

Ultrasound Assisted Biological Treatment of Aged Leachate from MSW Dump

Royal George¹, Latha P²P.G. Student, Department of Civil Engineering, College of Engineering Trivandrum, Kerala, India¹Professor, Department of Civil Engineering, College of Engineering Trivandrum, Kerala, India²

ABSTRACT: Leachate from aged solid waste dumps contains non-biodegradable organic matter as a major fraction making direct biological treatment difficult. The present study deals with the anaerobic treatment of aged leachate in a completely mixed suspended growth reactor (CMSGR) by using low frequency (16 KHz to 1 MHz) ultrasound as a pretreatment step. In the first part of the study the optimum condition for solubilisation of organic matter in leachate samples was investigated using various sonication durations at an ultrasound frequency of 30 kHz. In the second part of the study, CMSGRs were operated for both ultrasonically pretreated and untreated leachate samples. Pretreated leachate showed more reduction in COD and BOD (98% and 85.82%) than untreated leachate (80% and 93.27%) at an HRT of 21 days. Biodegradability was increased from 0.275 to 0.925 for pretreated leachate while it was reduced to 0.195 for untreated leachate after biological treatment.

KEYWORDS: Aged leachate, Pretreatment, Anaerobic treatment, Biodegradability, Ultrasound.

I. INTRODUCTION

Waste generation has become an inevitable part of our day to day activities. According to the Ministry of Urban Affairs, Government of India estimate, India is generating approximately 100,000 metric ton of solid waste everyday of which 90% is dumped in open place [1]. Waste in such open dumps decay and degrade with passage of time producing leachate that pollutes ground and surface water. Biological treatment is a widely preferred option for treating leachate to make it harmless or at least less harmful.

The characteristics of leachate depend largely on the waste composition and age of waste dump. Leachate from MSW dump more than five years old is considered as aged leachate and contains refractory organic compounds as its major fraction making its direct biological treatment less effective or ineffective sometimes. Here comes the importance of pretreatment.

In the recent years ultrasound has been accepted as having the potential for treatment of wastewater on integration with different biological processes [19,20]. Ultrasound is a form of energy generated by sound waves at frequencies that are too high to be detected by the human ear. The ultrasound band is divided into low frequency (16 kHz to 1 MHz) and high frequency (more than 1 MHz) bands [2]. SirusZinadini et al. [22] extensively studied ultrasound especially for sludge pretreatment before anaerobic processes to obtain better performance from anaerobic reactors by producing more bioavailable organic substrate and thereby facilitating the hydrolysis step. Jackline Freitas Brillhante et al. [2] investigated the role played by ultrasound as a sanitation technology for sanitizing fruits and vegetables. Naddeo V et al. [17] evaluated the effectiveness of ultrasound for disinfecting water. Ayman O et al. [18] investigated the effectiveness of ultrasound in increasing the biogas or methane production from anaerobic treatment of landfill leachate when used as a pretreatment.

The work in this paper is divided in two stages. 1) Optimization of ultrasound pretreatment 2) Biological treatment of both ultrasound pretreated and untreated leachate in CMSGRs. Paper is organized as follows. Section II presents the study objectives. Methodology of the current study is given in Section III. Section IV presents experimental results and discussion. Finally, Section V presents conclusion.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

II. OBJECTIVE

This research was conducted to investigate the efficiency and viability of low frequency ultrasound in pretreating aged leachate as to improve its biological treatment. The biological treatment was carried out in a completely mixed suspended growth anaerobic reactor. This paper also aims to propose an effective two-step method (ultrasonication followed by anaerobic biological treatment) to treat aged leachate from MSW dump and other similar wastewater containing refractory organic compounds so as to minimise and if possible avoid the adverse impact on the environment.

III. METHODOLOGY

A. General

Aged leachate from MSW dump was collected and characterized. Ultrasound pretreatment was provided using a sonicator called UP100 H for different durations of 20, 40 and 60 minutes in order to optimize it. A completely mixed suspended growth anaerobic reactor was designed. Two of them were fabricated; one for treating raw or untreated leachate and other for treating ultrasound pretreated leachate. The reactors were operated at different HRTs of 3, 6, 9, 12, 15, 18 and 21 days. The effluent sample from the reactors were analysed at each HRT.

B. Materials and Methods

1) Collection and Characterization of Aged Leachate:

The sample for the current study was collected from Chalai in Thiruvananthapuram, where about seven acres of land is heaped with waste from the entire city. 5L of leachate was collected and its initial characterization was done. The sample collected is shown in Fig.1. It was stored in closed containers at 4° C.

2) Analytical Methods:

The physical and chemical properties of the leachate were determined in accordance with standard methods (APHA, 2005).

3) Ultrasound Pretreatment:

Low frequency ultrasound pretreatment was given to leachate samples by using UP100H. It is shown in Fig.2.

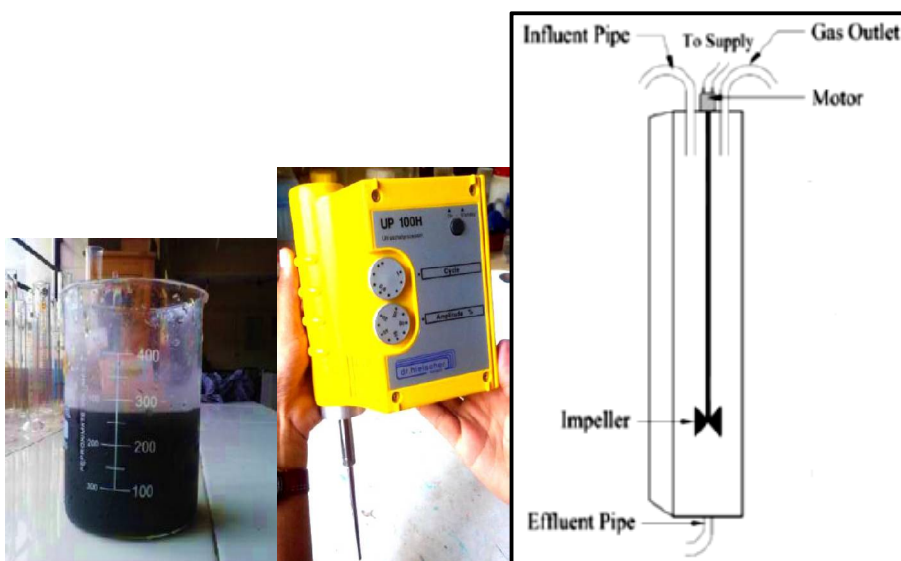


Fig.1: Sample Collected

Fig.2:UP100H

Fig.3:Schematic diagram of CMSGR

International Journal of Innovative Research in Science, Engineering and Technology

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The useful output power of UP100H is 100W and working frequency is 30 kHz. The leachate samples were sonicated in plastic vessels of volume 60 ml for different time periods including 20, 40 and 60 minutes. After sonication process, changes in COD, total suspended solid (TSS) and turbidity were monitored to find the optimum sonication duration. The leachate was then pretreated at the optimum sonication duration.

4) Experimental set-up for CMSGR:

A laboratory scale CMSGR was designed. The reactor was a square column of height 45 cm and side 9 cm, made of acrylic. A shaft with vanes at its tip functioned as the impeller and provided continuous mixing with the backing of amotor. Continuous mixing ensured suspended growth in the reactor by keeping the biomass in suspension. The reactor was provided with suitable arrangements for feeding, gas collection and draining of residues. Fig.3 shows the schematic configuration of the experimental set-up. The total volume was 3.6 L and working volume was 2.8L.

5) Operation of CMSGR:

Anaerobic biological treatment of the pretreated leachate was carried out in a CMSGR. A control CMSGR was also operated with untreated (raw) leachate to elucidate the role played by ultrasonication in enhancing the efficiency of anaerobic process. The reactors were operated at ambient temperature. Cow dung slurry was used as inoculum. After acclimatization the reactors were fed with leachate (one with untreated and other with pre-treated) at 1:2 dilution and was kept for the desired HRT. The continuous mixing provided by the mixer or impeller ensured suspended growth of microbes in the reactor. Leachate was allowed to stabilize under anaerobic condition.

Mixed samples were taken from the reactor at 3 days interval and were analysed. The CMSGR was continuously operated until steady state condition was achieved. Fairly constant values of the effluent COD and VSS indicated the achievement of steady state.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

A. Characteristics of Collected Leachate

TABLE I

CHARACTERISTICS OF COLLECTED LEACHATE

Parameter	Value
pH	8.3
Colour	Black
Nitrate (mg/L)	20
Total Nitrogen (mg/L)	45
Phosphate (mg/L)	13.5
Sulphate (mg/L)	150
BOD (mg/L)	5500
COD (mg/L)	20000
Biodegradability (BOD/COD)	0.275
Ammonia Nitrogen (mg/L)	2.95
Chloride (mg/L)	30
Total Suspended Solids [TSS] (mg/L)	1800
Turbidity (NTU)	750

B. Optimization of Pretreatment

1) Effects of ultrasound on COD concentration

Samples after 20, 40 and 60 min sonication are shown in Fig.4. COD concentration was measured against different ultrasound durations. The COD values increased up to 60 minutes as can be seen from the graph in Fig.5.

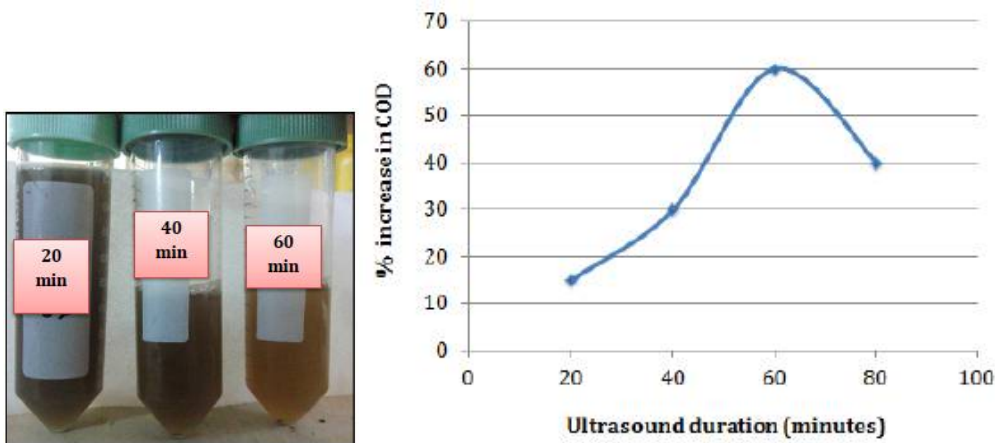


Fig.4:Samples after 20, 40 and 60 min sonication Fig.5:Percentage variation in COD with increase in ultrasound duration

Application of low frequency ultrasound to leachate samples transfers particulate matter to soluble COD. The increase in COD with increase in ultrasound duration indicates that the non-biodegradable organic matter in the raw leachate has been broken down or solubilized and is thus converted into biodegradable organic matter as a result of sonication. Then COD after 80 min sonication was also determined and was found to be 28000 mg/L which is lesser than that after 60 min sonication. Or after 60 min of sonication, there was a decrease in COD concentration of the leachate.

2) Effects of ultrasound on turbidity

Turbidity increase has been accepted as an indirect parameter for disintegration of particulate organic matter during ultrasound applications [18]. The influence of the applied ultrasound on turbidity parameter is shown in Fig.6. As can be seen from the figure, the initial turbidity of the leachate was increased due to the applied ultrasound energy. According to the results, the maximum turbidity increase of the leachate samples has been found to be for 60 min. The fundamental effect of ultrasound pretreatment in leachate is the disintegration of the suspended solids which is highly related with turbidity [17].

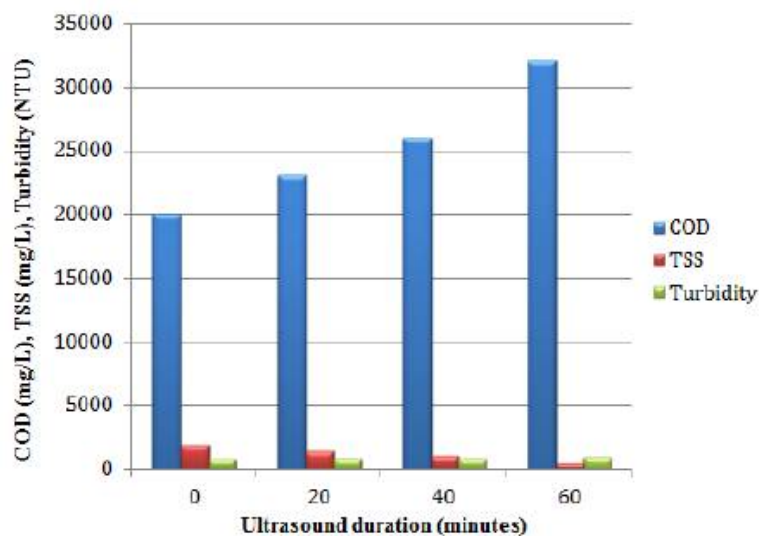


Fig.6:Effect of ultrasound on COD, TSS and turbidity of leachate

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3) Effects of ultrasound on suspended solids

Physical disintegration of suspended solids due to ultrasound has been found to reduce the total suspended solids concentration as shown in Fig.6. Figure shows the TSS decrease at different time periods. Maximum TSS reduction was observed after 60 min sonication.

From the trends observed in the changes in COD, turbidity and TSS with change in ultrasound duration, 60 min of ultrasonication was selected as optimum condition for pretreatment of leachate. Leachate was then subjected to low frequency ultrasound pretreatment for 60 minutes.

C. Biological Treatment of Untreated and Pretreated Leachate

Anaerobic biological treatment of pretreated leachate was carried out in the CMSG. A control CMSG was also operated with untreated (raw) leachate. Results of biological treatment on untreated and pretreated leachate are summarized below in Table 2 and Table 3.

TABLE 2
EFFLUENT CHARACTERISTICS OF UNTREATED LEACHATE

HRT days	TS mg/L	TFS mg/L	TDS mg/L	TSS mg/L	DFS mg/L	TVS mg/L	DVS mg/L	VSS mg/L	pH	COD mg/L
3	4200	1000	800	3400	0	3200	800	2400	7.77	4800
6	4400	0	1600	2800	0	4400	1600	2800	7.84	4000
9	3000	1400	0	3000	0	1600	0	1600	7.67	2400
12	3200	1200	1000	2200	0	2000	1000	1000	7.72	1600
15	3400	0	1600	1800	0	3400	1600	1800	7.77	800
18	3000	0	1100	1900	0	3000	1100	1900	7.78	800
21	3000	0	900	2100	0	3000	900	2100	7.58	400

TABLE 3
EFFLUENT CHARACTERISTICS OF PRETREATED LEACHATE

HRT days	TS mg/L	TFS mg/L	TDS mg/L	TSS mg/L	DFS mg/L	TVS mg/L	DVS mg/L	VSS mg/L	pH	COD mg/L
3	4000	0	2400	1600	0	4000	2400	1600	7.78	14000
6	4200	0	1600	2600	0	4200	1600	2600	7.88	8000
9	2800	0	0	2800	0	2800	0	2800	7.74	8000
12	3000	1000	1200	1800	0	2000	1200	600	7.72	6800
15	4600	2000	2200	2400	0	2600	2200	400	7.71	4400
18	4200	500	1500	2700	0	3700	1500	1200	7.72	4000
21	4000	0	1400	2600	0	4000	1400	2600	7.45	4000

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Graphs shown in Fig.7, Fig.8 and Fig.9 describe the changes in untreated and pretreated leachate as the biological treatment proceeds. Increased COD reduction was obtained for ultrasound pretreated sample (table 2 and 3) as can be seen from Fig.7. This is because of the solubilization of organic matter that took place during sonication which made it easier for the microbes to assimilate the organic matter thereby increasing the rate and extend of treatment. In the case of both raw and sonicated samples pH remained nearly neutral throughout the treatment (table 2 and 3) as shown in Fig.8. This shows that the volatile fatty acid concentration is at a minimum level. This indicates that a sufficient methanogenic population exists and sufficient time is available to minimize hydrogen and VFA concentrations [18].

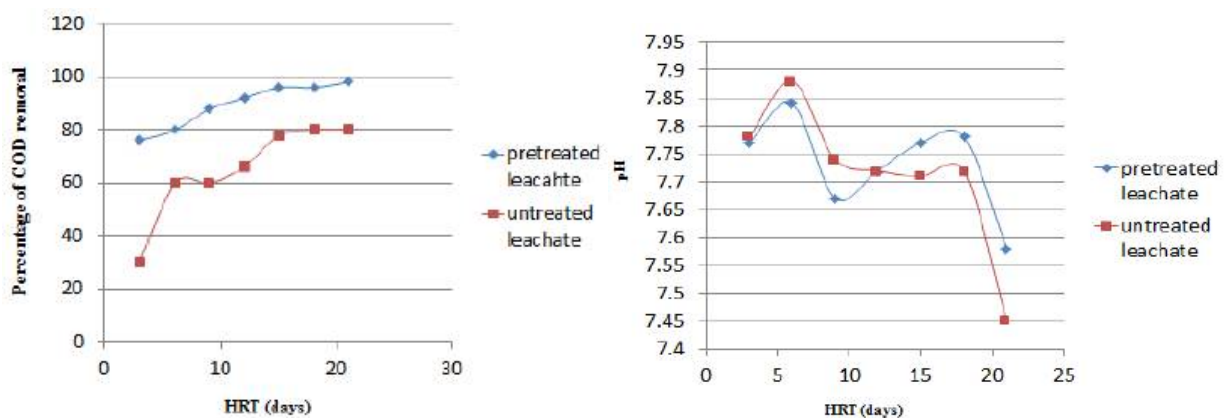


Fig.7:Percentage COD removal for untreated and pretreated leachate Fig.8:Variation in pH with HRT for untreated and pretreated leachate

VSS indicates the concentration of biomass in the reactor. Variation in VSS follow similar trend for both untreated and pretreated leachate as shown in Fig.9.

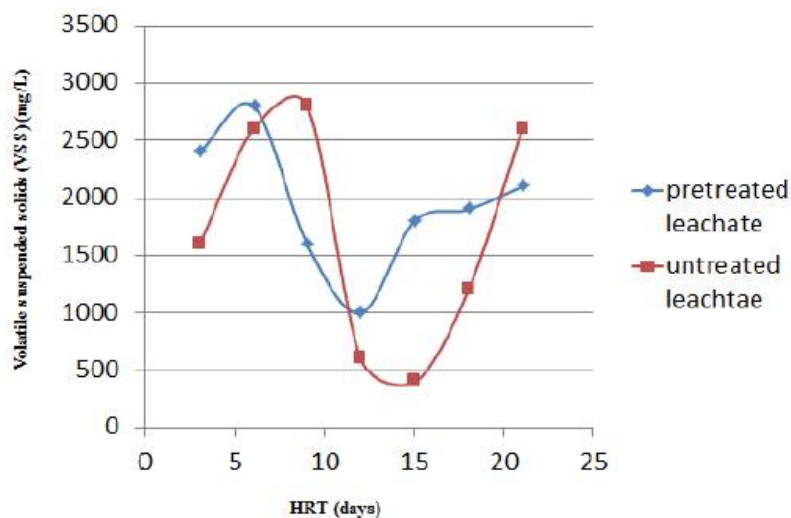


Fig.9:Variation in VSS with HRT for untreated and pre-treated leachate

4) Change in Biodegradability

In order to determine the biodegradability of leachate after treatment, BOD of untreated and pretreated leachate were estimated at the end of HRT. Table 4 gives the biodegradability values.

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TABLE 4
BIODEGRADABILITY AFTER TREATMENT

Parameter	Untreated leachate	Pre-treated leachate
BOD at the end of HRT (mg/L)	780	370
COD at the end of HRT (mg/L)	4000	400
Biodegradability at the end of HRT (BOD/COD)	0.195	0.925

V. CONCLUSION

Leachate obtained from ChalaiMSW dump was treated using combined ultrasound-biological process. Low frequency ultrasound of 30 kHz was applied prior to anaerobic treatment in CMSGR. Based on the test results 60 minute was found to be the optimum ultrasound duration for UP100H sonicator. Ultrasound assisted biological treatment removed 98% of COD and 93.27% of BOD, while direct biological treatment removed only 80% COD and 85.82% BOD. Biodegradability was increased from 0.275 to 0.925 for pretreated while it was reduced to 0.195 for untreated leachate after biological treatment (table 4). The overall result in table 5 and Fig.10 shows that ultrasound assisted biological treatment is an effective treatment option for aged leachate from MSW dump whose direct biological treatment would not be effective owing to the presence of refractory organic matter.

TABLE 5
SUMMARY OF TREATMENT OF AGED LEACHATE FROM MSW DUMP

Parameter	Raw leachate	Leachate after biological treatment		Leachate after ultrasound assisted biological treatment	
		Effluent quality	% removal	Effluent quality	% removal
COD (mg/L)	20000	4000	80	400	98
BOD (mg/L)	5500	780	85.82	370	93.27
Biodegradability	0.275	0.195		0.925	
TSS (mg/L)	1800	2600		2100	
pH	8.3	7.45		7.58	
Colour	Black	Light brown		Light yellowish brown	

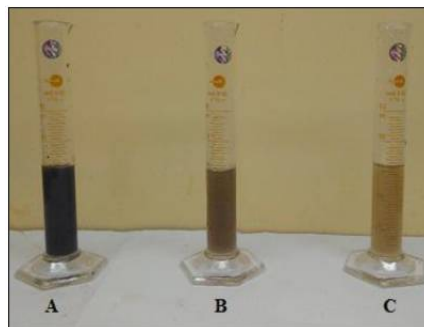


Fig.10:(A) Raw leachate, (B) Leachate after biological treatment, (C) Leachate after ultrasound assisted biological treatment

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