Leachate Characterization and Surface Groundwater Pollution at Municipal Solid Waste Landfill of Gohagoda, Sri Lanka

Nirmala Dharmarathne, Jagath Gunatilake

* Department of Geology, University of Peradeniya, Sri Lanka

Abstract- As a developing country, protecting groundwater resources is extremely essential in Sri Lanka. Landfills are one of the main sources of water pollution. The filling of the Gohagoda disposal yard, takes place at a distance about 50m from Gohagoda water intake plant. In addition, there is several boreholes located close proximity of the landfill, which used for drinking and domestic purposes. A study of composition of landfill leachate and groundwater pollution conducted at Gohagoda landfill site, which is located at north-west of Kandy city. The Leachate sampled at nine different locations of the landfill. Groundwater samples were collected using auguring at five locations. In addition, to detect the seasonal variation of the water quality in the nearby water wells, four water samples obtained during both wet and dry seasons. Leachate and groundwater were physically and chemically characterized. Parameters measured were pH, Sulphate, Nitrate, Nitrites, Heavy metals (Pb, Zn, Ni, Cr, CO, Fe, Mn, Cu). The results showed that leachate of the landfill were most likely methanogenic phase, based on the alkaline pH value recorded. These results also showed that significant number of borehole were contaminated where concentration of physio-chemical parameters are above the W.H.O standards required for drinking water. Therefore, this landfill is a threat for the environment, and government should do sanitary landfill to prevent further contamination of groundwater as well as soil.

Index Terms- Leachate, Ground water, contamination

I. Introduction

Sri Lanka as a developing country with limited land space and rapidly increasing population rate, possible subsurface environmental pollution problem resulting from liquid and solid waste disposal is to be considered with high priority. The leachate produced by waste disposal sites contains a large amount of toxic substances, which are likely to contaminate the groundwater. It may cause adverse effects on public health if the concentrations present in water increased beyond the WHO standards. Leachate is streaming down to the river through the paddy fields located bellow the disposal site. There is a bad smell around the site produced from waste. Solid wastes consist of the highly heterogeneous mass of discarded materials from the urban community as well as the more homogeneous accumulation of agricultural, industrial and mining wastes. Several disposal methods are available and more ones that are prominent are open dumping, composting, incineration, and sanitary land filling etc. However, lack of land for landfill and technologies for other treatment methods, open dump is resorted to in Sri Lanka. Nevertheless, it creates many environmental as well as heath problems.

The primary mechanism by which landfill contamination to groundwater is through generation of leachate and its infiltration bellow the water table. When Leachate from landfill mixes with groundwater, its forms a plume that spreads in the direction of the flowing groundwater. There are several forms of landfill emissions as gaseous emissions of volatile organic compounds, airborne particulate matter and landfill leachate (Slack et al., 2005). Among them, landfill leachate generation is a serious environmental problem associated with open dumpsites since landfill leachate is highly contaminated with different types of pollutants. The composition of landfill leachate varies from time to time and site to site due to the differences in waste composition, amount of precipitation, moisture content, climatic changes, site hydrology, waste compaction, interaction of leachate with the environment etc. (Kulikowska and Klimiuk, 2008; Umar et al., 2010)

Leachate contains large amount of organic matter (biodegradable and non-biodegradable), inorganic pollutants, heavy metals etc (Jaskelevicius and Lynikiene, 2009). The sources of pollutants are industrial products such as pesticides, paints, batteries, metals dumped. Pollutants in municipal landfill leachate can be classified in to four categories as (Alkassasbeh *et al.*, 2009; Asadi et al., 2008);Dissolved organic matter, Inorganic compounds, Heavy metals Xenobiotic organic substances.

Most of the lakes and rivers in the world are heavily polluted today and there are limited lands available for crude solid waste dumping. The increasing generation and accumulation of wastes produce serious environmental, economic, and social problems in both developed and developing countries. However, there is lesser likelihood to contaminate groundwater from solid wastes, which are dumped on open lands. The solid wastes comes from domestic households, institutions, industries etc. thus major elements, trace elements, heavy metals and other chemical substances could get concentrated in these sites. Due to leaching of those substances, groundwater can be contaminated up to un-acceptable extents. Landfills are sources of pollution of groundwater and soil due to the production of leachate and its migration through refuse. Leachate consists of high concentrations of physico chemical substances, which can pollute groundwater and soil. Water is one of the essential material required to sustain life and has long been suspected of being the sources of many of the illnesses of man. It was not until a little over hundred years ago that definite proof of disease transmission through water was established.

In the present study the impact of leachate percolation on groundwater quality was estimated from an unlined landfill site at Gohagoda, Sri Lanka. Various physico-chemical parameters including heavy metals and nutrients were analyzed in leachate and in groundwater samples to understand the possible link of groundwater contamination. The effect of distance of landfill from groundwater sources were also studied.

II. MATERIAL AND METHODS

Water quality analysis

To detect the effect caused by the waste disposal site on the groundwater system Groundwater samples collected from 5 boreholes to study possible impact of leachate percolation into groundwater of the area, the water samples were collected using Augur at 5 locations. Also in order to detect the water quality in the near by water wells, well water samples were obtained during both wet and dry season.

The powder pillow method for the spectrophotometer was used to measure the concentration of Nitrate, Nitrite, Sulphate, Phosphate of samples using the relevant wavelength. Heavy metal Cd, As, Zn, Cr, Fe, Mn, Co, Ni, Cu, Pb of the samples were measured using Atomic Absorption Spectrophotometer (AAS). AAS uses the flame atomic absorption method to calculation.

Leachate Analysis

Leachate sample were collected from several location (L1-L9). All suspended matter has been filtered using 42µm filter paper. Heavy metals, physical parameters, and nutrients in leachate samples were analyzed as mention in above

Table 1: Description of the sampling site

Sample no	Location	Depth to water table (m)
A1	Close to the landfill (25m), Downstream,450m elevation	1.8
A2	55m from the landfill, Downstream,447m elevation	1.35
A3	100m from the landfill 442.5m elevation, downstream	0.85
A4	150m from the landfill,440m elevation, Downstream	0.6
A5	Close to the river, Down stream,270m from the landfill	0.45

III. RESULTS AND DISCUSSION

Characteristic of Leachate

The pH of the Leachate depend not only the concentration of the acids that are present but also in the partial pressure of the CO_2 in the landfill gas that is in contact with the leachate. These results indicate that the leachates are at the later stage of methanogenic phase. This means that the age of landfill, rainfall and kind of waste are the most important factors which affect the composition of leachate. The average value of pH in leachate sample is about 7.9; it can be conclude that leachate is alkaline.

Electrical conductivity is used an indicator of the abundance of dissolved inorganic species or total concentration of ion. Electrical conductivity values show variety result between that Leachate. The highest value is obtained at the L9 with the value of 22.mS/cm where as the lowest value is obtained at the L1 with the value of 8.9mS/cm. However the EC value which are obtained for the leachate are not within the standard range of 0.7-4 $mScm^{-1}$ required for treated waste water discharge determined by local standards. When considering the average value of conductivity (13.36 mS/cm) is leachate samples were conclude that leachate was high amount of mineral salt.

Table 2: Insitu and Nutrients parameters of the leachate

Sample no	pH	Conductivity mS/cm)	NO_3^- In ppm	PO_4^{-3} In ppm	SO_4^{-2} In ppm
L1	7.83	8.9	6.3	26.3	2
L2	8.12	19	9.9	26.7	21
L3	7.9	10.9	26.9	19.6	17
L4	8.13	15.9	8.3	25.5	1
L5	8.2	13.8	10.6	31.8	3
L6	7.97	16.8	33.2	20.4	1.5
L7	7.84	9.8	6.9	18.1	2
L8	7.44	2.95	1.2	2.39	12
L9	8.41	22.2	2.1	24.4	180

The concentration of sulphate at the Leachate showed different values. The highest value is obtained at the L9 (Treatment plant) with the value of 180 mg/l. The treatment plant receives massive quantities of human excreta and other biological waste matter that can be the reason high value of sulphate concentration. In other Leachate samples sulphate concentration vary range between 1-17 mg/l. The concentration of nitrate for the leachate is range between 6.3-33.2 mg/l (Table 2). Average value of nitrate in leachate is about 14.5 mg/l. the nitrate of the leachate is chiefly from biological sources, human and animal excreta accounting for a large percentage of the total nitrogen load. The concentration of nitrogenous compound indicates the occurrence of extensive anaerobic bacterial activities. Nitrite oxidized in to the nitrate, which can be quickly assimilated by plant or otherwise reduced again to nitrite and NH_3. Therefore, the concentrations of nitrate for the leachate are higher than the nitrite. The concentration of phosphate of the Leachate showed different values. The highest value is obtained at the L5 with the value of 31.8 mg/l, where as the lowest value is obtained at the L8 with the value of phosphate is about 21.28mg/l.

The Concentration of heavy metals in leachate samples collected from the Gohagoda landfill site has been presented in table 3. The distribution of Fe at the Leachate shows different values. The highest Fe content of 9.2mg/l is measured at the L4 leachate sample; where as lowest content value of 1.18 mg/l is measured at the L5. The highest level of Fe in the L4 leachate samples indicates that Fe and steel scrap are also dumped in the landfill. The dark brown color of the leachate is mainly attributing to the oxidation of ferrous to ferric from and the formation of ferric hydroxide colloids and complexes with fulvic/humic substances (chu et al., 1994).

The distribution of Mn at the leachates shows value range between 0.27-2.91 mg/l and average value is about 0.35 mg/l. Zn concentration for nine leachate site is varying in between 0.10-9.9 mg/l. The presence of Zn in the leachate shows that the landfill receives waste from batteries and fluorescent lamps. Lowest concentration of heavy metal is heavy metal is recorded for Pb with the value range between 0.001-0.031mg/l. the presence of law concentration of Pb in the leachate sample indicate the there is no disposal of Pb batteries, chemicals for photograph processing, Pb based paints and pipe at the landfill site. The distribution of Cu at the leachates shows different value. The highest Cu concentration of 13mg/l is measured at L4 sample, where as lowest content value of 0.08mg/l is measured at the L1. The high concentration of Zn, Cu, Fe, and Mn was reported in L4. On the other hand most of these results are not within the standard acceptable level of treated wastewater discharge determined by international standards. Cr (0-0.31mg/l), Ni (0.07-0.76) and Co (0.01-0.23mg/l) were also present in the leachate samples. A variety of waste is dumped at Gohagoda landfill site which likely indicate the origin of Zn, Cr, Cu and Ni in leachate.

Table 3: Heavy metals concentrations in leachate samples

Sample no	Element Concentration (ppm) Zn	Cu	Fe	Mn	Cr	Ni	Co
LI	0.1	0.08	1.73	0.49	0.01	0.18	1.12
L2	0.5	0.31	17.8	0.57	0.01	0.76	0.23
L3	0.28	0.39	1.76	0.27	0.01	0.37	0.2
L4	9.9	13	92	2.7	0.01	0.42	0.16
L5	1.4	0.22	1.18	0.71	0.01	0.38	0.18

L6	0.77	0.39	5.19	2.91	0.01	0.52	0.01
L7	0.67	0.24	4.58	1.49	0	0.07	0.17
L8	1.39	0.27	8.9	0.67	0.06	0.07	0.16
L9	0.47	0.35	3.49	0.46	0.31	0.48	0.18

Groundwater Characteristics

pH values for all groundwater samples are shown in table 4. The highest value of 7.86 was measured in A5, where as the lowest value of 3.2 was measured in A1. The low pH value obtained for the underground water near the landfill is an indication of its effects on the water quality. The pH of the groundwater samples in A1, A2, and A3 borehole was about acidic, the range being 3.2-6.99. The results of the pH for all boreholes however are not agreement with the range value of 6.5-9.2 determined by international standards, which required for drinking water. The value of pH in the well water sample is ranged between 5.19-6.96, these result are not in agreement with the range value of 6.5-9.2 determined by international standards which is required for drinking water. In addition, there is clearly difference between pH value in dry and wet season. It can suggested that water samples carried out from well site sample collected during dry period show lower pH value that of the sample collected in wet period.

EC values show very different result between the boreholes. The highest value is in A1 (2.3 mS/cm) where as the lowest value recorded in A5 (0.1ms/cm). The high values of EC in A1,A2,A3,are higher than the range values of 0.45-1.0 mS/cm determined by local and international standards which is required for drinking water. These high conductivity values obtained for the underground water near the landfill is an indication of its effect on the water. Value of EC in the above three boreholes suggested that there is inorganic pollution compared to the other boreholes. Location near the landfill site so it may be due to the leaching of free ions from the waste. However the EC which are obtained for the well water samples are bellow or within the standards range. Also it can suggested that water samples carried out from well site during rainy period show higher EC value than the sample collected during dry period.

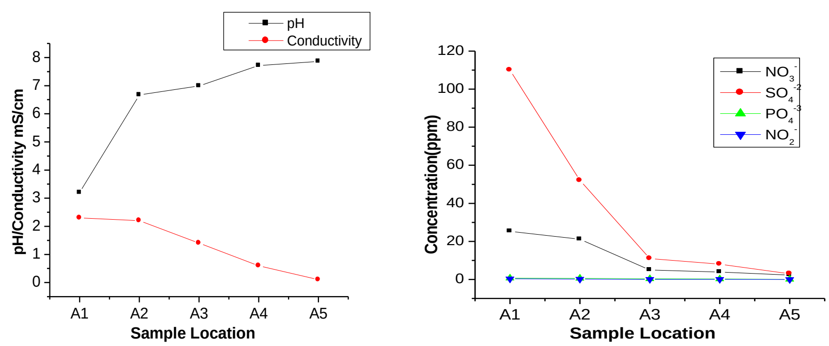

Figure 1 : Variation of pH, EC, nutrients values in ground water samples

Table 4. Insitu parameters and Nutrients parameters of the Ground water samples

Sample no	pH	Conductivity mS/cm	$N0_3^-$	SO_4^{-2}	PO_4^{-3}	NO_2^-
A1	3.2	2.3	25.3	110	0.72	0.296
A2	6.67	2.2	21.1	52	0.61	0.143
A3	6.99	1.4	5	11	0.33	0.1
A4	7.71	0.6	3.9	8	0.27	0.37
A5	7.86	0.1	2.3	3	0.07	0.023

The concentrations of sulphate between the boreholes are different. Concentration of sulphate in water sample are ranged from 3-110 mg/l in profile 1 and was significantly high at A1 (110 mg/l), where as the lowest concentration is measured in A5 with the value of 3mg/l. This high concentration of the sulphate value obtained for the underground water near the landfill is an indication of its effect on the water quality. The value of sulphate in well water sample is range between 4-49mg/l. Also there is clearly difference between the value of dry and wet season. It can be suggested that water sample carried out from well site sample collected during dry period show lower value than the sample collected during wet period. The concentration of sulphate in groundwater in this study area did not pose any significant water quality problem, because these results are within the standards acceptable level of drinking water determined by local and international standards. Nitrogen is found in a number of different forms in water, as nitrogen, ammonia and oxidized nitrogen such as Nitrite and Nitrate. The nitrate level in groundwater is varied. The higher level recorded in A1 with the value of 25.3mg/l where as lowest value is recorded in A5 with value of 2.3 mg/l. Some researchers have also reported increase in nitrate composition in groundwater due to the waste water dumped at the disposal site and likely indicate the impact of leachate which is further support that groundwater near landfill site is being significantly affected by leachate percolation. The concentration of nitrate in well water samples is range between 0.7-4.6 mg/l. also there is clearly difference between the value of dry and wet season. It can suggested that water samples carried out from well site sample collected during dry period show lower value that of the sample collected after the rainy period. The reason may be due to the high amount of leachate which migrates to the groundwater via soil. The highest PO_4^{-3} were measured at A1 with the value of 0.72 mg/l where as the lowest concentration is measured in A5 with the value of 0.17 mg/l. However Phosphate concentration is less compared to the other nutrient in water. Because phosphate were less soluble and poor mobility unlike nitrate, usually converted in to insoluble form and fixed in the soil. Phosphate may be contributed from unprotected septic tanks and result of discharge of excreta effluent in which most of the phosphate may have been derived from domestic detergent powder, animal waste. The concentration of phosphate in well water samples is range between 0.09-0.24mg/l and did not pose to any pollution conditions. The concentration of phosphate in well water sample is range between 0.09-0.24 mg/l. (table2). Also water samples carried out from well site sample collected during dry period show lower value that of the sample collected after the rainy period. The reason may be due to the enhanced leaching of material by the rain and which migrates to the groundwater via soil. The groundwater samples were analyzed for heavy metal such as Fe, Mn, CO, Cu, Zn, Pb, and Ni. As. The results are shown in table 4.9.

Table 5: Heavy metal concentration in ground water samples

Sample	Element concentration (ppm)						
	Fe	Zn	Cu	Mn	Cr	Ni	CO
A1	17.6	0.58	0.44	29.2	0.2	0.05	0.8
A2	17.2	0.36	0.18	26.1	0.1	0.04	0.2
A3	4.2	0.20	0.06	14.0	0.05	0.02	0.06
A4	3.99	0.11	0.03	7.1	0.03	0.01	0.02
A5	1.2	0.11	0.04	1.49	0.01	0.01	0.02

Heavy metal remains in the waste or at the waste-rock interface as result of redox controlled precipitation reactions. Further the metal mobility is also controlled by physical sportive mechanism and landfill has and inherent in situ capacity for minimizing the mobility of toxic heavy metals (pohland et al., 1993). This fixing of heavy metals reduces the risk of direct toxic effect due to ingestion of leachate contaminated groundwater. However once the leachate leaves the site the situation changes. The leachate is generally strong reducing liquid formed under methanogenic conditions and on coming in to contact with aquifer material has the ability to reduce sorbet heavy metals in the aquifer matrix. The most important reaction is the reduction of Fe and Mn to more soluble species. Hence the concentrations of these components increase under favorable conditions close to a landfill and may lead to serious toxic risk.

Fe concentration in water samples varied from 1.2-17.6 mg/l in profile 1(table 5) and found well above the WHO permissible limit in many samples. This means that borehole is affected by the migration of leachate from the body of the landfill. Presence of Fe in water can lead to change of color of groundwater. Mn concentration in the water sample varied from 1.49-29.2 mg/l in profile. The highest value of 29.2mg/l is measured in A1, where as the lowest value of 1.49 is measured in A5 (figure 2). This means that borehole is affected by the migration of leachate from the body of the landfill. The high concentration of Mn in A1, A2, A3, A4 are not within the standard acceptable level of drinking water. The concentration of Mn was found to be remarkably high at site W4 wit the value of 2.85mg/l. in the wet period. The high concentration of Mn in W4 site is not within the standard acceptable level of drinking water. However Fe concentration of all well water samples is within the WHO standard value. Also there is clearly difference between the value of dry and wet season. It can suggested that water samples carried out from well site sample collected during dry period show lower value that of the sample collected after the rainy period.

The highest concentration of Cu found in A1 with the value of 0.44 mg/l where as the lowest concentration of Cu is found in A5 with the value of 0.04 mg/l in profile (figure 2). The high concentration of Cu in A1, A2 are not within the standard acceptable levels of drinking water determined by international standards. The reason may be due to the effect of these boreholes by the migration of leachate in to the groundwater The concentration of Cu in all well water samples did not pose any water quality problem. Also there is clearly difference between the value of dry and wet season. It can suggested that water samples carried out from well site sample collected during dry period show lower value that of the sample collected after the rainy period. The concentration of Zn in all borehole did not pose any significant water quality problems, because these concentrations are bellow the standards acceptable level of drinking water. The highest concentration of Zn 0.58mg/l was measured in A1, where as lowest concentration was measured in 0.11 mg/l in profile1. Also it can suggested that water samples carried out from well site sample collected during dry period show lower value that of the sample collected after the rainy period.

The metal Pb, Cd, Ni, Cr is characteristic as toxic one for drinking water. The content value of Ni measured in the groundwater is varied. however the concentration of Ni in all boreholes are not within the standard acceptable level of drinking water. The reason may be due to the high concentration of Ni in leachate, which migrates to the ground via soil.

The highest concentration of Cr found in A1 with the value of 0.2mg/l, where as the lowest concentration of Cr is found in A5 with the value of 0.01mg/l. high concentration of Cr in A1,
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A2, A3 are not within the standard acceptable level of drinking water. The reason may be due to the effect of this borehole by the migration of leachate in to the groundwater. However Cr concentrations of all well water samples (except W4) are within the WHO standard value. Also water samples carried out from well site sample collected during dry period show lower value that of the sample collected after the rainy period.

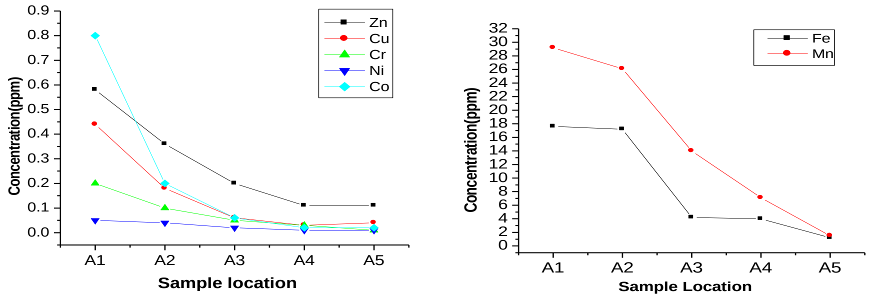

Figure 2: Variation of heavy metal along the profile

Table 6: Element concentrations of well water samples in both Dry and Wet period

Parameter	W1 Wet Period	W1 Dry Period	W2 Wet Period	W2 Dry Period	W3 Wet Period	W3 Dry Period	W4 Wet Period	W4 Dry Period
pH	5.19	6.8	5.69	6.1	6.78	6.96	6.52	6.78
Electrical Conductivity (mS/m)	0.1	0.25	0.26	0.36	0.7	0.82	0.3	0.69
Sulphate (ppm)	7	4	24	10	49	4	49	8
Nitrate (ppm)	2.5	2.1	4.6	4.3	1.3	0.7	3.2	0.4
Phosphate(ppm)	0.24	0.13	0.23	0.18	0.11	0.09	0.13	0.05
Zn(ppm)	0.22	0.12	0.13	0.11	0.12	0.18	0.14	0.06
Cu(ppm)	0	0.01	0.02	0.01	0.03	0	0.04	0.02
Fe(ppm)	0.29	0.11	0.24	0.22	0.54	0.52	0.58	0.53
Mn(ppm)	0	0	0.05	0	0.39	0.12	2.85	1.5
Cr(ppm)	0.05	0.02	0.05	0.03	0.1	0	0.06	0.12
Ni(ppm)	0.06	0.02	0.04	0.02	0.09	0.15	0.02	0.02
Co(ppm)	0	0	0.09	0.09	0	0	0.04	0

IV. CONCLUTIONS

Leachate of the Gohagoda landfill is most likely in methanogenic phase, which pH was 7.9. Most of parameters (including NO_3^-, Ni, Cu, Fe, CO) in the Gohagoda landfill Leachate exceeded the permissible limit required for treated wastewater discharge determined by the local and international standards. A1 and A2 are contaminated by Cu, Cr, Ni, Mn, Fe, CO and EC. A3 is contaminated by Cr, Ni, CO, Mn, Fe and EC. A4 is contaminated by Mn, Fe, CO. A5 is contaminated by Fe.

The concentrations of most of the measured parameters are the highest in borehole, which is close to the landfill. The groundwater quality improves with the increase in distances of the borehole from the landfill site. As there is no natural or other possible reason for high concentration of these pollutans, it can be concluded that the leachate has significant impact on groundwater quality near the areas of the Gohagoda landfill site. Samples collected during dry season show lower concentration of elements and nutrients than the samples collected after the rainy season. That may be due to the enhanced leaching of material by the rain.

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AUTHORS

First Author – Nirmala Kumuduni Dharmarathne, Department of Geology, University of Peradeniya kumudu142@gmail.com
Second Author – Jagath Gunatilake, Senior Lecturer, Department of Geology, University of Peradeniya, aajkg@yahoo.com

Correspondence Author – Nirmala Kumuduni Dharmarathne, Department of Geology, kumudu142@gmail.com