

Development and Performance Evaluation of the Leachate Treatment System at Gohagoda Municipal Solid Waste Disposal Site

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Abstract: A private company with technical support of University of Peradeniya has undertaken the task of rehabilitating the Gohagoda dumpsite. Not all of the leachate collection system (*LTS*) is completed yet and runoff water too gets mixed with the leachate on one side of the dumpsite. The *LTS* consisting of leachate collection tanks, a leachate treatment bioreactor(*LTB*) followed by an algae pond(*AP*), a floating wetland(*FW*), two sub-surface constructed wetlands(*SCWs*), two charcoal filter-beds(*CFBs*). *LTS_{outlet}* is being discharged into a natural stream (*NS*). In this research, the existing *LTS* was improved and the performances were evaluated. To determine the surface water quality of surrounding area and performance of the *LTS*, samples were obtained from 13 pre-defined points on weekly basis for two months, analysed for 14 quality parameters.

Average pH, dissolved oxygen (DO), chemical oxygen demand (COD) and biochemical oxygen demand (BOD) of inlet leachate to the *LTS* were 7.74 ± 0.35 , $0.46 \pm 0.5 \text{ mg/L}$, $24,552 \pm 2,612 \text{ mg/L}$ and $4,125 \pm 965 \text{ mg/L}$ respectively. *LTS_{outlet}* of pH (7.16 ± 0.23) was within the Central Environmental Authority water quality discharge standards. Average salinity, EC, DO, TDS, TSS, TS, VS, VSS, BOD, COD, PO_4^{3-} , NO_3^- and NH_4^+ of *LTS_{outlet}* were $0.84 \pm 0.25\%$, $1.71 \pm 0.52 \text{ mS}$, $0.63 \pm 0.6 \text{ mg/L}$, $852 \pm 261 \text{ mg/L}$, $1,058 \pm 199 \text{ mg/L}$, $1,303 \pm 772 \text{ mg/L}$, $406 \pm 220 \text{ mg/L}$, $609 \pm 111 \text{ mg/L}$, $217 \pm 177 \text{ mg/L}$, $780 \pm 1,049 \text{ mg/L}$, $2.33 \pm 3.29 \text{ mg/L}$, $0.97 \pm 0.27 \text{ mg/L}$, $4.38 \pm 1.59 \text{ mg/L}$ respectively. Average pH, TDS, BOD, PO_4^{3-} and NO_3^- and NH_4^+ of *NS_{outlet}* were 7.69 ± 0.39 , $1,457 \pm 930 \text{ mg/L}$, $1,382 \pm 784 \text{ mg/L}$, $5.04 \pm 6.36 \text{ mg/L}$, $1.58 \pm 1.26 \text{ mg/L}$, $4.3 \pm 2.02 \text{ mg/L}$ respectively. The average removal efficiency of BOD was 95%.

The lower values of the indicative parameters were when the *LTS* was stabilizing and attaining the required standards even without high growth in *SCWs*, until heavy rainfall occurred. Therefore, it is essential to install sub-surface leachate interceptor drains and those connected to the leachate treatment system. It will require a proper dumpsite cover system to reduce infiltration and thus promote runoff. It is imperative to monitor and evaluate frequently the system and improve it with an aerated biological indicator pond.

Keywords: Clay-polythene-clay biofilter liner, Dumpsite, Rehabilitation, Leachate treatment

1. Introduction

The final disposal of municipal solid waste (MSW) is yet a major problem and an immense burden on the environment [4,5,6] and the local authorities, particularly in the most urbanized areas such as in Colombo, Dehiwala-Mt Lavinia and Kandy in Sri Lanka [2]. All of the dumpsites are located in environmentally sensitive areas and near residential, commercial or institutional establishments [2]. For instance, the Gohagoda dumpsite in Kandy is bounded by the river Mahaweli to the east with very little rock exposures but only weathered soil profiles [7] which is the major fresh water supplier for down-stream communities for drinking, agricultural and

sanitary requirements. The Gohagoda dumpsite which has an aerial extent of 2.5ha [7] has been used since 1960s for open dumping of MSW collected within Kandy City limits and Harispaththuwa Pradeshiya Shabha (HPA). At present, about 150tonnes of MSW is disposed daily [1]. A project was developed by the EcoTech Lanka Limited with the collaboration of University of Peradeniya and Kandy Municipal Council (KMC) to rehabilitate the Gohogoda dumpsite and establish an integrated solid waste management system [1]. A Leachate management is one of major challenges in the rehabilitation efforts of the

dumpsite. The estimated leachate generation was 30,810m³/year [1].

Therefore, during the rehabilitation, an integrated leachate treatment system (*LTS*) was designed and established by combining landfill bioreactor technology with clay polythene clay composite liner system developed at University of Peradeniya which can reduce its strength to manageable level [3]. The *LTS* consisting of leachate collection tanks, a leachate treatment bioreactor (*LTB*) followed by an algae pond (*AP*), a floating wetland (*FW*), two sub-surface constructed wetlands (*SCWs*), two charcoal filter-beds(*CFBs*). Not all of the leachate collection system is completed yet and runoff water too gets mixed with the leachate on one side of the dumpsite. *LTS_{outlet}* is being discharged into a natural stream (*NS*). In this research, the existing *LTS* was improved and the performances were evaluated.

2. Materials and method

Improvements of the *LTS* which were done by the company and performance evaluation leachate treatment system were undertaken from 16th September 2014 to 25th October 2014.

2.1 Improvement of the leachate treatment system

The *LTB* was re-established with two leachate pumps, starter switches and level sensors. The blocked pipes with biofilms of *LTB* were cleaned and replaced with easy maintenance system. New pipelines to pump leachate to *AP* were laid. A gravel screen and a wetland around the *LTB* were constructed in order to collect and treat permeate.

After completing the construction of the *AP*, it was filled with fresh water to test the liner integrity for a month (20/08/2014 – 20/09/2014). The inflow and outflow pipe line installations were completed. An aeration system was installed and oxygenating rate tests were carried out before sending effluents of the sewage treatment system and *LTB*. DO concentration of the *AP* in 10 different locations during day and night time (26/09/2014 - 27/09/2014) were measured. Water hyacinth (*Eichhorniacrassipes*) plants were planted in the *FW*. The fencing around the *AP* and *SCWs* was done. Re-planting of cattail (*Typhalatifolia spp.*) plants in the *SCWs* was done and also a charcoal filter bed was converted to a wetland with water hyacinth (*Eichhorniacrassipes*) in order to improve efficiency of the treatment system.

In the absence of a proper leachate collecting network in the North East (NE) part of the dumpsite, a leachate collecting system comprising of two de-silting wells and a leachate storage tank was established and the pumping of the collected leachate commenced on 07th November 2014 with a leachate pump and floater switch and a delivery PVC pipe line in to the *LTB*. After connecting this leachate storage well to the *LTB*, most of the leachate flowing in to the natural stream was arrested, notably not the washouts during heavy rains as runoff.

2.2 Wastewater / water sampling locations for performance evaluation of the leachate treatment system

In order to obtain wastewater/ water samples in and around the site, sampling locations were selected as shown in Figure 1. Sampling was done on weekly basis from 14.10.2014 to 25.11.2014. SP1, SP2 and SP3 were sampling locations of the dumpsite, leachate collecting tank and leachate collection system of NE side respectively. SP4 and SP5 were the outlet of the *LTB* and the outlet of the sewage treatment system respectively. SP6 and SP7 were positioned in the in the *AP* while SP8 was placed in the *FW*. SP9 and SP10 were outlets of the *FW* and *SCWs* (*LTS_{outlet}*) respectively. Then SP11 was located on the natural stream which is flowing directly to the Mahaweli river. And SP12, SP13 were located on upstream and down steam of the river, respectively as shown in Figure 1.

3.3 Analytical parameters

Samples were obtained on three occasions before activating the leachate treatment system. The collected samples were tested for physical, chemical and biochemical parameters namely pH, electrical conductivity, salinity, DO, total dissolved solids (TDS), total solids (TS), volatile solids (VS), total suspended solids (TSS), volatile suspended solids (VSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), N(NH₄⁺), N(NO₃⁻), P(PO₄⁻³) by using standard methods. Laboratory analysis was done at the University of Peradeniya. Removal efficiency (RE) was calculated by using equation1 and data was analyzed descriptively.

$$RE (\%) = (I - O) / I \times 100 \quad (1)$$

Where, I - Inlet and O - Outlet concentration

3. Results and Discussion

3.1 Overview of the performances of leachate treatment system

3.1.1 Leachate collecting network

Leachate collecting network is consisting of sub surface drains, PVC pipe lines and collecting tanks. Leachate is treated inside the collecting system too. As reported by [1], biofilms have been formed with time on the inner surface of the leachate collecting

system of backfill and slotted pipes due to that leachate is treated. Also due to crust formation and pipes are being blocked, so a flushing system is needed to clear the collecting network otherwise there could be a negative impact on the system. Leachate collecting network should be further improved to collect all the leachate without contaminating soil, because leachate flow spreads on the ground, creating vast pollution effects on soil, surface water and groundwater.

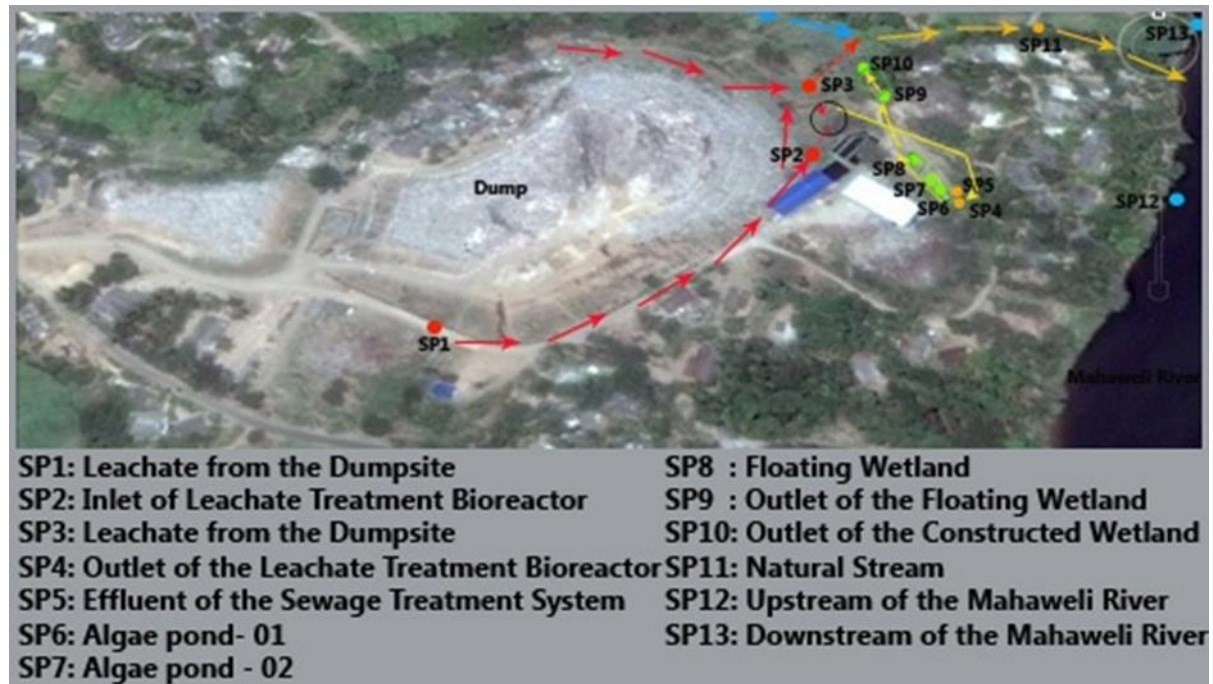


Figure 1: Sampling locations

3.1.2 Leachate treatment bioreactor

In the *LTB*, the pipes which are used for recirculation and pumping out of the system also suffer from the same fate of crust formation, thus flushing of the system is required as in the case of pipe network maintenance. Due to collection of runoff with heavy rainfall, the amount of leachate collected though the leachate collection system did increase far beyond the design capacity of the leachate treatment system. Therefore, the hydraulic retention time of the reactors drastically reduced. Consequently, the system did not function properly. This situation will continue, unless otherwise interceptor sub-surface drains are installed and connected to the leachate treatment system. After installation of interceptor subsurface leachate collection system, the dumpsite should be covered with bio-filter liner system immediately as proposed by Ecotech Lanka Ltd.

3.1.3 Algae pond and floating wetland

AP is full of water, up to 1.0 m in depth and algae lives with the uptake of nutrients of the leachate for their biological activities digesting the materials. But the nutrient content in the leachate is low for the growth of algae. Therefore, sewage treatment system effluent which is having a good carbon and prosperous sources was also directed to the *AP*.

DO is an important and critical factor for living aquatic organisms like algae. Therefore, with the supply of the required and optimum oxygen levels, the treatment effect can be enhanced in aerobic treatment systems. Figure 2 shows the DO concentration variation with time throughout on 27.09.2014 after fixing the aerator and before discharging the effluent to the *AP*. According to that DO concentration in day time was higher than night time that's because of respiration and photosynthesis of algae. Those two biological activities are occurring at day light and not in dark time.

Consequently, in early morning DO concentration is much lower due to respiration effect and microbial uptake during night. *FW* is consisting of water hyacinth plants which have also treatment effect on wastewater. These plants do uptake organic and inorganic materials from wastewater for their biological activities. As expected, all the parameters did decline when the effluent went through the *FW*. Highest treatment can be seen before flowering stage for better performance because after flowering, the growth is lesser and precipitates nutrients like phosphate, heavy metals etc. *AP* and *FW* needs higher DO concentration and sunlight for photosynthetic organisms. Due to overload of the reactors during rainy period, algae died and plant growth reduced due to high concentration of leachate. Treatment effect also did decrease due to less retention time. So *AP* and *FW* were diluted by adding water, therefore algae and plants are growing again, thus the system was improving.

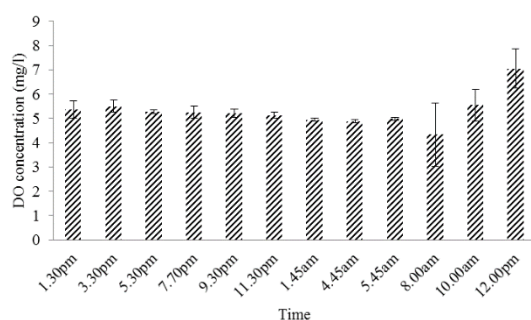


Figure 2: Do concentration variations of algae pond on 27.09.2014

3.1.4 Subsurface constructed wetlands

The effluent from the *FW* is then directed to the *SCWs*. Cattail plants are growing in the *SCWs* by up taking organic and inorganic compounds from the effluent of partially treated leachate and sewerage for their biological activities. There are also two charcoal filter beds that adsorb the organic and inorganic compounds of the effluent. Plants are not well grown yet, but there is an impact on leachate treatment. Cattail plants should be in the growth phase for better performance.

After plants grow to reproductive phase, plants should be pruned and some replaced. These plants need protection from animals too, thus fences are constructed surrounding the *SCWs*. *SCWs* should be followed by a bio-indicator pond. According to results, all the parameters have been declined after *SCWs* treatment.

3.2 Natural stream and river

At early stage of study period, the natural stream was directly contaminated with leachate and wash down to the River *Mahaweli*. After establishment of 2nd leachate collecting tank, direct contamination of leachate was arrested. With heavy rainfall interception, due to absence of dumpsite cover system, leachate was mixed with runoff water and therefore the quantity of leachate drastically increased and the treatment system got overloaded. Subsequently, during the rainy period, leachate was not directed through the leachate treatment system. Therefore, according to the study results, still the quality of natural stream water was poor and did not reduce to the required standards. Even though, the direct flow of leachate to natural stream is arrested, the quality of water may not be improved up to permissible level rapidly due to remaining deposits on the boundaries of the stream. Further, there is an abundant paddy land adjacent to the natural stream which was contaminated with landfill leachate for many years. So the runoff and washouts from this paddy land contaminate the stream water. This ecosystem will recover and rejuvenate slowly; otherwise intervention should be to expedite the recovery process. Although, effluent is treated to acceptable standards, it gets re-contaminated and it is an important issue for the stakeholders. According to the results, water quality of downstream was lower than upstream. This is certainly due to inflow of contaminated water from the natural stream.

3.3 Performance of the leachate treatment system

3.3.1. pH, salinity, conductivity, DO

The leachate quality and quantity generated from dumpsite are strongly affected by hydrological conditions and the conditions of the dumpsite. Recorded pH, salinity and EC values are higher in stabilized leachate. Leachate quality reduced with aging. pH, salinity and EC reduced with time during the study period, this may be due to interception of heavy rain during this period. With rainfall interception, dumpsite leachate gets diluted. Average pH, salinity, EC and DO concentration variation in sampling locations during the study period are shown in Figure 3. pH, salinity, EC declined when the effluent went through the system as shown in Figure 3 and with time as shown in Figure 4.

Leachate is normally in basic condition. Average pH of inlet of the LTB was 7.74 ± 0.35 during the study period, which indicates that the dumpsite is under methanogenic conditions. Average pH value of the outlet of the LTB was 7.78 ± 0.04 , thus indicating

that the LTB was also under anaerobic conditions. pH of the leachate decreased when it did flow through the treatment system. Highest reduction of pH did occur in the algae pond and the sub-surface constructed wetland. According to stipulated wastewater discharge standards by the Central Environmental Authority (CEA), pH value of the effluent should be in the range of 6.0-8.5. The average pH value of outlet of the leachate treatment system was 7.16 ± 0.23 , so it was under permissible limit. The high values of leachate conductivity reflect the large content of soluble inorganic. Although, EC of the system declined to low levels, but at the end of the study period, it was high because the system got overloaded. Permissible EC level according to CEA standards is $2,250 \mu\text{S}$. In the system outlet, the average EC was $1,715 \pm 516 \mu\text{S}$. The DO concentration of the dumpsite leachate is very low indicating that the dumpsite is under anaerobic conditions. DO concentration of the LTB outlet did fluctuate with time but it reduced in latter part of the study period, indicating the LTB is becomes the substrate for the acedogenic and methanogenic microorganisms reaching complete anaerobic conditions with time. The DO concentration of the algae pond was very low that varied between 0.25-0.92 mg/L. Less population of algae was due to higher intensity of rainfall during the study period with overcast sky conditions. Under those conditions, aeration system was used to provide adequate oxygen for microbial activity. However, algae are growing rapidly at present, thus providing oxygen for the microbes

3.3.2 Variation of solids

At the latter part of the study period, solid concentrations increased because of system failure due to heavy rains. Average solid content variations in sampling locations during the study period are shown in Figure 3. According to this study, average TDS and TSS of the inlet of LTB were $5,592 \pm 698.2$ mg/L and $7,453 \pm 2,640.7$ mg/L respectively. TDS comprises mainly of inorganic salts and dissolved organics. According to stipulated wastewater discharge standards by the CEA, maximum allowable limit of TDS concentration for discharge effluent is 2,100mg/L. The average TDS value of the discharge effluent of the leachate treatment system was 852 ± 261 mg/L. So it did not exceed the allowable limit. As can be seen, TSS reduced at each treatment step of the system and with time also. According to CEA standards maximum permissible TSS level is 50mg/L but the average of the system outlet was $1,057.8 \pm 199.4$ mg/L during the study period which is much higher.

3.3.3 Variation of chemical oxygen demand (COD)

BOD is an index of the oxygen demanding properties of biodegradable material in water. COD is a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. Recorded average BOD and COD values in sampling locations during the study period are given Figure 3. The BOD and COD values recorded for the leachate is very high. This may be due to the reason that with time the solid waste material gets degraded and the waste constituents percolate down along with rain water thus polluting groundwater nearby to MSW landfill site. BOD value varies according to age of landfills. Recorded average BOD and COD values of the leachate in this dumpsite were $3,919 \pm 576.56$ mg/L and $21,535 \pm 2,224.72$ mg/L respectively. BOD and COD reduced with aging of the dumpsite, but the dumpsite was still operational. BOD is an important parameter in water quality. When microbial activities are taking place, the demand of oxygen is increasing because of break-down of biodegradable materials.

According to the results, BOD of leachate reduced through the treatment system during the study period. Average BOD value of the system outlet was 216.7 ± 177.2 mg/L. The highest BOD reductions were observed from the LTB where anaerobic microorganisms are functioning without any oxygen. According to Central Environmental Authority (CEA) standards, the BOD value of the effluent of the leachate treatment should be 30 mg/L, so the BOD of the effluent should be further reduced before releasing to the natural stream. COD is also important parameter in water quality. When chemical reactions are occurring oxygen is used. As in Figure 3, COD did decrease when flowing through the treatment system. The accepted COD level is 250 mg/L according to CEA standards. Although the average is $868.86 \pm 1,028.4$ mg/L, in the last week of the study period, it did reach permissible levels in this system. According to Figure 3, highest reductions of COD were from LTB where anaerobic conditions and mineralizing taking place.

3.3.4 Variation of available phosphorous, nitrate nitrogen and ammonium nitrogen

Recorded average available phosphorous, nitrate nitrogen and ammonium nitrogen values during the study period are given in Figure 4. According to stipulated wastewater discharge standards by the CEA, the maximum allowable limit of available phosphorous and ammonium nitrogen of the discharge effluent are 5mg/L and 50mg/L

respectively. Average available phosphorous and ammonium nitrogen concentration of discharge effluent of the leachate treatment system were $2.33 \pm 3.29 \text{ mg/L}$ and $4.38 \pm 1.59 \text{ mg/L}$ respectively. Phosphorus and nitrate content of leachate fluctuated with time and nitrate increased whenever there was high rainfall. Ammonium nitrogen was higher due to

anaerobic digestion of organic nitrogen and generation of ammonium which was not converted into nitrite and nitrate because of lesser oxygen concentration in leachate. Nitrate and phosphate were decreasing via the system components.

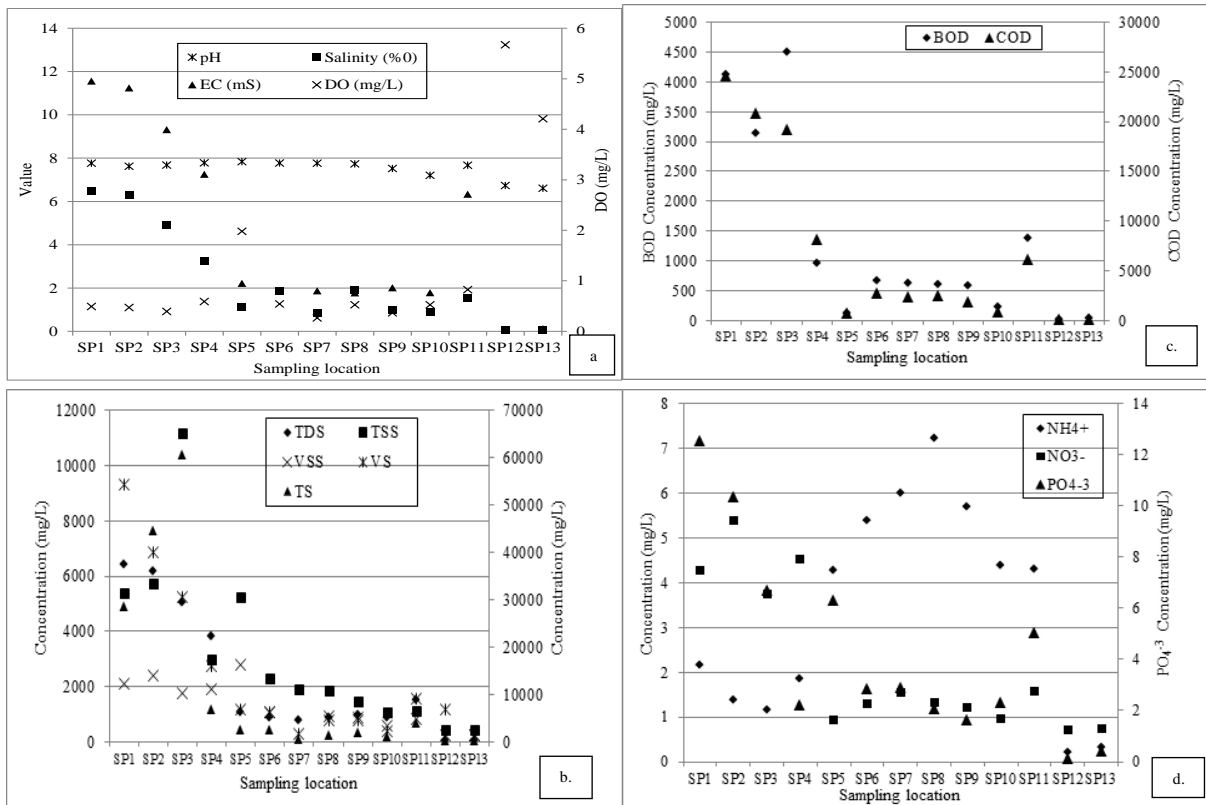
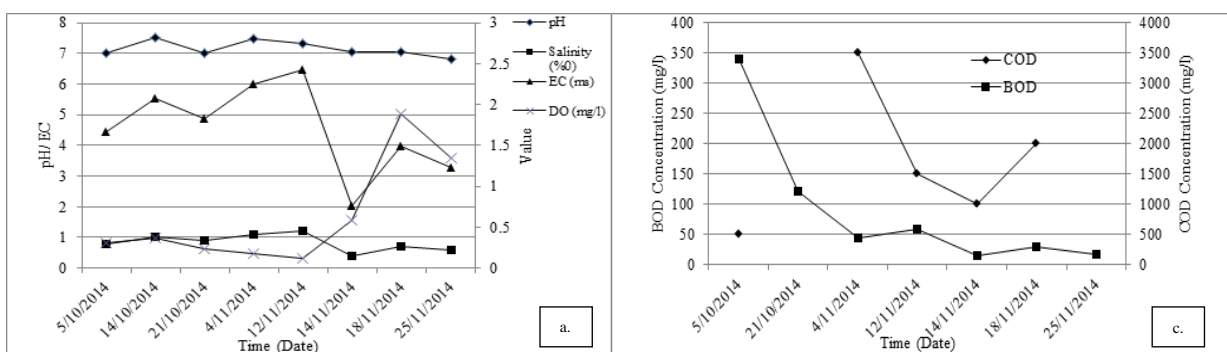


Figure 2: Recorded average values of quality parameters of the sampling points during the study period (a.) pH, salinity, EC and DO; (b.) Solid content; (c.) BOD and COD (d.) NH_4^+ , NO_3^- , PO_4^{3-}



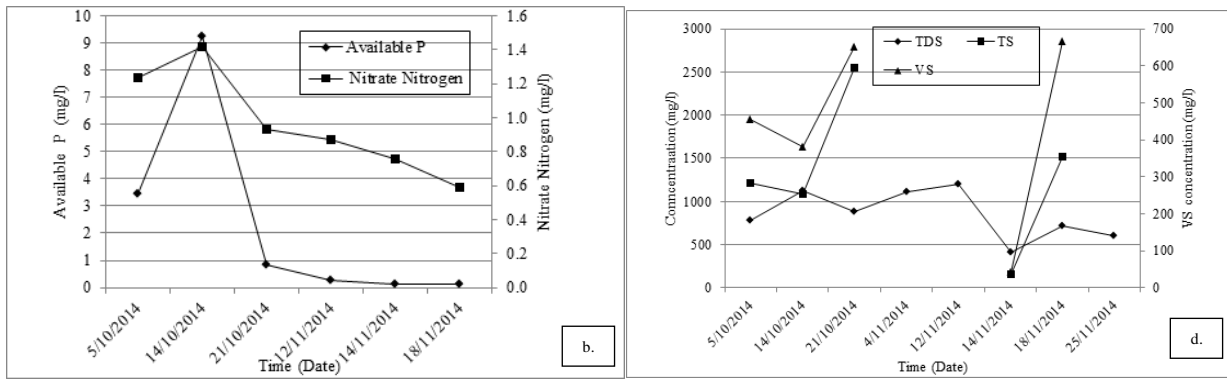


Figure 3: Quality parameters of the leachate treatment outlet variations with time (a.) pH, salinity, EC and DO; (b.) Solid content; (c.) BOD and COD (d.) NO_3^- , PO_4^{3-}

3.4 Removal efficiency (%) of the leachate treatment system

Table 1 shows components and total removal efficiency (RE) of the LTS. According to the Table 1, highest salinity RE is from AP. High solid RE is from the LTB and the AP. Highest RE of COD and BOD is from AP and SCWs respectively. Highest RE of PO_4^{3-} is from LTB, NO_3^- is from AP, NH_4^+ is from

SCWs. During the study period, RE of salinity, EC, TS, TDS of the leachate treatment system was $72.18 \pm 17.73\%$, $72.03 \pm 22.63\%$, $93.13 \pm 7.39\%$, $75.82 \pm 16.65\%$ respectively which is indicating higher performances of the system even at the initial stabilization period. The removal efficiency will be increased with time through the stabilization of the system and interventions.

Table 1: Removal efficiency of the leachate treatment system

Parameter	Average Removal Efficiency %				
	LTB	AP	FW	CW & CFB	Total
Salinity	53.16 \pm 29.61	75.29 \pm 0.78	8.33 \pm 11.78	24 \pm 32.52	72.18 \pm 17.73
EC	54.47 \pm 37.62	72.24 \pm 0.81	10.66 \pm 8.44	24.76 \pm 37.74	72.03 \pm 22.63
TDS	55.87 \pm 36.51	74.33 \pm 0.87	12.32 \pm 10.55	26.61 \pm 36.84	75.82 \pm 16.65
TS	79.31 \pm 19.7	71.19 \pm 25.73	33.57 \pm 11.28	54.82 \pm 38.28	93.13 \pm 7.39
VS	53.39 \pm 2.74	55.26 \pm 18.3	68.86 \pm 31.8	34.82 \pm 0.66	87.09 \pm 9.23
TSS	68.23 \pm 17.02	61.58 \pm 22.67	40.74 \pm 11.88	34.5 \pm 55.99	90.15 \pm 11.8
VSS	53.2 \pm 0.34	47.94 \pm 9.13	19.77	26.76 \pm 21.78	70.34 \pm 21.08
BOD	62.2 \pm 36.49	27.01 \pm 21.13	70.79 \pm 36.02	77.48 \pm 21 \pm 82	94.77 \pm 2.87
COD	58.5 \pm 5.13	66.04 \pm 2.89	34.37	42.58	86.92 \pm 7.63
PO_4^{3-}	55.79 \pm 26.96	10.81 \pm 7.03	27.43 \pm 17.59	39.53 \pm 38.96	57.23 \pm 11.45
NO_3^-	41.56 \pm 12.64	69.86 \pm 8.73	17.23 \pm 12.9	31.85 \pm 32.28	74.16 \pm 9.35
NH_4^+	-101.12 \pm 30.3	-231.24 \pm 41.44	21.26 \pm 0.98	45.76 \pm 36.15	-218.39 \pm 114.7

4. Conclusions and Recommendations

The dumpsite generates high strength leachate and the strength may be reducing with time. pH is an important indicative parameter and it is within the CEA discharge water quality standards. BOD, COD, EC, TDS, phosphate and ammonium have reached

CEA discharge water quality standards. Salinity values were low. The system efficiency seems to improve with time and the combined system will be able to comply with the CEA standards, on condition that biological systems are maintained and have adequate growths of algae and plants.

However, VSS far exceeded CEA standard because of high microbial activities in the algae pond and inadequate removal in the constructed wetland. Nevertheless, the system was stabilizing even without much growth in sub-surface constructed wetland and it was attaining the required standards, until heavy rainfall occurred. The system cannot cope with total rainfall going through it, thus drastic reduction of retention time to treat the effluent to the required standards. This situation will continue, unless otherwise interceptor sub-surface drains installed and connected to the leachate treatment system. The dumpsite will require a proper cover system to reduce infiltration and thus promote runoff. It is advisable to construct a biological indicator pond with adequate aeration, so as to convert ammonia to nitrite and nitrate. It is imperative to continue the monitoring and evaluation of the process.

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