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CHARACTERISTICS OF LEACHATE GENERATED AT LANDFILL SITES AND PROBABLE RISKS OF SURFACE AND GROUNDWATER POLLUTION IN THE SURROUNDING AREAS : A CASE STUDY OF MATUAIL LANDFILL SITE, DHAKA

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ABSTRACT

The characteristics of leachate and its probable risks on surface and groundwater pollution were investigated following the analysis of some chemical parameters of the leachate generated in the Matuail landfill site, Dhaka, Bangladesh. The laboratory test results on untreated grab leachate samples show high concentration of TDS (734 ppm), COD (1631 ppm), NH_4^+-N (1253 ppm), HCO_3^- (27962 ppm) and certain heavy metals such as Ni (1.05 ppm) and Cr (0.74 ppm) and have very high potential for contaminating ground and surface water. Biological treatment through aeration and sedimentation improves the quality of leachate significantly. However, parameters such as COD (1437 ppm) are found to be still high even after treatment. The surface water samples around the landfill site appear to be contaminated, most probably, through the overflow of leachate. Groundwater parameters, however, satisfy drinking water quality standard except, the concentration of NH_4^+-N (maximum 74.2 ppm) and K (maximum 25 ppm).

Key words: Leachate, Pollution, Solid waste, Landfill

INTRODUCTION

Solid waste production in Dhaka city is estimated to roughly 7000 t/d in 2010 and projected to be increased to approximately 8300 t/d by 2015 (Hasan *et al*. 2009). These wastes are dumped in the landfill sites as the cheapest means of solid waste management system. The waste dumped in this process causes various aesthetic and public health problems and also attracts insects, rodents and various disease vectors. The solid waste, in this dumping process, undergoes slow, anaerobic decomposition over a period of 30 - 50 years and generate substantial amount of leachate with decomposition products, heavy metals and a variety of hazardous pollutants which may seep from the landfill site into underground aquifers and thus polluting much needed urban water resources. There are also possibilities of surface runoff and/or overflow of the leachate to the surrounding agricultural lands, ponds, canals and rivers causing surface water quality deterioration.

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The sanitary landfill project at Matuail is located on the north of Dhaka-Demra highway which lies between latitude 23º43.35′ and 23º42.97′N and longitude 90º26.83′ and 90º27.2′E. About 65% of total wastes generated daily in Dhaka city is disposed of at Matuail landfill site (DCC-JICA 2008). The site was actually converted to a sanitary landfill from an open landfill site. The area is vulnerable to monsoon floods due to low-lying topography (BWDB 2003).

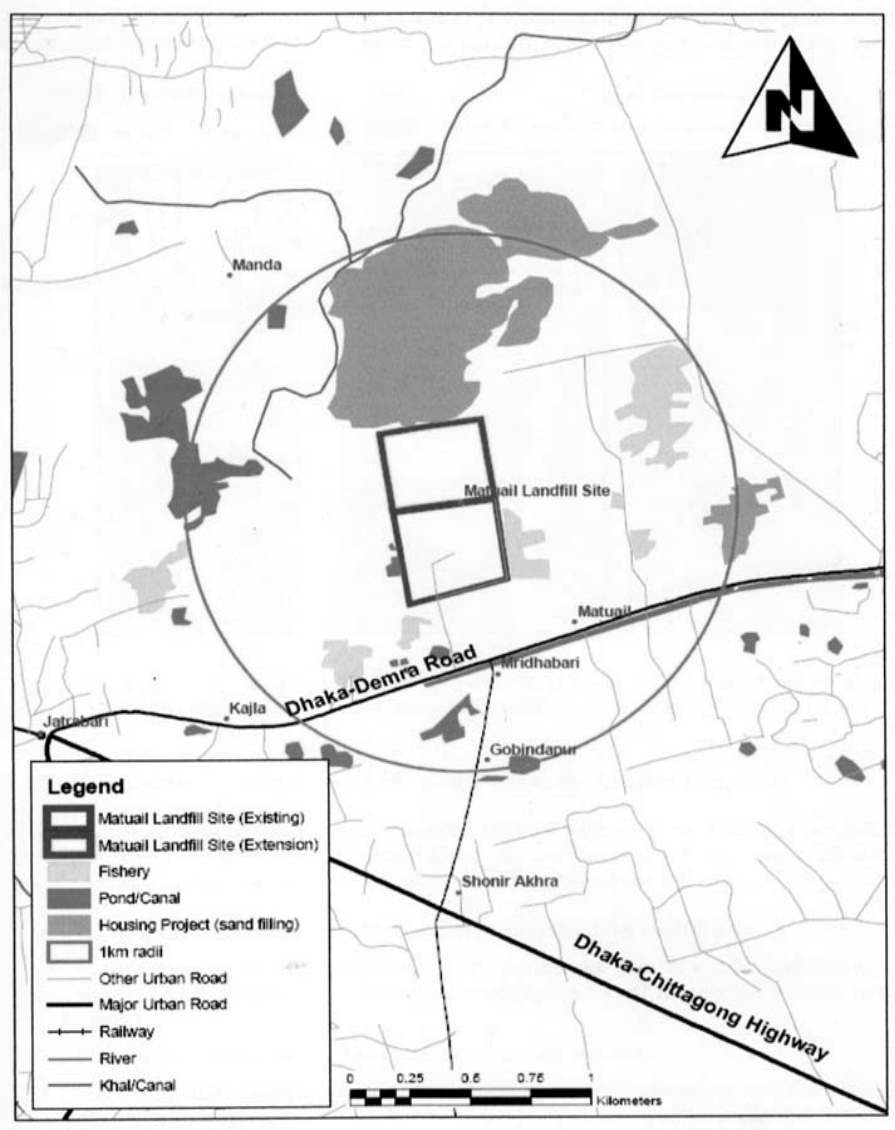

Fig. 1. Map showing the Matuail landfill area and its immediate surrounding (BRTC and BUET 2008).

The Matuail landfill broadly lies within the geological framework of Dhaka city characterized by multiple aquifers overlain by thick clay aquitard of varying thickness. The thickness of this clay unit varies and averages to about 8 m. The clay dominated lithology makes this unit an ideal impermeable layer and that can be expected to deter groundwater flow through it. The general direction of groundwater flow is from north to south (IWM-DWASA 2006). Since the main aquifer beneath Dhaka is heavily used for water supply by Dhaka Water Supply and Sewerage Authority (DWASA), the local groundwater flow dynamics in the main aquifer is significantly influenced by the operation of more than 426 production wells (deep tube-wells) of DWASA. According to Bangladesh Agricultural Development Corporation (BADC), the thickness of the upper clay unit is up to 20 m and the underlying upper sand unit is 30 - 40 m thick. The main aquifer is found at depth of about 60 - 70 m. Fig. 1 shows the areas in and around the Matuail landfill site. The areas immediately bordering the eastern sides of the landfill site is lowlands and extensively used for fisheries; while those on the western side are used for small-scale cultivation. The area immediately bordering the northern boundary of the land acquired for the proposed new landfill is being developed for a major housing project. The amount of wastes dumped in the site per year, leachate production rate and quality, and project activities has changed significantly over the last three years (DCC-JICA 2008).

The present investigation aims at analyzing some chemical parameters such as chemical oxygen demand (COD), ammonium (NH_4^+-N), nitrate (NO_3^--N), carbonate (CO_3^{2-}), bi-carbonate (HCO_3^-), calcium (Ca^{2+}), calcium and magnesium ($Ca^{2+}+Mg^{2+}$), chloride (Cl^-), lead (Pb), nickel (Ni), zinc (Zn) etc. in the leachate, ground and surface water and investigate its link to pollution, if any.

MATERIALS AND METHODS

For the present study, two leachate samples were collected (untreated and treated) from the north side of landfill. Untreated leachate sample was collected from the internal roadside drain located at 90º27.118′E and 23º43.190′N. Treated leachate sample was collected from a treated pond located at 23º43.208′N and 90º27.118′E. Grab water samples were collected for surface water quality analysis from two ponds used for fisheries located at southern and eastern side of the landfill. Surface water-1 (SW-1) was collected from the location at 23º43.223′N and 90º27.118´E and surface water-2 (SW-2) was collected from the location at 23º42.962′N and 90º27.012′E. Groundwater samples (GW-1, GW-2, GW-3 and GW-4) were collected from specific wells only after it has been pumped sufficiently to ensure that the samples represent the groundwater that feeds the well. GW-1 was collected from a hand tube-well located at 23º43.223′N and 90º27.181′E, which was mainly used to analyze groundwater quality of the landfill site at

a depth of about 115 feet. GW-2 was collected from a drinking water deep tube-well (about 400 feet in depth) located at 23º43.017′N and 90º26.996′E. The other deep tube-well (418 feet in depth) water sample, GW-3 was collected from the location at 23º42.961′N and 90º27.013′E. GW-4 was hand tube-well water at a depth of about 130 feet located at 23º42.12´N and 90º27.15´E.

During samples collection, 250 ml PVC sampling bottles for leachate and 125 ml PVC sampling bottles for surface and groundwater were used. For laboratory analysis, four bottles each of treated and untreated leachate samples, and 20 bottles each of surface water and ground water samples were collected. During sampling, sample bottles were rinsed 2 - 3 times with the water being collected, and 0.45 µm membrane filter was used to remove unwanted particles from the water samples. To prevent the loss of certain cations such as Cd, Cu, Cr, Ni and Zn and so forth by adsorption, or ion exchange with the walls of glass containers, some sampling bottles were acidified with concentrated HCl or HNO_3 to pH below 2.0 and the other were un-acidified and used to analyze for anions. Samples collected were carefully transported to the laboratory located at the Department of Soil, Water and Environment, University of Dhaka and were preserved in refrigerator under appropriate environment to prevent precipitation of heavy metallic ions before chemical analysis. A GARMIN 12 channel GPS was used to record the geographic locations of the sampling points. Electrical conductance (EC), total dissolved solid (TDS), dissolved oxygen (DO) and pH were recorded for each sample on the spot using portable EC meter (Hanna-Germany), TDS meter, DO meter and pH-meter (Hanna-Germany), respectively. The quantitative analysis was carried out for most of the chemical parameters of collected samples involving volumetric, colorimetric and atomic absorption spectrophotometer method. Parameters such as COD, CO_3^{2-}, HCO_3^-, Ca^{2+}, Ca^{2+}, Mg^{2+} etc. were determined by the volumetric chemical analysis procedure whereas heavy metal contents of all samples were determined by using atomic absorption spectrophotometer. K and Na contents were determined using flame photometer.

RESULTS AND DISCUSSION

The pollution potential of leachate depends on its composition and it usually contains high concentrations of a wide range of contaminants. Uncontrolled and untreated leachate of a landfill site pollutes the surrounding soil, surface water and groundwater and hence a potential threat to human and environment (Bhuiya *et al*. 2002). The local people as well as fisherman use the surrounding low-land areas extensively for fishing. On the other hand, agriculture is practiced and rice and vegetables are grown in the perennial water bodies mostly during the dry season. The comparison among different parameters of treated and untreated leachate sample shows that untreated leachate sample contains high concentration of different pollutants including total

dissolved solids, COD, NH_4^+-N, NO_3^--N, HCO_3^-, chloride, potassium and certain heavy metals whereas biological treatment through aeration and natural attenuation through sedimentation pond improve the quality of treated leachate sample significantly, although certain parameters such as COD are still high in treated leachate sample (Table 1). Improperly managed and over flooded untreated leachate during rainy season have a high potential to pollute the soil and surface water within and around the project site. However, parameters such as COD and Cl^- in both treated and untreated leachate samples and NH_4^+-N in treated leachate sample are within the typical range for commonly used indicator parameters at the landfill site according to the Solid Waste Association of North America (SWANA) (Table 1).

Table1. Characteristics of landfill leachate.

Parameters	Unit	Concentration present		Typical range for commonly used indicator parameters (SWANA 1991)
		Untreated sample	Treated sample	
pH value	-----	6.93	5.20	5.3 - 8.5
Electrical conductivity	µs/cm	10900	1210	---------
Total dissolved solids	mg/l	734	224	---------
Dissolved oxygen	”	0.9	1.4	--------
COD	”	1630.944	1436.784	3,000 - 45,000
Ammonium	”	1252.79	15.477	10 - 800
Nitrate	”	2198.57	76.82	5 - 40
Carbonate	”	720	72	---------
Bicarbonate	”	27962.4	3660	--------
Calcium	”	14	3	200 - 3,000
Magnesium	”	3	6	50 - 1,500
Chloride	”	976.25	266.35	100 - 3,000
Lead	”	Nil	Nil	--------
Chromium	”	0.744	0.036	--------
Nickel	”	1.048	0.097	-------
Zinc	”	0.378	0.0448	--------
Cadmium	”	0.0056	0.0006	--------
Copper	”	0.147	0.0256	--------
Sodium	”	40	30	200 - 2,000
Potassium	”	1125	150	200 - 2,000

The lowlands located on the southern and eastern sides of the landfill site are used for fisheries. During rainy season, drainage water, containing leachate from dumping site, flows into the lowlands and surface water bodies surrounding the site and pollutes them. The surface water quality at the dump site before the construction of sanitary landfill did not meet the water quality requirements for domestic uses (BRTC and BUET 2008). As a

part of this study, a total of two surface water samples (SW-1 and SW-2) were collected from southern and eastern sides of the landfill area.

The parameters of surface water samples show the presence of high concentration of COD, NH_4^+-N, HCO_3^-, K and low dissolved oxygen content of (Table 2) indicating the pollution of these water bodies by landfill leachate containing drainage water during high rainfall condition. According to the Bangladesh Environmental Conservation Rules-1997, the two samples do not meet the water quality standard for fish cultivation (GoB 1997).

Table 2. Characteristics of surface water collected from Matuail landfill site.

Parameters	Unit	Concentration present	
		SW-1	SW-2
pH value	-----	6.5	6.6
Electrical conductivity	µs/cm	370	799
Total dissolved solids	mg/l	196	427
Dissolved oxygen	”	3.2	2.3
COD	”	50.48	38.83
Ammonium	”	15.4	23.8
Nitrate	”	8.4	5.6
Carbonate	”	36	43.2
Bicarbonate	”	322.08	614.88
Calcium	”	14	32
Calcium + magnesium	”	40	110
Chloride	”	177.5	88.75
Lead	”	0.0	0.03
Chromium	”	0.5	1.03
Nickel	”	0.23	0.40
Zinc	”	0.266	0.116
Cadmium	”	0.003	0.005
Copper	”	0.066	0.2
Sodium	”	20	20
Potassium	”	150	100

Possible groundwater pollution is a major concern at the Matuail solid waste disposal site. Out of four groundwater samples, two samples (GW-3 and GW-4) were collected from further south for analysis of different water quality parameters. GW-1 was collected from hand tube-well which is mainly used to analyze groundwater quality of the landfill site at a depth of about 115 feet. GW-2 (about 400 feet of depth) and GW-3 (about 418 feet of depth) were collected from drinking water deep tube-well and GW-4 (about 130 feet of depth) from a hand tube-well based on location and depth information provided by the local people residing near the landfill site. Comparison of groundwater quality parameters shows that, the groundwater samples satisfy most of the drinking water quality standard but the concentration of NH_4^+-N and K (Table 3) were found to be

present in high concentration than Bangladesh drinking water quality standard in all the collected tube-well samples at or near the landfill area (DoE 1992). Also the concentration of HCO_3^- for the groundwater samples of GW-1, GW-2 and GW-4 appeared to be higher than Bangladesh drinking water standard.

Table 3. Characteristics of groundwater collected from Matuail landfill site.

Parameters	Unit	Concentration in Groundwater Samples				Bangladesh drinking water standard (DoF 1992)
		GW-1	GW-2	GW-3	GW-4	
pH value	-----	6.8	7.4	7.0	6.9	7
Electrical conductivity	µs/cm	937	271	211	412	-----
Total dissolved solids	mg/l	502	143	111	398	1000
Dissolved oxygen	”	5.3	4.4	4.4	5.2	6
COD	”	3.88	7.76	3.88	3.87	4
Ammonium	”	15.4	74.2	21	9.78	0.5
Nitrate	”	5.6	8.4	21	5.4	50
Carbonate	”	21.6	14.4	50.4	20.98	------
Bicarbonate	”	556.32	351.36	263.52	551.78	339
Calcium	”	78	62	24	71	75
Calcium + magnesium	”	190	40	10	177	120
Chloride	”	177.5	88.75	133.125	179.45	600
Lead	”	0.05	0.05	0.05	0.05	0.05
Chromium	”	0.05	0.05	0.05	0.05	0.05
Nickel	”	0.021	0.016	0.018	0.012	0.1
Zinc	”	5	0.4	0.4	4.1	5
Cadmium	”	0.001	0.001	0.001	0.001	0.005
Copper	”	0.01	1	1	0.023	1
Sodium	”	10	10	10	18	200
Potassium	”	25	25	25	15.65	12

CONCLUSION

The risk of pollution of surrounding lowlands (used for agriculture and fisheries) is particularly high during the wet season, when such flow of drainage water/leachate would be much higher. So management of untreated leachate should be made more carefully in the studied area especially during rainy season. The deeper aquifer lying beneath the Dhaka city is the primary source of potable water for the population of Dhaka although the piezometric surface goes much lower compared to the previous years due to higher abstraction rates and insignificant amount of recharge in the urban area. The landfill site is however, not likely to pose any threat to the water quality of the main aquifer, which is located at a depth of about 60 to 70m below ground surface and is overlain by a thick clay layer. The shallow aquifer around the project site is not widely used for supply of water for domestic use, therefore, possible public health risks from contamination of the shallow aquifer is also not significant. It may be due to the higher travel time required by

the leachate to reach the shallow aquifer compared to the time required for complete degradation of leachate. Hence, the risk of groundwater pollution is very low, provided the clay layer is continuous and no fracture is present through this overlying clay layer. Under the present situation, the best option is to continuously monitor the quality of shallow groundwater around the project site and proper geophysical investigation should be carried out for the identification of possible leakage in a regular basis.

REFERENCES

Bhuiya, M.A.H., N.E. Huq and M.M. Hossain. 2002. Unplanned Waste Disposal and Its Possible Impacts on Subsurface Environment of Dhaka City, Bnagladesh. *In* : *Bangladesh Environment 2002*, Vol.2. (ed.). M. Ahmed, A. Tanveer and Badruzzaman, BAPA, Dhaka, Bangladesh. pp. 723-731.

BRTC and BUET. 2008. Environmental Impact Assessment: Solid waste Management and Construction of Landfill at Matuail, pp. 1(1) - 5(8).

BWDB. Ground water Circle-2. 2003. The compilation of Aquifer test analysis results. Water supply paper No.WSP-534, Dhaka, pp. 2-32.

DCC-JICA. 2008. Clean Dhaka Master Plan Progress Report: 2004-2007. Dhaka City Corporation-Japan International Cooperation Agency, Dhaka. pp. 17-21.

DOE. 1992. Environmental Quality Standards for Bangladesh. Report. Department of Environment, Ministry of Environment and Forest, GOB.

GoB. 1997. Environment Conservation Rules 1997. Department of Environment, Ministry of Environment and Forest, Government of People's Republic of Bangladesh, June 1997.

Hasan, M. R., K. Tetsuo and S. A. Islam. 2009. Landfill Demand and Allocation for Municipal Solid Waste Disposal in Dhaka City - An Assessment in a GIS Environment. *Journal of Civil Engineering (IEB)*. **37**(2): 133-149.

IWM-DWASA. 2006. Resource Assessment and Monitoring of Water Supply Sources for Dhaka City, Final Report, prepared by the Institute of Water Modelling (IWM) for Dhaka Water Supply and Sewerage Authority (DWASA), July 2006.

SWANA. 1991. The solid Waste Association of North America, A professional Association in Solid Waste Management, U.S.A.

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