Leachate Treatment Potential with Stabilization Ponds

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Abstract: Landfill leachate is one of the main environmental hazards generated due to municipal landfills. Common practices in a well-designed sanitary landfill is to collect the leachate at its bottom using perforated collection systems and treat them to reduce the contaminants up to the level issued on environmental guidelines. For this purpose there are many leachate treatment methods practiced in all over the world. Among them waste stabilization ponds though not widely used are applied in some tropical countries mainly due to the tropical hot weather conditions. Therefore in a country like Sri Lanka, waste stabilization ponds can be a promising alternative for leachate treatment considering its tropical weather condition. In this study a preliminary research has been concluded to ascertain the potential of the stabilization ponds to treat the landfill leachate under local conditions in Kandy. Here a treatment system comprising of a series of ponds was used in a lab scale model with two trial sessions at two different hydraulic retention times to observe the variation of contaminants mainly Biochemical Oxygen Demand (BOD₅), Chemical Oxygen Demand (COD) and Ammonium Nitrogen. The obtained results show that a considerable reduction in BOD₅ over 89%, COD over 93% and ammonium nitrogen over 78%. Also it was observed increasing the hydraulic retention time though show improved removal efficiencies for BOD₅ and Ammonia reduction, its influence of COD reduction was not significant.

Keywords: Ammonia Nitrogen, BOD, COD, Leachate, Sanitary Landfill, Stabilization Ponds.

1 INTRODUCTION

Today waste leachate is considered a main environmental hazard generated through municipal landfills. Since leachate is generated as a result of percolation of rainwater or other liquid squeezing out of dumped waste through waste decomposition, it is highly contaminated with organic and inorganic compounds. Thus the composition of leachate generated at a landfill varies widely depending on the type of waste dumped and the age of the landfill. At a typical solid waste dump, the generation of leachate is mainly affected by the composition of the wastes and precipitation or similar water percolating through waste deposited fill. Once in contact with decomposing solid waste, the superfluous waters (such as rainwater or water sprayed for enhancing decomposition) percolates through solid waste, not only collecting the squeezed out liquid matter out of the dump but also accumulating both the biological and chemical constituents such as methane, carbon dioxide and a complex mixture of organic acids, aldehydes, alcohols and simple sugars of the decomposing waste. As a result, leachate is regarded as a liquid that contains high amounts of dissolved and suspended materials and if not properly handled, would cause severe contamination problems. A study in Germany suggests that leachate production rates at landfills are often between 12 and 22 % of the annual precipitation (Heyer & Stegmann, 2005)

Often an improper leachate management system at a landfill can cause it to leach into the environment. In such a case the leachate will contaminate not only the underlying soil, but passing through the underlying soil it will contaminate groundwater resources, as well as the surrounding surface water resources. Remediation of such a contamination after the event can be very difficult, lengthy, and expensive.

Possible risk of contamination from leachate mainly comes from its heavy organic content and high concentration of ammonia (Shah, 1999). Toxic substances such as tracer heavy-metals etc are commonly not found at high concentrations in municipal sanitary landfills. However if present in substantial concentrations such as in an industrial waste dumps, especial measures are necessary to make sure not to release such heavy metals to the outside environment. Commonly in most municipal waste landfills the pathogenic microorganisms in leachate are often cited as the most important, but these organism counts reduce rapidly with time in a landfill and is mostly applies to the recent-fresh leachate only.
Because of its high strength, leachate streams running directly into an aquatic environment can have both acute and chronic impact on the receiving waters which may be very severe and can severely diminish bio-diversity and greatly reduce populations of sensitive species. Where toxic metals and organics are present this can lead to chronic toxin accumulation in both local and far distant populations.

Common practice in a well-designed sanitary landfill is to collect all leachate generated using a perforated collection system and treats them to reduce the contaminants to the level issued on environmental guidelines. In this regard there are many leachate treatment methods practiced in all over the world and among them waste stabilization ponds (Gloyna, 1971) though not widely used, is an emerging option in tropical countries mainly due to the tropical hot weather conditions. In a country like Sri Lanka, waste stabilization ponds can be a promising alternative for leachate treatment considering its tropical weather condition. In this research preliminary research study has been concluded to ascertain the potential of the stabilization ponds to treat the landfill leachate. Here a treatment system comprised of series of ponds was used in a lab scale model with several trial sessions to observe the variation of contaminants mainly Biochemical Oxygen Demand (BOD$_5$), Chemical Oxygen Demand (COD) and ammonium nitrogen. The efficiencies of reducing those contaminants were obtained in each trial session.

2 METHODOLOGY

2.1 Pond Models

A three stage pond system was investigated for the treatment of leachate collected from the dumpsite at Gohagoda, Kandy (Wimalasuriya, 2011). The three ponds were established with constant volumes, constant depth units for continuous gravity feeding. The three ponds were designed to operate; Pond 1 as an anaerobic pond, Pond 2 as a facultative pond and the Pond three as a maturation pond. However during operations through dissolved oxygen measurements it was realized that both pond 1 was mainly anaerobic, pond 2 except for a thin layer on top was behaving in anaerobic condition while the pond 3 in facultative condition. Dimensions of the pond models used are given in Table 1 below.

<table>
<thead>
<tr>
<th>Pond Type</th>
<th>Length/(m)</th>
<th>Width/(m)</th>
<th>Height/(m)</th>
<th>Liquid Volume/(m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond 1</td>
<td>Cylindrical (diameter-460mm)</td>
<td>0.700</td>
<td>0.116</td>
<td>0.116</td>
</tr>
<tr>
<td>Pond 2</td>
<td>0.760</td>
<td>0.400</td>
<td>0.300</td>
<td>0.091</td>
</tr>
<tr>
<td>Pond 3</td>
<td>1.020</td>
<td>0.595</td>
<td>0.090</td>
<td>0.055</td>
</tr>
</tbody>
</table>

2.2 Efficiencies

Efficiencies of reducing those contaminants were obtained in each trial session.
2.2 Operating Conditions

The ponds were tested for two set of hydraulic retention times (HRTs) by changing the feed flow rates. Operated flow rates and the retention times are shown in Table 2 below. Accordingly the overall total retention times during trials 1 and 2 were approximately around 27 days and 41 days respectively. These tested detention times are comparable with common HRTs employed in conventional stabilization pond systems treating wastewaters. Experimental runs, during first and second trials were over 75 days and over 30 days respectively.

<table>
<thead>
<tr>
<th>Trial No.</th>
<th>Flow Rate (l/ day)</th>
<th>Detention time/ (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pond 1</td>
<td>Pond 2</td>
</tr>
<tr>
<td>1</td>
<td>9.7</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>6.4</td>
<td>18</td>
</tr>
</tbody>
</table>

2.3 Wastewater Sampling

Samples for testing during the investigation were collected from inlets and outlets at four points (influent to pond 1, effluent from pond 1, effluent from pond 2 and finally effluent from pond 3) in regular intervals during the entire period of the investigation. Collected samples were tested for 5 day Biochemical Oxidation Demand (BOD$_5$), Chemical Oxidation Demand (COD) with Colorimetric determination, Nitrate-N with Cadmium reduction method, Ammonium-N with Nessler method, Phosphates with Molybdovanadate method, pH and Electrical Conductivity (EC) following the AWWA standard methods for water and wastewater analysis (1995).

3 RESULTS AND DISCUSSION

3.1 Organic Matter Removal

As described above, this investigation was carried out in two trials under the conditions given in Table 2; trial 1 for duration of over 75 days and trial 2 for duration of over 30 days respectively. The obtained BOD$_5$ values and COD values at the end of each trail with respect to each pond are shown respectively in figure 1 and figure 2 below.

According to these results, pond 1 and pond 2 show a higher reduction for BOD$_5$ than that was observed in pond 3. The obtained BOD$_5$ removal percentages with trial 1 and trial 2 shows that in ponds 1, 2 and 3 had 40.1%, 57%, 26.89% and 54.12%, 62.72%, 40.51% removals respectively. According to these results, the highest BOD$_5$ percentage reductions were observed both during trial 1 and trial 2 at pond 2. This may be due to the reason that the efficient conversion of complex organic matter into simpler forms by hydrolysis under anaerobic conditions at the first pond. Due to this hydrolysis process, the less or non biodegradable COD is converted into easily biodegradable BOD yielding a higher BOD reduction in the second pond. Further the reduction of BOD$_5$ in the second trial which had a longer retention times shows better results than in the first trial. In summary the cumulative BOD$_5$ reduction at the pond system during trial 1 and trial 2 were 81.2% and 89.8% respectively.

Conversely, observed results show that the COD reduction in the first pond is higher compared to other ponds (figure 2). This as explained can be mainly due to the rapid anaerobic digestion process removing easy COD at the 1st pond. The obtained COD reduction percentages with trial 1 and trial 2 for ponds 1, 2 and 3 were 77.5%, 33.3%, 27.6% and 75.6%, 45.1%, 30.2% respectively. The obtained respective cumulative COD reduction at the pond system during trial 1 and trial 2; 93.6% and 90.2% are higher than that of the efficiencies obtained for BOD$_5$. As the hydrolysis and fermentation phases present in the anaerobic ponds, with the available long retention times more reduction of COD is expected. Though a
marked BOD removal differences were observed in the two trials, COD reduction show almost same levels.

![BOD concentrations at sampling points](image)

**Figure 2 BOD₅ variation**
Note: sample points 1, 2, 3 and 4 represent influent to pond 1, effluents from pond 1, 2 and 3 respectively

![COD concentrations at sampling points](image)

**Figure 3 COD variation**

### 3.2 Variation of Nitrogen and Other Compounds

Pond system was also investigated for the removal of nitrogen compounds; ammonia and nitrate. The results obtained show that the first pond did not show significant improvements with respect to Ammonium Nitrogen reduction. However the Ammonium Nitrogen removal at the second and third ponds showed considerable improvements. The observed Ammonia Nitrogen values in mg/l at the influent to ponds and at the corresponding values at the end of each pond during trial 1 and trial 2 were 988, 885, 655, 365 and 1075, 910, 570, 230 respectively. This Ammonia-N variation is shown in figure 3 below. The obtained values yield Ammonia-N removal efficiencies of 10.4%, 26%, 44.3% and 15.4%, 37.4%, 59.7% respectively at each pond for trail 1 and trail 2. Further the overall Ammonia-N reduction percentages
observed after treatment with each pond for trial 1 and trial 2 are shown in figure 4. As aerobic condition with at least a 1mg/l dissolved oxygen requirement for effective nitrification justified the obtained results. However the longer retention time in trial two show better Ammonia-N removal than in trial 1 as expected.

The observed Nitrate Nitrogen levels at each pond during the investigation are shown in Figure 5 below. Compared to ammonia reductions observed, the observed nitrification levels at each pond shows significant de-nitrification taking place in the pond system. De-nitrification occurs when oxygen levels are depleted and nitrate becomes the primary oxygen source for microorganisms. Due to rapid nitrification and the presence of anaerobic zones in the second and third ponds, de-nitrification was expected to be higher and the observed Ammonia and Nitrate levels in pond 2 and 3 correctly prove this assumption.
Further to these compounds, the pH observed during the entire study was above eight throughout the system, which were favourable for organic matter removal and nitrification and de-nitrification.

![Figure 6 Nitrate variation](image)

### 4 CONCLUSIONS

Stabilization ponds are more economical and use natural processes to treat liquid waste. In this study, the capability of a series of stabilization ponds in treating landfill leachate was investigated. The preliminary results of this study shows that the stabilization ponds can make a considerable reduction in COD, BOD$_5$ and ammonium nitrogen within a twenty seven to forty one day retention cycle. The observed overall treatment efficiencies during the study were 81% to 90% for BOD$_5$, 90% to 94% for COD and 63% to 78% for Ammonium Nitrogen.

### 5 REFERENCES


Standard Methods for Water and Wastewater Analysis (1995); American Water Works Association