ASSESSMENT OF SUB-LEACHATE POLLUTION INDEX (SUB – LPI_{hm}) TO DETERMINE THE HEAVY METAL POLLUTION POTENTIAL OF LANDFILL LEACHATE AT THIRUPPERUMTHURAI LANDFILL SITE, BATTICALOA

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ABSTRACT: Solid waste management may be defined as the discipline associated with controlling the generation, storage, collection, transfer and transport, processing and disposal of solid waste in a manner that is accordance with the best principles of health, economics, engineering, conservation, aesthetics and other environmental consideration. Solid waste management is a major challenge in urban areas throughout the world. Solid wastes are mainly disposed to landfill because landfill is the simplest, cheapest and most cost-effective method of disposing of waste. Leachates from landfill site cause environmental degradation and health hazards due to resultant ground water pollution. A technique to quantify the leachate pollution potential of solid waste landfills on a comparative scale is the use of index known as the leachate pollution index (LPI). The sub-LPI_{hm} is a quantitative tool by which the leachate pollution potential of heavy metal of the landfill can be reported uniformly. The sub-leachate pollution index for heavy metal provides a convenient means of summarizing complex heavy metal pollution data and facilitates its communication to decision makers and the general public. This study was attempted to assess sub-LPI_{hm} of Thirupperumthurai landfill site which is located in Batticaloa district. Leachate samples were collected during the period of September 2015 to January 2016. Samples were analyzed to determine the concentration of heavy metals such as Lead, Zinc, Nickel, Chromium and Arsenic. The sub-LPI_{hm} was calculated by using Delphi technique. The sub-LPI_{hm} values of each points (A, B and C) were 1.4705, 1.4974 and 1.4957 respectively. The overall sub-LPI_{hm} value of Thirupperumthurai landfill site was 1.4997. The results of this study will be used in developing site specific remediation technologies in landfill leachate treatment.

Keywords: Delphi technique, Landfill, Leachate pollution index, Thirupperumthurai.

21. INTRODUCTION

Solid waste management has been a major problem faced by the Batticaloa Municipality like other Municipalities in Sri Lanka. Rapid population growth and development activities lead toproduce significant amount of garbage in urban areas. It has to be noted that generation of garbage is increasing rapidly year by year. Landfilling which is the controlled disposal of waste on the land, is well suited to developing countries as a means of managing the disposal of wastes because of the flexibility and relative simplicity of the technology. Landfilling controls the exposure of the environment and humans to the detrimental effects of solid wastes placed on the land. Landfill is the preferred method of waste disposal in Sri Lanka and many other parts of the world (Harshani*et al.,* 2015). Landfill leachate is the liquid produced by natural humidity and water present in the residue of organic matter and the result of the biological degradation of organic matter. Due to numerous biochemical reactions occurring within the waste body these landfills produce biogas and leachates, which contribute to the pollution of air, water and soil. Landfills are considered as one of the major threats to groundwater (Fatta*et al.,* 1999). Municipal landfill leachate is highly concentrated complex effluents which contain dissolved organic matters, inorganic compounds and heavy metals (Ogundiran and Afolabi, 2008).

The overall pollution potential of landfill leachate can be calculated in terms of Leachate pollution index (LPI). The LPI represents the level of leachate contamination potential of a given landfill (Kumar and Alappat, 2003). LPI is an increasing scale index, where a higher value indicates poor environmental condition based on the Delphi technique; which is an opinion research technique to extract information from a group of panel lists. The formulation process involved selecting variables, deriving weights for the selected pollutant variables, formulating their sub-indices curves and finally aggregating the pollutant variables to arrive the LPI. The main objective of this study was to assess the sub-leachate pollution index for heavy metals at Thirupperumthurai landfill site to ensure that the site is environmentally sound and sustainable.

2. METHODOLOGY

2.1 Description of study area

This study was conducted atThirupperumthurai landfill site which is located in Manmunai North DS Division, Batticaloa District, Eastern province of Sri Lanka. According to Manmunai North Divisional Secretariat statistics more than 89,758 people are living in Batticaloa Municipal Council area. The climatic condition of the study area comprises a wet season during North-East monsoonal period (September to January) characterized by high mean precipitation (1250 ± 230 mm). The mean temperatures ranges from 21.5 ± 7.6 ºC in the wet season (Meteorological department, Batticaloa, 2012).

2.2 Leachate sampling

Figure 1: The satellite image of the location of sampling points

Leachate samples were collected from three leachates sampling points (A, B and C) at Thirupperumthurai landfill site. All the leachate generated finds its paths into the surrounding environment. Leachate samples were collected from the base of solid waste heaps where the leachate was drained out by gravity. Leachate samples were collected from September

2015 to January 2016. Various leachate pollutant variables (Heavy metals) such as Zn, Pb, Ni, Cr and As were analyzed to determine sub-leachate pollution index (Sub-LPI_{hm}) of leachate discharge from Thirupperumthurai landfill site.

Table 1 shows the GPS coordinates of the selected sampling points.

Table 1: GPS coordinates of the selected sampling points

Points	Northing	Easting
A	7^{o} 722381’	81^{o} 673571’
B	7^{o} 722311’	81^{o} 674172’
C	7^{o} 723260’	81^{o} 674087’

2.3 Sample Analysis

Atomic Absorption Spectroscopy (GBC 932 plus model) was used to analyze the samples to determine the values of heavy metals.

2.4 Data Analysis

Data was analyzed by using the Delphi technique to determine the sub-index for heavy metals (sub-LPI_{hm}).

2.5 Calculating LPI

a. *Variable selection*

Five leachate’s heavy metals were selected for inclusion in sub-LPI.

b. Variable weights

The weights for these five heavy metals were calculated based on the significance levels of the individual pollutants. The weight factor indicates the importance of each pollutant variable to the overall leachate pollution. Table 2shows the weight factor of the selected heavy metals.

Table 2: The weight factor of the selected heavy metals

Heavy metals	Weight factor
Zn	0.056
Pb	0.063
Ni	0.052
Cr	0.064

As	0.061

Source: (Kumar and Alappat, 2003)

c. Variable curves

The averaged sub index curves for each heavy metals were drawn to establish a relation between the leachate pollution and strength or concentration of the heavy metals. The sub-index curves for all the pollutant variables were reported by Kumar and Alappat (2003).The averaged sub index curves are the curves that represent the relation between leachate pollution and the strength or concentration of the heavy metals.

d. Variable aggregation

The weighted sum linear aggregation function was used to sum up the behaviour of all the leachate pollutant variables. The various possible aggregation functions were evaluated by Kumar and Alappat (2003), to select the best possible aggregation function. The Leachate Pollution Index can be calculated using the equation.

3. RESULTS AND DISCUSSION

3.1 Variation of heavy metals concentration in landfill leachate

a. Variation of Zinc (Zn) concentration

The variation of the Zn concentration during the period of September 2015 to January 2016 is shown in Figure 2. According to the Figure 2, Zinc concentration ranged from 0.23 to 0.68 ppm.

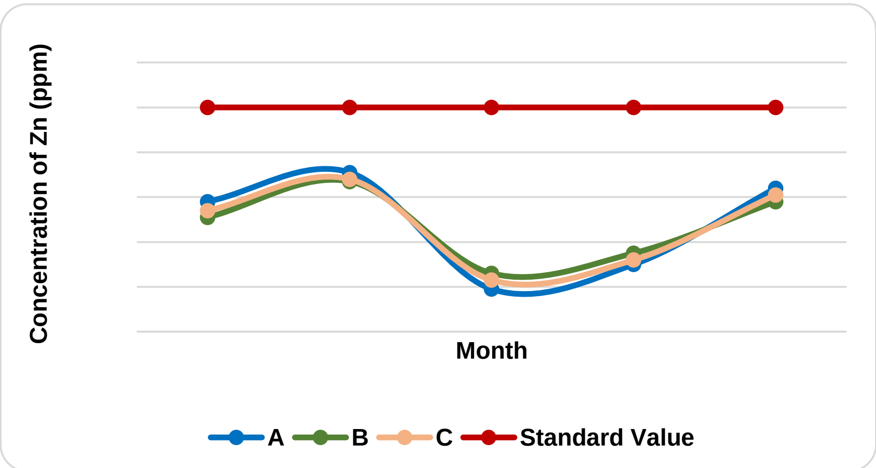

Figure 2: Variation of Zn concentration

The maximum contamination level of Zn allowed for the drinking water is less than 1 ppm (WHO, 2006).According to this finding, all sampling points show the lower Zn concentration than the permissible limits. In October, sampling points show the higher Zn concentration than other months. The Zn contamination may be as the result of wastes containing Zn metals which were dumped in the landfill site, decomposed and found its way into the water table (Igbinosa and Okoh, 2009). These activities can increase Zn levels in the environment.

b. Variation of Lead (Pb) concentration

The variation of the Pb concentration during the period of September, 2015 to January, 2016 is shown in Figure 3. It shows the concentration of Pb in the landfill leachate ranged from 0.001 – 0.14 ppm.

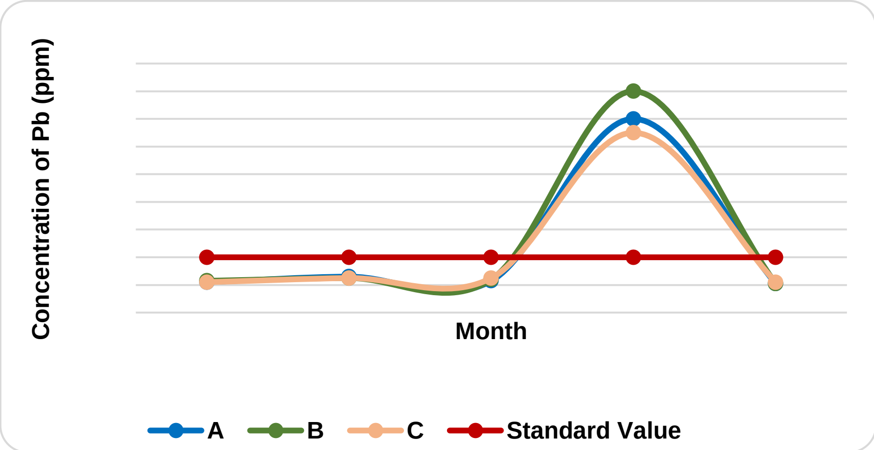

Figure 3: Variation of Pb concentration

Based on this study, In December 2015, all 3 sampling points show the higher concentration of Pb than permissible limits. Lead and lead alloys are commonly found in pipes, storage batteries and cable covers.The presence of Pb in the different leachate sampling points indicated that the disposal of Pb batteries, chemicals from photograph processing andPb based paints. (Moturi*et al.*, 2004).

c. Variation of Nickel (Ni) concentration

The variation of the Ni concentration during the period of September, 2015 to January, 2016 is shown in Figure 4. According to Figure 4, concentration of Ni ranged from 0.020 to 0.141 ppm.

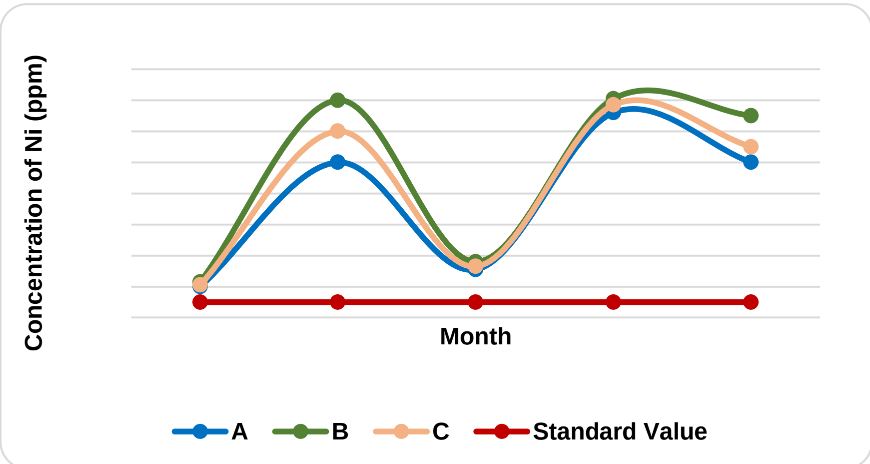

Figure 4: Variation of Ni concentration

According to Figure 4, all sampling points show the higherNi concentration than the permissible limits. The values of Ni is excess in landfill leachate because of the disposal of batteries in the siteand the majority (about 80%) of Ni is used in alloys because it imparts such properties as corrosion resistance, heat resistance, hardness and strength (Reinhart, 1993).

d. Variation of Chromium (Cr) concentration

The variation ofCr concentration during the period of September, 2015 to January, 2016 is shown in Figure 5. It shows that the Cr ranged from 0.051 to 0.214 ppm during the study period.

Cr in the samples indicates the disposal of considerable amounts of steel in the site (Reinhart, 1993). Sampling points in October 2015 and December 2015 show the higherCr concentration than the permissible limits.Chromium is come to landfill in different ways such as Cr compounds are used widely in applications that include pigment for textile dyes, paints, inks, and plastics, corrosion inhibitors, wood preservatives (OSHA, 2006).

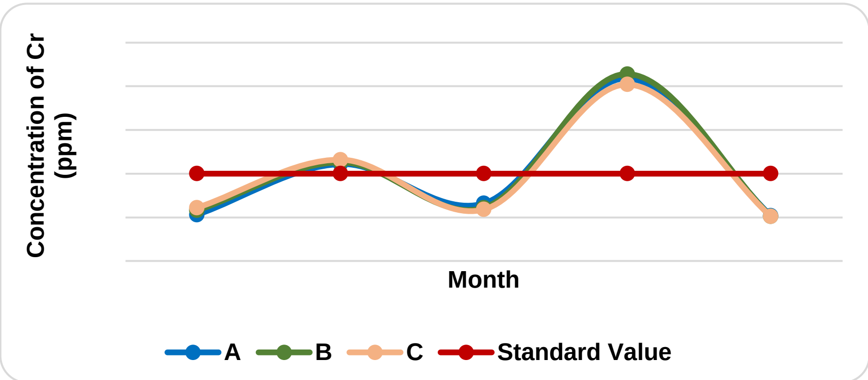

Figure 5: Variation of Cr concentration

e. Variation of Arsenic (As) concentration

The variation of the As concentration during the period of September, 2015 to January, 2016 is shown in Figure 6.

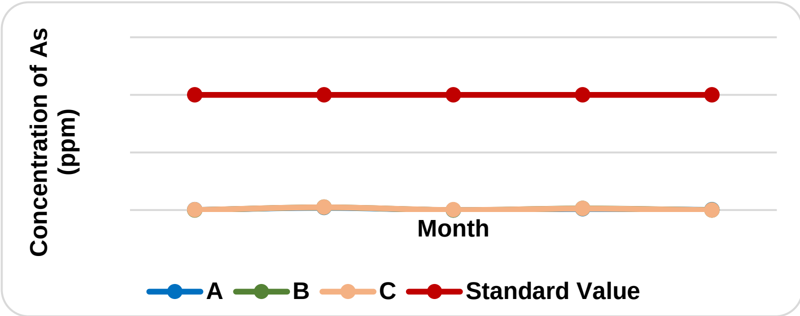

Figure 6: Variation of As concentration

In Thirupperumthurai landfill site, As concentration was ranged from 0.00 to 0.00024 ppm in September, 2015 to January, 2016. The concentration of As was low in all sampling points. This is shown in Figure 6. Arsenic compounds are used commercially and industrially in the manufacture of a variety of products such as transistors, lasers, semiconductors, glass production, pigments, textiles, paper, metal adhesives, ceramics, wood preservatives, explosives and pesticides. Therefore, the samples indicated that there is no pollution threatening. Arsenic is introduced into water through the dissolution of rocks, minerals and ores,from industrial effluents including mining wastes, atmospheric deposition and fertilizers(Hindmarsh and McCurdy, 1986).

f. Average concentration of heavy metals

Figure 7 shows the average concentration of five heavy metals from September 2015 to January 2016.The average concentration of Zn was higher in every month than the other heavy metals because of higher amount of Zn batteries, fluorescent lamps and Zn containing solid waste materials collected from different area and deposed in landfill site.

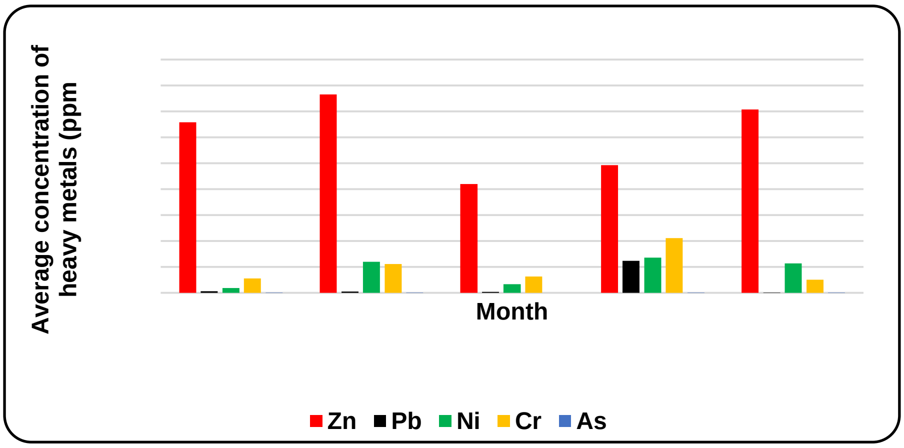

Figure 7: Variation of heavy metals concentration

3.2 Assessment of sub-LPI for heavy metal (sub-LPI_{hm})

According to the Figure 8, the sub-LPI_{hm} values were varied from point to point at Thirupperumthurai landfill site, which is from 1.4705 to 1.4957. The highest value was observed at point C and lower value was observed at point A. The variation of values may be due to the differences in waste composition, moisture content, site hydrology, topography of landfill site, waste compaction, interaction of leachate with the environment, etc.

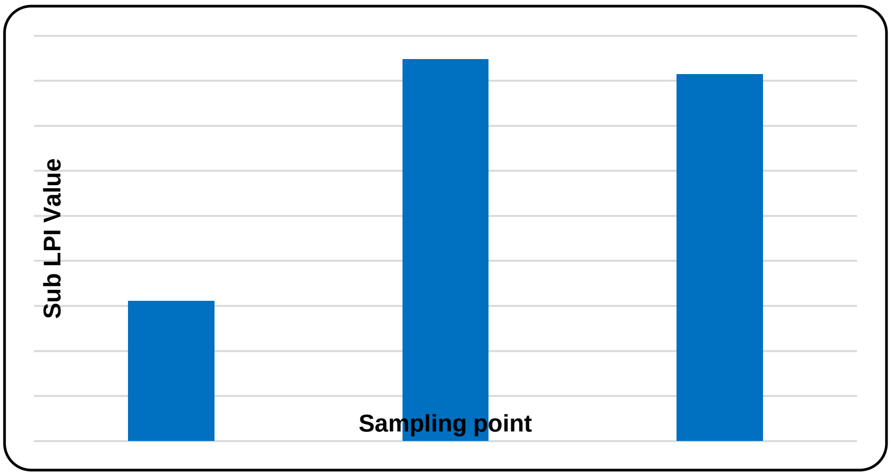

Figure 8: The sub-LPI_{hm} values atthree sampling points

Based on the table 3, the standard value of sub-LPI_{hm} for landfill leachate reported by Kjeldsen*et al.* (2002), heavy metals concentration at Thirupperumthurai landfill site was lower. Figure 9 shows the sub-LPI_{hm} values during the period of September, 2015 to January, 2016. The sub-LPI_{hm} values were ranged from 1.4902 to 1.5084 during the study period. Higher sub-LPI_{hm} value was observed in September and lower value was observed in December.

Table 3: Sub-LPI_{hm} for leachate from each Sampling points

Sampling site	Sub-LPI_{hm}
A	1.4705
B	1.4974
C	1.4957
Landfill leachate(Standard value)	5-62.9

Falling rain on the top of the landfill is the main contributor to the generation of leachate (Jhnamnani and Singh, 2009). Excess rainwater percolates through the waste layers in a landfill. A combination of physical, chemical and microbial processes in the waste transfers the pollutants from the waste material into the percolating water (Christensen andKjeldsen, 1989). All the dissolved heavy metals in the leachate were removed from sampling points as the results of higher rainfall in December, 2015. Higher rainfall lead to lower concentration of heavy metals at all sampling points in December, 2015.Therefore Lower amount of rainfall leads to higher concentration of sub-LPI_{hm} value in September, 2015.The results of the study showed clearly the nature of landfill leachate from different points and months due to the differences in waste composition, moisture content, climatic conditions, etc.

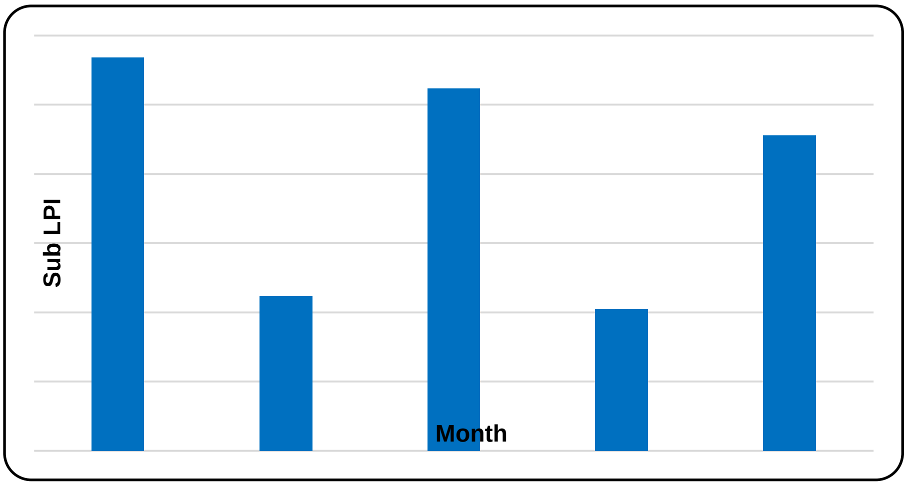

Figure 9: The sub-LPI_{hm} values in various month

4. CONCLUSION

The sub-LPI_{hm} provides the information about the pollution potential of heavy metals of leachate of Thirupperumthurai landfill site at a particular period. The sub-LPI_{hm} values of the points were A (1.4705), B (1.4974), C (1.4957). The overall sub-LPI_{hm} value of Thirupperumthurai landfill site was 1.4878. Parameters such as rainfall, temperature, pH and distance from landfill site may influence in the values of sub-LPI_{hm}. There was negative correlation between rainfall and sub-LPI_{hm}. Higher sub-LPI_{hm} values were obtained in September, 2015 because of lower rainfall and lower sub-LPI_{hm} values were obtained in December, 2015 due to higher rainfall. According to this result, Thirupperumthurai landfill site has low Sub-LPI_{hm}value. Therefore, this landfill site has low environmental pollution potential. However,further study should be needed to assess the sub-LPI for organic and inorganic to determine the total LPI value.

5. REFERENCES

Christensen, T. H. and Kjeldsen, P. (1989). Basic biochemical processes in landfills. IN: Sanitary Landfilling: Process, Technology, and Environmental Impact. Academic Press, New York. p 29-49, 9 fig, 3 tab, 34 ref.

Fatta, D., Papadopoulos, A. and Loizidou, M. (1999). A study on the landfill leachate and its impact on the groundwater quality of the greater area. Environmental Geochemistry and Health, 21(2), 175-190.

Harshani, H. M. D., Nawagamuwa, U. P. and Senanayake, A. (2015). Evaluation of cover soil properties of solid waste dumpsites in Colombo District, Sri Lanka. Journal of the National Science Foundation of Sri Lanka, 43(2).

Hindmarsh, J. T. and McCurdy, R. F. (1986). Clinical and environmental aspects of arsenic toxicity. CRC Critical Reviews in Clinical Laboratory Sciences, 23:315–347.

Igbinosa, E. O. and Okoh, A. I. (2009). Impact of discharge wastewater effluents on the physicochemical qualities of a receiving watershed in a typical rural community. International Journal of Environmental Science & Technology, 6(2), 175-182.

Jhnamnani, B. and Singh, S. K. (2009). Groundwater contamination due to Bhalaswa landfill site in New Delhi. International Journal of Environmental Science and Engineering, 1(3), 121-125.

Kjeldsen, P., M. A. Barlaz, A. P. Rooker, A. Baun, A. Ledin and T. H. Christensen (2002). Present and Long-Term Composition of MSW Landfill Leachate: A Review. Critical Reviews in Environmental Science and Technology. 32(4): 297-336.

Kumar, D. and Alappat, B. J. (2003). A technique to quantify landfill leachate pollution, In: Proceedings of the Ninth International Landfill Symposium, Cagliari, Italy, Paper no.400.

Meteorological department, Batticaloa. (2012). Annual Climatological Report, Sri Lanka.P:76-79.

Moturi, M. C. Z., Rawat, M. and Subramanian, V. (2004). Distribution and fractionation of heavy metals in solid waste from selected sites in the industrial belt of Delhi, Environmental Monitoring and Assessment, vol. 95, pp. 183-199.

Occupational Safety and Health Administration, (2006). Occupational exposure to hexavalent chromium. Final rule. Federal register, 71(39), 10099.

Ogundiran, O. O. and Afolabi, T. A. (2008). Assessment of the physicochemical parameters and heavy metal toxicity of leachate from municipal solid waste open dumpsite. International Journal of Environmental Science and Technology, Vol. 5(2), pp. 243-250.

Reinhart, D. R. (1993). A review of recent studies on the sources of hazardous compounds emitted from solid waste landfills: a US experience. Waste management and research, 11(3), 257-268.

World Health Organization, (2006). A compendium of drinking water qualityStandards in the Eastern Mediterranean Region.