of specialty papers, cardboards, brown papers etc. In addition, various chemicals are produced as a byproduct of the pulp and paper industry. Paper is made by pulping wood, bleaching this pulp and then spreading it out into sheets to make it into paper. At various stages of the process, chemicals are used to give the paper particular properties, such as the bleaching chemicals that make paper white (and which also enable it to subsequently be coloured).

Narsi R. Bishnoi, R.K. Khumukcham and Rajender Kumar(2006):An experimental study was carried to find out the degradability of black liquor of pulp and paper mill wastewater for biomethanogenesis in continuous stirred tank reactor (CSTR) and followed by activated sludge process (ASP). Continuous stirred tank reactor was used in present study for anaerobic digestion of black liquor, while completely mixed activated sludge system was used for anaerobic digestion. A maximum methane production was found upto 430ml/day, chemical oxygen demand was reduced upto 64% and total volatile fatty acid increased upto 1500mg/l from 975mg/l at 7.3 pH, 37 ºC temperature and 8 days hydraulic retention time during anaerobic digestion[3]

P.Tamilchelvan and M.Dhinakaran(june 2012): In this article an attempt is made to study the highly complex and is characterized by high content of organic, inorganic and chromium, suspended solids and dissolved solids present in Tannery waste water. Treatment of tannery waste water is carried out by physical, chemical, biological or the combination of these methods. Anaerobic digestion process exhibited better performance for treating high strength tannery wastewater effectively, compared with conventional reactors. After 48 days of study the pH maintained is 8.0, T. Alkalinity decreases from 3400.00mg/L to 135, COD decreases 11680 to 2300mg/L and BOD5 decreases from 3410 to 2906mg/L[4]

III. MATERIAL AND METHODOLOGY

A. *Fabrication and Experimental Setup*

The schematic diagram of experimental setup used for the present study is shown in figure 2. Aspirator bottle no.1 of 10.0L capacity will be used as digester with working volume of 8.0L. The digester was connected with the bottleno.2 of 5.0L capacity, which will contain the brine solutions .The amount of gas collected in bottle no. 2 replaces the same amount of brine solution to bottle no. 3. For the initial startup, cow dung slurry and septic waste are used as seed sludge and mixed with wastewater and placed in the digester for acclimatization. From 6^{th} ^{day} regular wasting of digested sample and feeding of the fresh sample were continued until steady state conditions were reached. The study was carried out for different organic loading rate of0.5-1.5 kg $COD/m^3.d$ at ambient temperature (room temperature).

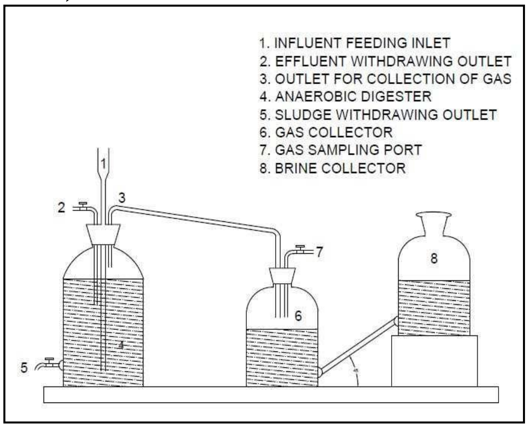

Fig. 2: Experimental setup of anaerobic digester

B. *Startup of Reactor*

During the start-up of the *Digester* (Paper wastewater) was loaded with 2.0 L of cow-dung slurry and 6.0 L of Paper wastewater, this mixture gave a composite COD of 382mg/L. By wasting 300mL of digested sludge, the reactor was adjusted to7.0 every day and the reactor was operated till stabilization achieved (30 days). During organic loading of 0.5-1.5 kg COD/m^3.d, 300mL of loaded with fresh wastewater of volume 300mL with a COD concentration of 300 mg/L. The reactor pH effluent sample was collected for analysis of various physico-chemical parameters such as pH, COD, alkalinity, total solids and the analysis were carried out as per the standard methods for the examination of water and waste water (AWWA) 20th edition

C. *General Characteristics of Textile Wastewater*

The fresh wastewater samples were brought from Gemini graphics private limited, Kamthana, Bidar, Karnataka." to P.D.A Engg. College laboratory and preserved in deep freeze, to analyze the typical characteristics. The key pollutants in the wastewater are organic compounds and solids. Biodegradability may be estimated on the basis of BOD /COD ratio. This ratio ranges between 0.43-0.64, which indicates that the part of the organic compounds in the wastewater is not easily biodegradable. The BOD$_5$ is487mg/L, COD is 1120mg/L & Total Solids in waste water was found to be 1840 mg/L. When wastewater contains high concentration of organic matter, dissolve doxygendepletes because of the breakdown of organic matte r, in absence ofoxygen,sulphate acts as an electron acceptor to produce H_2S and odour. The characteristics of paper waste are shown in Table1.

IV. RESULTS AND DISCUSSION

The results of variation of percentage COD and percentage BOD removal are shown in Fig 3, Fig 4 &Fig 5 for varying Organic Loading Rate (0.5-1.5kgCOD/m^3.d).

Sl.no	Characteristics	Paper waste water
1	Color	Brown
2	pH	11
3	Total solids, mg/L	1840
4	Dissolve solids, mg/L	1460
5	Suspended solids, mg/L	380
6	BOD$_5$@20^{0}C, mg/L	487
7	COD, mg/L	1120
8	Chlorides, mg/L	456
9	Alkalinity, mg/L	810
10	Nitrates, mg/L	67

Table 1: Characteristics of Paper Waste

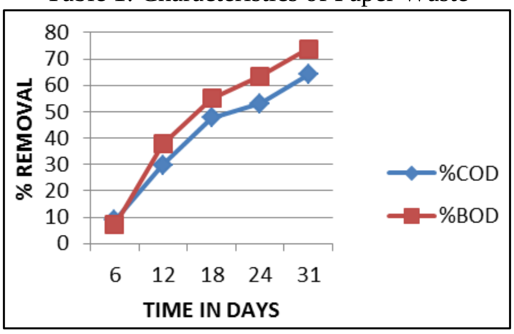

Fig. 3: Variation of % COD and % BOD for OLR=0.5 kg COD/m^3.d

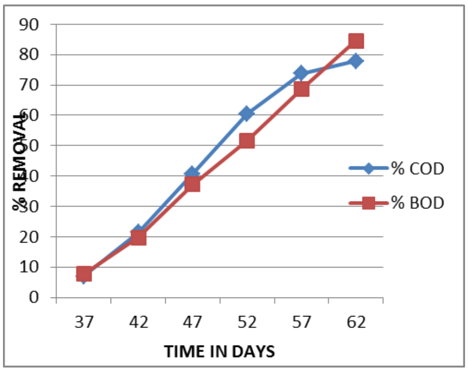

Fig. 5: Variation of % COD and %BOD for OLR=1.5 kg COD/m^3.d

The reactor was started with an OLR of 0.5kg COD/m^3.d and operated for a period of 25 days till it attains stabilization. During this period the pH is maintained from7.02-7.04. The COD reduced from 382-139 mg/L and BOD reduced from 156-42mg/L refer Figure 3. On 30thday the maximum COD and BOD removal efficiency obtained is63.61% & 73.07%. As the time increased, %COD removal increased& attained optimum value on 30th day. When the OLR was increased from 0.5 to 1.0 kg COD/m^3.d (37-62 days) &operated for a period of 25days till it attains stabilization. Throughout the study period the pH is maintained from7.04-7.00, the COD reduced from 746-165 mg/L and BOD reduced from 325-50mg/L refer Figure 4. On 62nd day the maximum COD & BOD removal efficiency obtained is 77.88 % & 84.61. As the time increased, %COD removal increased & attained optimum value on 62nd day. When the OLR was increased from 1.0 to 1.5 kg COD/m^3.d (68-93 days) & operated for a period of 25days till the reactor stabilizes. Throughout the study period the pH is maintained from 7.03-7.04, the COD reduced from 1013-179mg/L and BOD reduced from 424-95mg/L refer Figure 5. On 93rd day the maximum COD & BOD removal efficiency obtained is 82.32 % & 77.49%. As the time increased, %COD removal increased & attained optimum value on 93rd day.

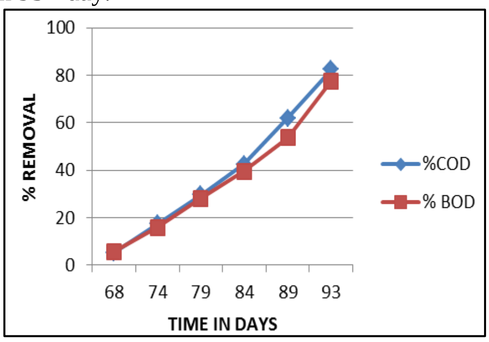

Fig. 4: Variation of % COD and %BOD for OLR=1.0 kg COD/m^3.d

V. CONCLUSIONS

The maximum COD removal efficiency is 82.32 % achieved after 30th day (optimizing time) at an organic loading rate of 1.5 kg COD/m^3.d. It was noticed that the percent COD removal was increased and attained optimum value on 93rd day from the start up. As the OLR was increased from 0.5to 1.5 kg COD/m3.d, percent COD removal increased from 8.9-63.61%, 6.97-77.88% and 5.23-82.32%, percent BOD removal increased from 7.05-73.07%, 7.69-84.61% and

5.66-77.49%, respectively. The Maximum COD removal is obtained on 93rd day and Maximum BOD removal is obtained on 62nd day.

REFERENCES

[1] Lawrence, A.W. and McCarty, P.L. (1969), methane formation in anaerobic treatment", J. control Fed.. Vol. 41, pp. R1-R7
[2] Santosh Kumar Garg (2008) "Sewage Disposal and Air Pollution Engineering" 21st Edition. Page No. 535.
[3] Annual of Practice No. 16 (1968), "Anaerobic sludge digestion", WaterPollution Control Fed., Washington DC, pp. 30-39.
[4] Standard Methods for the examination of Water and Wastewater, 21st edition (APHA, AWWA and Water Pollution Control Federation, Washington D C) 2005.
[5] Narsi R. Bishnoi, R.K. Khumukcham and Rajender Kumar "Biodegradation of pulp and paper mill effluent using anaerobic followed by aerobic digestion" Journal of Environmental Biology April 2006

