Bangladesh J. Sci. Res. **29**(1): 31-39, 2016 (June)

CHARACTERISTICS OF MUNICIPAL LANDFILL LEACHATE AND ITS IMPACT ON SURROUNDING AGRICULTURAL LAND

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Abstract

An investigation was carried out to assess the characteristics of leachate and its impact on surrounding agricultural land of the Matuail landfill site, Dhaka, Bangladesh. Leachate samples were collected from active dumping areas; soil and plant samples from three different sites of surrounding agricultural areas. Water quality parameters like pH, DO, BOD, COD, TDS were measured for leachate samples and heavy metals like Cu, Zn, Pb, Cd, Ni were analyzed for leachate, soil and plant samples. The results showed that untreated leachate concentrations of DO, BOD, COD and TDS were 1.34, 96, 1343 and 7120 mg/l, respectively that exceeded inland surface water standard but the concentrations of DO (7.49 mg/l), BOD (10 mg/l) and TDS (790/l) in the treated leachate pond were found within the permissible limits. The leachate samples are not contaminated with heavy metals as these are present below the toxic limits. The heavy metal concentrations in agricultural soils are below the permissible limits except Pb; but in plants the concentrations of Cu, Zn and Pb exceeded the critical limits.

Key words: Solid waste, agricultural land, leachate, Matuail landfill.

Introduction

The huge population of the Dhaka city directly or indirectly generates thousands of tons of solid and liquid wastes everyday, including toxic, nontoxic and hazardous wastes. The main sources of these wastes are households, markets, institutions, streets, public areas, commercial areas and manufacturing industries. The Dhaka city corporation is responsible for collection, transportation and final disposal of solid wastes in Dhaka city area. The burial of municipal solid wastes in landfills is the most common disposal alternative in developing countries because of its simple and easy operation, low cost, less technological involvement and comfort of implementation (Barrett and Lawlor 1995). There is often indiscriminate waste disposal without concern for human health impacts or environmental degradation. The problems of solid waste management are compounded by the rapid urban population growth caused by rural to urban migration over stretching resources (Yhdego 1995). City wastes constitute one of the most crucial public health and environmental problems in its inhabitants (Adebilu and Okenkule 1989, Rotich *et al.* 2006).

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Landfilling is an eligible and economical way of municipal solid waste disposal, but if it is not done in a proper way, it adversely affects soil and water quality by leachate liquid (El-Fadel *et al.* 1997). Landfill leachate is generated by excess rainwater percolating through the waste layers in a landfill. In the waste transfer pollutants from the waste material to the percolating water is a combination of physical, chemical and biological processes (Christensen and Kjeldsen 1989). Mechanisms of contaminant removal include leaching of inherently soluble materials, leaching of soluble biodegradation products of complex organic molecules, leaching of soluble products of chemical reaction and washout of fines and colloids (Hennebert *et al.* 2013). The characteristics of the leachate produced are highly variable, depending on the composition of the solid waste, precipitation rate, site hydrology, compaction, cover design, waste age and interaction of leachate with the environment and landfill design and operation (Nartey *et al.* 2012). Leachate from decomposed solid waste conveys heavy metals such as Fe, Cu, Cd, Ni, Pb, Zn etc. and toxic chemicals (Haque *et al.* 2013). Due to heavy rainfall during monsoon leachate from such landfills flow out into the adjacent areas resulting contamination of agricultural land. Usually the adjacent areas of the dumping site are used as cropping field by the local people and in this way hazardous substances may be accumulated by the plant from the decomposed waste and leachate from the dumping site. Several studies have been carried out about the characteristics of leachate and probable risks of surface and ground water pollution in the surrounding areas of Matuail landfill site (Azim *et al.* 2011, Haque *et al.* 2013) but very little is known about the impact of landfill leachate on surrounding agricultural land. The objective of this inquisition, therefore, is to know the characteristics of municipal solid waste landfill leachate and its impact on surrounding agricultural land.

Materials and Methods

Matuail landfill site is located between latitude 23º42.97' and 23º43.35' N and longitude 90º26.83' and 90º27.2' E, a low-lying agricultural land and about 65% of total wastes generated daily in Dhaka city are disposed here. It is a semi-aerobic landfill which is in pipe system, half circle of it is solid in lower part and upper half is perforated where natural air is passed by. Leachate from dumping site is stored in leachate pond, which is treated with lime, $FeSO_4$, polymer etc. and stored in another pond; then discharged through irrigation channel.

Leachate samples were collected for this experiment from both treated and untreated leachate ponds and discharged path of treated leachate waste-water i.e. used for irrigation. Soil and plant samples were collected from three different sites of surrounding agricultural land (surrounded area of the landfill used for agriculture). Both soil and plant samples were dried, ground and sieved for chemical analysis.

The pH, DO (dissolved oxygen) and TDS (total dissolved solid) of leachate samples were determined immediately after sample collection. The BOD (Biological oxygen demand) was measured by refrigerated thermal autoning machine (FTC 90E). The COD (Chemical oxygen demand) was determined by $K_2Cr_2O_7$ in 50% H_2SO_4 and the remaining amount of $K_2Cr_2O_7$ was titrated with a standard Mohr's salt (0.125N $FeSO_4$ $(NH_4)_2$ SO_4) solution (Huq and Alam 2005). Total N of leachate, soil and plant samples were determined by Kjeldahl method following concentrated H_2SO_4 digestion (Jackson 1962). Total concentration of P, K, S, Fe, Mn, Cu, Zn, Pb, Cd and Ni in leachate, soil and plant were analyzed by digesting leachate with concentrated nitric acid (Huq and Alam 2005), digesting soil with aqua-regia at a ratio of 1 : 10 and digesting plant with nitric acid followed by perchloric acid (Jackson 1962). Total phosphorus was estimated colorimetrically using a spectrophotometer by developing yellow color with vanadomolybdate, total potassium by flame photometer and total sulfur by turbidimetric method using spectrophotometer (Jackson 1962). However, measurements of total nutrient content are not so useful indicators of sufficiency for plant growth, because only a small portion of the nutrients are available for plant. Moreover, it is widely accepted that determining the total content of heavy metals in a soil is neither sufficient to understand their relative mobility and ecological availability as contaminants nor particularly useful as a tool to estimate potential risks (Adriano 2001). Hence, for determination of available N, P, K and S in soil 1N KCl, Bray and Kurtz solution, 1N ammonium acetate and Morgan's solution, were used, respectively as extracting agents (Huq and Alam 2005). Soil was extracted by using 1N HCl with a ratio of 1 : 33.33 in case of available Fe, Mn, Zn, Cu Pb, Cd and Ni determination (Chowdhury *et al.* 2010). After digestion the concentrations of Fe, Mn, Cu, Zn, Pb, Cd and Ni in leachate, soil and plant samples were estimated by Atomic Absorption Spectrophotometer. The statistical analyses were made using software Stata version 12.

Results and Discussion

The physical and chemical parameters of leachate samples from treated and untreated ponds were analyzed to estimate its pollution potential (Table 1). The pH of the leachate ranged from 8.00 to 8.23, confirmed slightly alkaline in nature. The measured pH value shows that all the samples are within the permissible limit pH 6 to 9 (DoE 2003).

Dissolved oxygen is an important parameter in water quality assessment and reflects the physical and biological processes prevailing in the water. An adequate supply of DO is necessary for good water quality, survival of aquatic organism and decomposition of waste by microorganism (Dara 2002). The maximum value of DO (7.49 mg/l) was recorded in treated leachate pond while the minimum value (1.34 mg/l) recorded at untreated leachate pond. The discharged leachate sample shows lower value of DO than the treated leachate sample which reflects the untreated leachate might be mixed with the treated leachate in the discharged path. The lowest value of DO in untreated leachate indicates organic pollution. Previous study (Azim *et al.* 2011) also observed lower value of DO in untreated leachate (0.9 mg/l) than the treated leachate (1.4 mg/l). According to DoE (2003), the treated leachate was succeeded to keep the DO value within the permissible limit (4.5 to 8).

The highest value of BOD (96 mg/l) was found in untreated pond where the DO value was lowest. The concentration of BOD in treated leachate sample recorded 10 mg/l that was present within the permissible limit according to DoE (50 mg/l), whereas the BOD in untreated leachate sample exceeded it. The result shows that BOD in leachate sample of treated pond considered as suitable for fish culture and other purposes.

Table 1. Physico-chemical parameters of leachate samples.

Parameters	Leachate samples			Reference value for inland surface water (DoE 2003)
	Untreated	Treated	Discharged	
pH	8.23 ± 0.12	8.00 ±0.15	8.17 ± 0.11	6 - 9
DO (mg/l)	1.34 ± 0.5	7.49 ±1.0	3.64 ± 0.8	4.5 - 8
BOD "	96 ± 8	10 ±1.5	49 ± 3	50
COD "	1343 ± 42	253 ±18	328 ± 16	250
TDS "	7120 ±165	790 ±19	3360 ± 87	2100

The concentration of COD in untreated, treated and discharged leachate sample was found 1343, 253 and 328 mg/l, respectively also in well agreement with Azim *et al.* (2011), where COD was found 1630 mg/l but in treated leachate the value of COD differed from Azim *et al.* (2011), where COD was found 1436 mg/l. The values of COD in all leachate samples exceeded the permissible limit (250 mg/l) (DoE 2003) which may consequently affect the aquatic life.

The value of TDS for leachate samples ranged from 790 to 7120 mg/l. The result shows that the TDS value of the treated leachate is below the permissible limit but untreated and discharged leachate lie above the limit (Table 1). Haque *et al.* (2013) also reported a similar result for TDS of untreated leachate sample (7178 mg/l) but for treated leachate sample Haque *et al.* (2013) showed higher value of TDS (6637 mg/l) comparable to the present study (790 mg/l). In the study area, leachate is treated by using lime, $FeSO_4$, polymer etc. which may decrease the COD, BOD and TDS concentrations in treated pond, where lime and $FeSO_4$ act as coagulants and polymer as coagulant aids.

Table 2 shows the nutrient and heavy metal concentrations in different leachate samples that indicate the concentrations of total N, P, K and S are higher in untreated leachate than the treated leachate sample. The high N concentration in all leachate samples might be due to the refuse dumps that can lead to increase N concentrations (Abbas *et al*. 2009). Disposal of organic waste (mainly vegetable waste) might contribute to increase the phosphorus concentration in leachate sample (Fuentes *et al.* 2006).

The Fe concentration in leachate samples ranged from the 2.87 to 3.41 mg/l (Table 2). As the permissible limit of Fe is 2 mg/l for inland water (DoE 2003), result shows that the Fe values of all leachate samples exceeded the permissible limit. The abundance of Fe containing wastes such as cutlery and surgical instruments, cutting tools, metal cans, kitchen wastes etc. may contribute to increase Fe concentration in leachate sample. Haque *et al.* (2013) also found Fe concentration above the permissible limit in both treated and untreated leachate.

Table 2. Concentrations of nutrients and heavy metals (mg/l) in leachate samples.

Parameters	Leachate samples			Reference value for inland surface water (DoE 2003)
	Untreated	Treated	Discharged	
N	980 ± 11	140 ± 3	400 ± 7	-
P	3.1 ± 0.07	0.23 ± 0.01	1.17 ± 0.02	-
K	973 ±13	164 ± 5	545 ± 8	-
S	17.05 ± 1.9	0.78 ± 0.05	6.57 ± 0.6	-
Fe	3.41 ± 0.05	2.87 ± 0.02	3.04 ± 0.01	2
Mn	0.17 ±.001	0.08 ± 0.001	0.21 ±.002	5
Cu	0.09 ±.001	0.03 ±.00	0.07 ±.001	0.5
Zn	2.3 ± 0.02	0.034 ± 0.003	0.07 ±.002	5
Pb	0.02 ±.001	BDL*	0.01 ±.00	0.1
Cd	BDL*	BDL*	BDL*	0.05
Ni	0.17 ± 0.01	0.01 ± 0.00	0.09 ±.01	1

*BDL = Below detection limit.

The concentrations of Mn, Cu, Zn, Pb, Cd and Ni of different leachate samples are below the permissible limits in this study as compared to inland surface water standard (DoE 2003). The concentrations of Cu and Zn in treated leachate show more or less similar value by previous study (Azim *et al.* 2011). In the present study the leachate sample has shown no appreciable increase of concentration of Pb (Table 2). The concentration of Ni was found lower in this study than the previous study (Azim *et al.* 2011); where Ni concentrations varied from 1.048 µg/g (untreated leachate) to 0.097 µg/g (treated leachate).

The high nutrient status in soil of surrounding agricultural areas of the landfill sites indicates that the soil is good for crop production (Table 3). The N and S concentrations were found higher in site 1 than the other sites. The total N shows a significant positive relationship with available N at 0.1% level (r = 0.98***). The P concentration was observed slightly higher in site 2 than the other sites. The available P concentration was very low compared with total P concentration, might be due to the abundance of Fe in the soil that may fix the excess phosphorus (Jokubauskaitė *et al*. 2015). The total K concentration shows almost similar result in soil of all sites.

The concentration of total Fe was high in site 2 but did not exceed the permissible limits (100 - 210000 µg/g, Huq and Alam 2005). A significant positive correlation existed between the available Fe and total Fe at 5% level (r = 0.72*). The maximum values of total Mn, Cu and Zn were observed in site 1, but were below the permissible limits (7 - 8423 µg/g for Mn, 2.5 - 60 µg/g for Cu and 3 - 762 µg/g for Zn) (Huq and Alam 2005). The relationships between total and available Mn, Cu and Zn were significant and positive at 0.1% level (r = 0.98***, 0.93*** and 0.93***, respectively). Both total and available concentration of Pb was observed higher in site 1 than the other sites and exceeded the permissible limit for Pb in soil (2 - 100 µg/g, Kloke 1980), this might be due to the reason that the site 1 was located very close to the active waste dumping site and strong possibility of deposit Pb from the waste and leachate. The relationship between

Table 3. Nutrient and heavy metal concentrations (µg/g) in soil of surrounding agricultural areas of the landfill sites.

Elements	Soils in surrounded agricultural areas						Reference value for soil (Huq and Alam 2005, Kloke 1980)	Correlation coefficient value (r) between total and available elements
	Site 1		Site 2		Site 3			
	Total	Available	Total	Available	Total	Available		
N	2790 ± 80	230 ± 9	1918 ± 480	180 ± 6	1981 ± 120	190 ± 7	-	0.98***
P	192 ± 13	3.62 ± 0.03	210 ± 24	2.56 ± 0.02	196 ± 21	2.67 ± 0.02	-	–0.72*
K	1740 ± 62	330 ± 7	1657 ± 81	355 ± 4	1700 ± 53	341 ± 8	-	–0.92***
S	1679 ± 75	61.7 ± 6	1149 ± 59	102 ± 29	1078 ± 45	75.1 ± 9	-	–0.79*
Fe	12536 ± 96	4840 ± 41	14330 ± 114	5990 ±166	13998 ± 21	5112 ± 24	100 - 210000	0.72*
Mn	141 ± 10	123 ± 5	93 ± 8	67 ± 9	110 ± 15	79 ± 3	7 - 8423	0.98***
Cu	28 ± 0.8	21 ± 0.6	25 ± 0.3	18 ± 0.9	26.1 ± 2	20 ± 1.1	2.5 - 60	0.93***
Zn	76 ± 3	52 ± 4	59 ± 4	39 ± 2	60 ± 6	43.1 ± 2	3 - 762	0.93***
Pb	840 ± 11	661 ± 11	42 ± 2	22 ± 0.9	73 ± 5	36 ± 4	2 - 100	0.99***
Cd	0.3 ± 0.01	0.19 ± 0.01	0.08 ± 0.00	0.03 ± 0.001	0.12 ± 0.01	0.10 ± .01	3	0.96***
Ni	18.7 ± 0.2	6 ± 0.2	15.7 ± 0.4	5 ± 0.1	15.1 ± 0.1	5 ± 0.9	50	–0.24

*, **, *** indicate significance at 5, 1 and 0.1% level, respectively.

available Pb and total Pb was indicated by the significant positive correlation at 0.1% level (r = 0.99***). Similarly, Cd and Ni concentrations were found higher in site 1 than the other sites but did not exceed the critical limits (Cd < 3 µg/g, Ni < 50 µg/g, Kloke 1980).

Table 4 shows that the concentrations of nutrient are high in all plants (vegetable) of three sites. Plant samples show high concentrations for Fe and Mn in entire agricultural areas of the landfill sites but are lower than that of toxic levels (18 - 3580 µg/g for Fe, 17 - 334 µg/g for Mn, Huq and Alam 2005). The concentrations of Cu, Zn and Pb in plant of all sites were found high and exceeded the critical level for plants (15 - 20 µg/g for Cu, 150 - 200 µg/g for Zn, 10 - 20 µg/g for Pb, Sauerbeck 1982). Though the values of Cu, Zn and Pb (except site 1) in soil were below the toxic level, the high concentrations of these elements in plant might be due to the surface runoff or overflow of leachate to the surrounding agricultural land or used discharged leachate containing toxic element for irrigation. The higher concentration of Pb in soil of site 1 might contribute to high concentration of Pb in plant (spinach) of this site (site 1).

Table 4. Nutrients and heavy metal concentrations in plant (vegetable) of surrounded agricultural land of the landfill sites.

Elements	Plants in surrounded agricultural areas			Reference value for plant (Huq and Alam 2005, Sauerbeck 1982)
	Site 1 (Spinach)	Site 2 (Cauliflower leaf)	Site 3 (Tomato leaf)	
N (%)	3.09 ± 0.8	3.51 ± 0.9	3.99 ± 0.6	-
P "	0.24 ± 0.02	0.21 ± 0.01	0.19 ± 0.02	-
K "	5.56 ± 0.5	4.12 ± 0.09	5.27 ± 0.7	-
S "	0.45 ± 0.09	0.98 ± 0.1	0.75 ± 0.05	-
Fe (µg/g)	288 ± 13	295 ± 26	618 ± 35	18 - 3580
Mn "	111 ± 19	91 ± 7	59 ± 4	17 - 334
Cu "	34 ± 2	21 ± 1.8	24 ± 2.3	15 - 20
Zn "	389 ± 46	126 ± 17	101 ± 11	150 - 200
Pb "	148 ± 30	22 ± 5	18 ± 2	10 - 20
Cd "	6.2 ± 0.8	0.2 ± 0.008	0.16 ± 0.004	5 - 10
Ni "	2.3 ± 0.1	1.3 ± 0.05	1.7 ± 0.09	20 - 30

The concentrations of Cd and Ni in plant of site 1 (spinach) show higher value than the other sites, might be due to the high concentration of Cd and Ni in soil of site 1 but all the values are below the toxic level (5 - 10 for Cd, 20 - 30 µg/g for Ni, Sauerbeck 1982). The nutrients and heavy metal concentrations in plant differ from site to site may be due to their different concentrations in soil or different uptake rates of different plant species because metal accumulation in plants depend on plant species, growth stages, types of soil and metals, soil conditions, weather and environment (Chang *et al.* 1984). The accumulation of heavy metals in vegetables represent a direct pathway for their incorporation into the human food chain (Florijin and Beusichem 1993). The health risk will also depend upon the chemical composition of the waste material, its physical characteristics, types of vegetables cultivated and the consumption rate (Cobb *et al.* 2000).

Conclusion

Most of the water quality parameters indicate that the treated leachate samples are better than untreated leachate as the values are below the permissible limits. The leachate of the landfill site does not contaminate the soil but it may contaminate the plant due to overflow of leachate or use of contaminated irrigation water. As a result the observed values of Cu, Zn and Pb in plant exceeded the permissible limits. The leachate, soil and plant samples collected from the landfill site are rich in both nutrients and heavy metals because of different types of waste dumping without segregation. If the dumping site is properly managed by segregating the waste according to their source, then this site may be used for agricultural production. The findings present an overview of the environmental concerns from landfilling practices and can assist in managing the landfill site in an effective way. Hence, the adverse effects of generated waste on environment can be minimized.

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(Manuscript received on 26 June, 2016; revised on 16 August, 2016)