LECHATE TREATMENT USING STABILIZATION PONDS IN TROPICAL ENVIRONMENTS

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Abstract - Among available options, for its simplicity and economic advantages, landfilling is still one of the most common method of disposing solidwaste worldwide. Anyhow, solidwaste landfilling is not entirely trouble free, poorly managed fills, a common practice in the developing world, leads to many harmful side-effects including water and soil pollution. In most instances, handling landfill lechate often the most common cause for pollution is a challenging, complicated and a costlier exercise. Therefore introducing simpler, affordable landfill lechate management techniques suitable for developing nations like Sri Lanka is vital. This study evaluates the ability of waste stabilization ponds a widely accepted low cost wastewater treatment option in treating MSW generated lechate under tropical conditions. Both laboratory and field scale pond systems were tested treating MSW lechate for organic matter and ammonium-N removal. Results obtained show over 95%, 85% and 70% reductions for COD, BOD_5 and ammonium-N removals respectively. Further, the tropical climate conditions show much favorable environment for enhanced and reliable treatment.

Keywords - Ammonium Nitrogen, BOD, COD, Leachate, Sanitary Landfill, Stabilization Ponds.

I. INTRODUCTION

In any form of solidwaste management, no matter what waste prevention, re-use or recycling options are in place, there will always be a portion of refuse that needs final disposal. Among techniques in use today, though not the best option on hand, waste landfilling for its simplicity and cost effectiveness continues to play a major role in solidwaste disposal. Often improper landfilling, the case in many developing countries leads to numerous problems (Aziz et.al. 2010, Bhalla et. al. 2012, Palma et al. 2002).

Leachate is the concentrated liquid waste by-product released at a landfill through percolation of rainwater or other liquid water squeezing out of dumped waste. Such percolating waters during its passage through the fill accumulates waste pollutants by physical, chemical and microbial processes to generate lechate. Depending on the age and the type of deposited waste, a leachate stream may contain a diverse array of chemical compounds including organic contaminants biodegradable or refractory, ammonium-nitrogen, heavy metals, chlorinated organic and inorganic salts (Renou et. al. 2008, Adhikari and Khanal 2015). Further, the composition and the generation rate of lechate in a landfill shall vary depending upon many factors; the waste moisture content, the precipitation pattern, the degradation stage of the waste etc. making it one of the most complicated, difficult and expensive waste streams to handle. Therefore, many landfilling facilities especially what are found in developing countries often ignore its treatment resulting numerous problems.

Stabilization ponds or lagoons on the other hand are large artificial water bodies in which wastewater is treated by natural occurring processes; solar light, wind and microorganisms. While stabilization ponds were traditionally used for sewage treatment, today they also are popular among industrial wastewater treatments especially for strong organic wastewaters. In a typical pond system, anaerobic and facultative ponds are designed for COD removal, while the aerobic ponds are mainly designed for pathogenic and nutrient removal. Though still very much in use, many temperate regional countries consider stabilization ponds as less attractive option for wastewater treatment as they are slow, highly climatic dependent and land intensive treatment operations. However their simple and cheap operations can be very attractive option for developing countries including treating strong wastewaters like lechate. According to Mehmood et. al. (2009) and Renou et. al. (2008), waste lagoonings have shown encouraging results in treating landfill lechate with records over 90% COD and over 80% ammonia removals. Further the tropical warm weather condition continuing throughout the year, stabilization ponds can make a good alternative for leachate treatment in countries like Sri Lanka where investments for waste management is very limited. Therefore this study evaluates the ability of stabilization ponds in treating landfill lechate in Sri Lanka under tropical conditions.

II. MATERIALS AND METHODS

The aim of this study was to determine the capacity of stabilization ponds in treating leachate generated at typical landfillings in Sri Lanka. Two pond chains ; anaerobic, facultative and aerobic in series at both laboratory scale and field scale were operated treating MSW lechate. The laboratory scale unit was operated under fixed conditions feeding lechate collected from a near-by open landfill at Gohagoda, Kandy Sri Lanka. The field scale unit was operated, using lechate produced from constructing two lysimeter landfill units at the study site itself. The field site was located some 20 km away from Kandy near the Gampola town in the wet region of Sri Lanka where the annual rainfall is around 2,000 to 2,500 mm. The lysimeter landfill units having impermeable bottom liners were

loaded with fresh municipal solidwaste taken from Gampola town. Top of each lysimeter was covered with a semi permeable capping to allow partial rainwater infiltration. Lechate generated at these lysimeters were collected in retention tanks before feeding it to the pond system at constant rates. The feed lechate characteristics in Table 1 show that the Gohagoda landfill site was found to be in an intermediate or acetogenic state (Renou et. al. 2008, Adhikari and Khanal 2011) while the lower BOD to COD ratio observed with lysimeter unit lechate can be due to their temporary storage before use.

In both laboratory and field scale units, the anaerobic ponds were operated at a HRT (Hydraulic Retention Time) of around 20 days but, the facultative and aerobic ponds in laboratory scale units had much lower HRT compared to that of the field scale units (Table 2). Further the laboratory-scale unit maintained almost a constant Organic Loading Rate (OLR) throughout its entire operation, while the varying OLR at field scale unit is a good example to show the lechate strength dependency upon the weather conditions (rainfall). Further, during long dry spells the lechate to field scale unit had to be diluted with stored rain water on several occasions to maintain a constant HRT.

Table 1. Feed Lechate Characteristics in milligram per liter

Parameter	Laboratory Scale Unit	Field Scale Unit
BOD_5	1,120 to 1,190	860 to 1,422
COD	6,990 to7,540	4,800 to 8,100
NH_4-N	850 to 900	184 to 325
BOD_5/COD ratio	0.16	0.18

Table 2 Design and Operational Data of Pond Systems

Pond Type	Laboratory Scale Unit				Field Scale Unit			
	HRT (days)	OLR (g COD/m^3.d)	Pond Volume (L)	Surface area (m^2)	HRT (days)	OLR (g COD/m^3.d)	Pond Volume (liters)	Surface area (m^2)
Anaerobic	20	360-390	288	0.36	19	250-440	3000	2.0
Facultative	8	520-525	112	0.28	19	170-300	3000	5.0
Aerobic	4	440-450	58	0.10	13	50-100	2000	10.0

The feed lechate and each pond outlet were monitored weekly for 5 day Biochemical Oxidation Demand (BOD_5) using the Winkler titration method, Chemical Oxidation Demand (COD) using the colorimetric determination and ammonium-N using the Nessler method following the AWWA standard methods for water and wastewater analysis (1995). Also from time to time the pond pH and ORP (oxidation-reduction potential) too were monitored to determine the condition and the oxidizing state of each pond.

III. RESULTS AND DISCUSSION

The chronological COD, BOD_5 and NH_4^+-N removal at field scale and laboratory scale units are summarized in Table 3 and Table 4 below. In both cases, the highest COD removal is achieved at the facultative stage. Field scale study results show good BOD removal in all three ponds with the highest being recorded at the aerobic stage. At laboratory scale controlled study, a significantly higher percentage BOD removal is obtained at the facultative pond. Ammonium-N removal was better with the field scale unit, mainly at aerobic pond where the surface area to volume ratio and the wind effect was considerable.

Table 3 COD, BOD and ammonium-N removal efficiencies at Field Scale Study

Week	Anaerobic Pond			Facultative Pond			Aerobic Pond		
	COD (%)	BOD_5 (%)	NH_4-N (%)	COD (%)	BOD_5 (%)	NH_4-N (%)	COD (%)	BOD_5 (%)	NH_4-N (%)
4	35.9	36.0	20.0						
7	19.3	47.8	16.3	40.0	64.5	50.2			
8	47.3	48.8	10.3	60.9	47.2	50.0	33.3	81.4	60.8
9	14.7	-	50.3	64.1	-	40.6	34.4	-	62.2
10	50.6	58.1	64.6	76.4	60.2	34.6	14.3	90.8	77.6
11	19.2	66.9	63.8	73.0	65.3	47.8	30.0	79.6	89.4
12	44.1	48.4	46.5	67.9	72.3	27.1	21.3	61.6	76.7

Table 4 COD, BOD and ammonium-N removal efficiencies at Laboratory Scale Study

Week	Anaerobic Pond			Facultative Pond			Aerobic Pond		
	COD (%)	BOD_5 (%)	NH_4-N (%)	COD (%)	BOD_5 (%)	NH_4-N (%)	COD (%)	BOD_5 (%)	NH_4-N (%)
5	-	37.7	32.0	-	-	-	-	-	-
6	-	38.5	34.3	-	60.3	23.6	-	-	-
7	-	41.2	28.7	-	61.7	21.4	57.1	41.2	41.1
8	48.1	39.0	29.7	55.5	58.4	22.5	54.5	33.2	36.5
9	46.2	40.1	31.8	56.4	61.1	23.6	56.7	42.3	40.2

The chronological COD and ammonium-N removal observed at field scale system is given in Figure 1 below. The OLR rate and the corresponding anaerobic pond performances show direct bearing on each other. The organic loading to the anaerobic pond ranged from 250 to 440 g COD/m^3.d. The two extremes lowest & highest OLR reported in 8 & 9 week respectively. However, results show any performance reduction at anaerobic pond is well absorbed by the other two ponds to give a fairly constant reliable overall COD and ammonium removals.

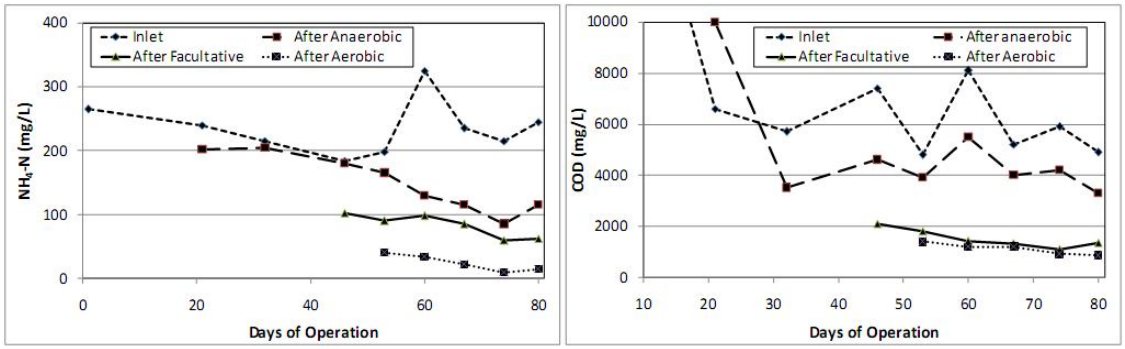


Figure 1 Ammonia Nitrogen and COD Variation in Field Scale unit

The overall COD, BOD and ammonium-N removals attained with the laboratory scale unit and the field scale unit is tabulated in Table 5 below. The 75 to 90% COD, 84 to 96% BOD_5 and 66 to 96% ammonium-N removals are higher than similar cases reported by Renou et. al. (2008), Orupold et. al. (2000), T. Mzehlum (1995) and Martins et. al. (2013).

Table 5 The overall BOD and COD and Ammonium-N removals

End of Week	Laboratory Scale unit			Filed Scale Unit		
	COD (%)	BOD_5 (%)	NH_4-N (%)	COD (%)	BOD_5 (%)	NH_4-N (%)
7	90.2	86.3	68.2	-	-	-
8	89.5	84.4	66.1	81.1	-	78.3
9	89.6	85.6	68.3	75.4	93.6	82.8
10	-	-	-	85.2	95.9	93.2
11	-	-	-	82.5	96.3	96.2
12	-	-	-	85.6	94.9	93.5

Renou et. al. (2008) reviewing several past aerated lagoon studies treating lechate at HRTs similar to this study confirming 60 to 97% COD removal, Orupold et. al. (2000) reporting 55–64% COD removal with lagooning, Maehlum (1995) treating diluted lechate with onsite anaerobic–aerobic lagoons combined constructed wetland system reporting 70% nitrogen removal and Martins et. al. (2013) operating three ponds in series but with longer HRTs and at various operating conditions: conventional, with artificial aeration and with aeration & recirculation for lechate treatment achieving 35-82% and 75–99%, for soluble COD and ammonium-N removal show more or less lower efficiencies than what is reported in this study. In addition, unlike reported by Maehlum (1995) where temperature variation making serious impact on lagoon performances treating lechate, no serious drops in efficiency due to temperature is observed in these

studies probably due to warm temperatures experienced throughout the operations. Rodrigues et.al (2009) too show better COD removals as high as 89% in Brazil, where the testing conditions were tropical.

In summary the field scale final effluent after twelve weeks of running show 48 mg/L, 850 mg/L and 14 mg/L BOD_5, COD and NH_4-N levels. Final effluent BOD_5, COD and NH_4^+ fluctuated in the range 35-80 mg/L, 850-1,400 mg/L and 9-40 mg/L during 8^{th} to 12^{th} weeks. The laboratory scale final effluent after nine weeks show 168 mg/L, 752 mg/L and 283 mg/L BOD_5, COD and NH_4-N respectively. Thus coupling the pond system effluent with a polishing treatment stage is required to achieve the a 30 mg/L BOD_5, 250 mg/L COD the standard requirements in Sri Lanka.

CONCLUSIONS

The field and laboratory scale stabilization pond systems treating lechate generated from domestic solidwaste landfilling show promising BOD_5, COD and ammonium-N removals. The overall COD, BOD_5 and NH_4^+-N removals ranged from 89-90%, 84-86% and 66-68% and 75-85%, 94-96% and 78-96% respectively with laboratory scale and the field scale units. The tropical conditions show a much steadier performance for organic matter and NH_4-N removal than reported in temperate countries. In summary though land intensive, the simple cost effective pond system can be a better option for developing nations especially in the tropical belt to care for lechate from non-engineered landfills where no protection at present is in place.

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