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Impact of Landfill Leachate on Surface and Ground Water Quality

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ABSTRACT
Physical, chemical and bacteriological analyses of leachates, surface and ground water samples of Rowfabad landfill at Chittagong, Bangladesh were carried out to ascertain the magnitude of dumpsite pollution of surface and ground water during rainy and winter season. Surface water samples were collected from distances of 100, 200, 300, 400 and 500 m, respectively away from the landfill. Groundwater samples were collected from 3 points within 0.30 km radius of the landfill. All the samples were analyzed for relevant physico-chemical and biological parameters according to internationally accepted procedures and standard methods. Concentration of DO was found very low (0.8 mg L^{-1} in winter and 0.2 mg L^{-1} in rainy season), while, BOD (550 mg L^{-1} in winter and 216 mg L^{-1} in rainy season) and COD (745 mg L^{-1} in winter and 430 mg L^{-1} in rainy season) were high in the leachate sample. The presence of faecal coliform in ground water (15/100 mL in winter and 71/100 mL in rainy season) was upsetting. The higher concentration of iron (3.26 mg L^{-1} in winter and 2.61 mg L^{-1} in rainy season) and arsenic (1.7 mg L^{-1} in winter and 0.9 mg L^{-1} in rainy season) in ground water were found alarming. Necessary steps should be taken by the authority to prevent further contamination from leachate.

Key words: Municipal, solid waste, landfill, leachate, contamination, treatment

INTRODUCTION
Municipal Solid Waste (MSW) disposal is a global concern (Aderemi *et al*., 2011), especially in developing countries across the world, as poverty, population growth and high urbanization rates combine with ineffectual and under-funded governments to prevent the efficient management of wastes (Cointreau, 1982; Doan, 1998). Land filling is the simplest, cheapest and most cost effective method of disposing of waste in both developed and developing nations of the world (Barrett and Lawlor, 1995). Municipal landfill leachate is highly concentrated complex effluents which contain dissolved organic matters, inorganic compounds such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals such as cadmium, chromium, copper, lead, zinc, nickel and xenobiotic organic substances (Lee and Jones-Lee, 1993; Christensen *et al*., 2001). Landfills have been identified as one of the major threats to groundwater resources (Fatta *et al*., 1999; USEPA, 1984). Waste placed in landfills or open dumps are subjected to either groundwater underflow or infiltration from precipitation. The dumped solid wastes gradually release its initial interstitial water and some of its decomposition by-products get into the water moving through the waste deposit. Such liquid containing innumerable organic and inorganic compounds is called "Leachate". This leachate accumulates at the bottom of the landfill and percolates through the soil (Mor *et al*., 2006). Groundwater pollution is mainly due to the process of industrialization

and urbanization that has progressively developed over time without any regard for environmental consequences (Longe and Balogun, 2010). Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site. Such contamination of groundwater resource poses a substantial risk to local resource user and to the natural environment. The impact of landfill leachate on the surface and groundwater has given rise to a number of studies in recent years (Saarela, 2003; Abu-Rukah and Al-Kofahi, 2001; Looser *et al.*, 1999; Christensen *et al.*, 1998; De Rosa *et al.*, 1996; Flyhammar, 1995). Many approaches have been used to assess the contamination of groundwater. It can be assessed either by the experimental determination of the impurities or their estimation through mathematical modeling (Moo-Young *et al.*, 2004; Hudak, 1998; Stoline *et al.*, 1993; Butow *et al.*, 1989). A number of scholars (Longe and Balogun, 2010; Akinbile and Yusoff, 2011; Kumar *et al.*, 2012; Karnchanawong *et al.*, 1993; Jhamnani and Singh, 2009; Sabahi *et al.*, 2009; Vasanthi *et al.*, 2008; Abid and Jamil, 2005; Abu-Rukah and Al-Kofahi, 2001) have examined the possible water contamination around municipal landfills by using the microbiological examination and physico-chemical analysis of leachate and ground water. The main focus of these scholars has been to find out the impact of landfills on ground water quality, quantitative analysis of level of water contamination and the identification of possible threats to the local environments and residents as well. Groundwater is the major source of potable water supply in the study area and its contamination is a major environmental and health concern. The study was carried out during January to December 2009 to assess the physical, chemical and biological parameters of surface water, ground water and leachate of Rowfabad land fill during rainy and winter season.

MATERIALS AND METHODS

General description of the study area: Chittagong is the gateway and the second largest city of Bangladesh with a substantial, self-sustaining economic base. Chittagong lies between latitude 22°14' N and 22°24' N longitude 91°46' E and 91°53' E (Islam, 2003) and stands on the bank of the river Karnafully. It is situated at the extreme southeastern part of the country. It comprises about 209.66 sq km (Islam, 2003). It is upgraded as Municipal Corporation and finally as City Corporation in 1990 (CDA, 1992).

Temperature: The mean monthly temperature in Chittagong ranges from 21.2°C in November to 28.4°C in April. The mean monthly minimum temperature ranges from 17.0°C in November to 25.10°C in July. The mean annual maximum and minimum temperature are 30.9 and 24.4°C, respectively (Meteorological Department).

Rainfall: The highest concentration of precipitation is during the period from June to September with pre and post monsoon periods of rain during April, May and October. November to March constitute the dry season. Average rainfall is found in Chittagong 700-1000 mm in rainy season (Meteorological Department).

Population: Population of Chittagong Metropolitan Area (SMA) has already been increased from 23,07,000 in 1991 and the predicted population in 2001 is 27,43,000 (BBS, 1992). On average nearly 40,000 people a year being added by natural increase over the ten-year period 1991-2001. Besides, many people are migrating from other areas of the country contribute to the population increase in the city. Total population of Chittagong city at now is 32,09,650 (male: female, 16,63,679: 15,45,971) (BBS, 2009).

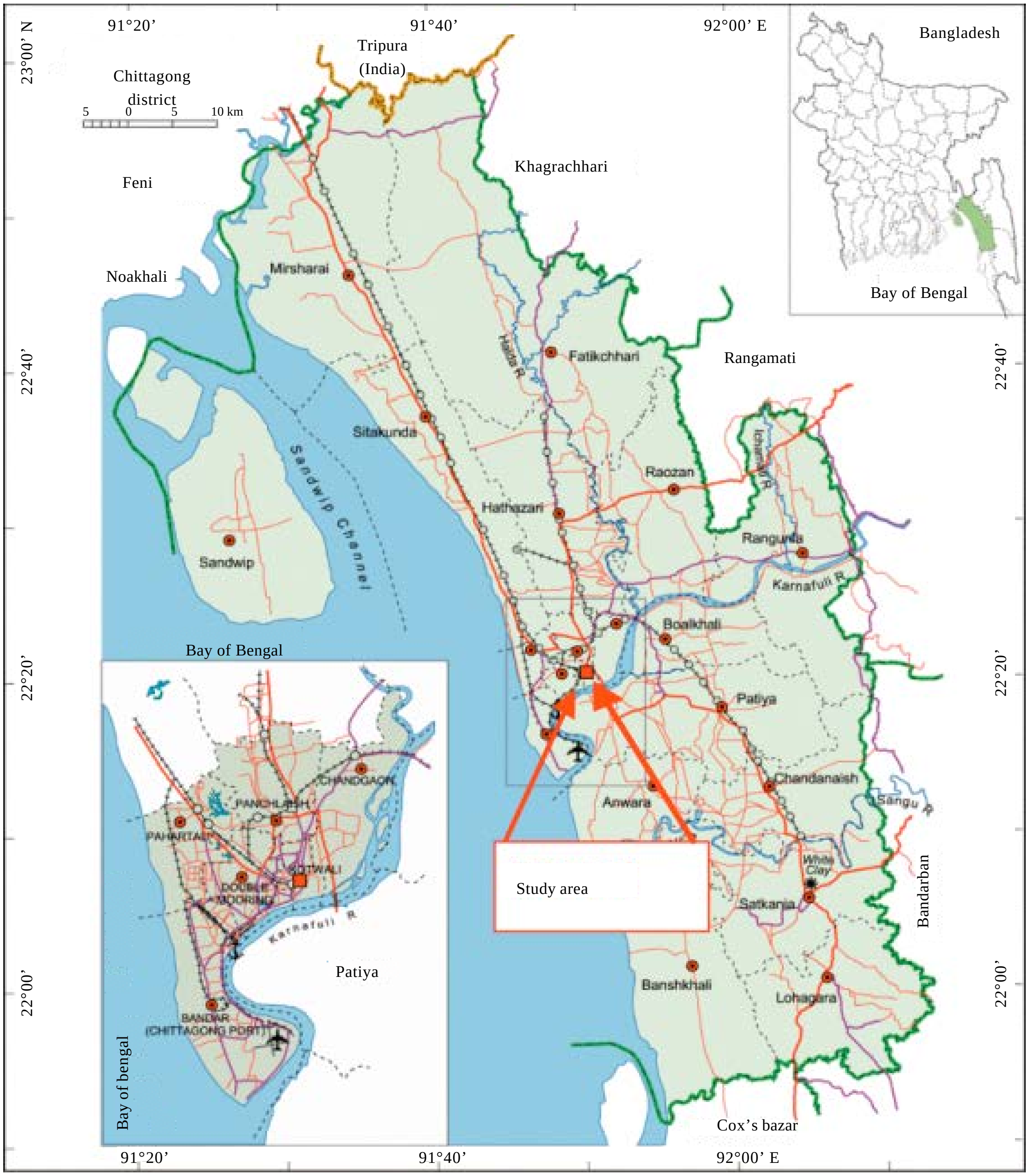


Fig. 1: Map of study area (Islam, 2003)

Selection of the study area: The study was conducted at Rowfabad landfill in the Chittagong City Corporation (CCC) of Bangladesh. There are 41 wards (administrative areas) in CCC (Rahman *et al.*, 2006). The study area selection was purposive (Fig. 1).

Sampling of surface water, ground water and leachate: Sample water was collected in a 1 L plastic bottle and filled the total volume of the container and a cap was locked enough so that no air space can be remained inside the bottle. The plastic bottles were first washed thoroughly using detergent and dried. Before taking water, the bottles were rinsed with the water to be taken as sample. Water samples both surface water and ground water along with leachate were collected after some flush outs. After taking water samples, the bottles were labeled accurately by mentioning the name and location of the sample site, date and time of collection, etc. Surface water samples were collected from distances of 100, 200, 300, 400 and 500 m, respectively away from the landfill. To assess the extent of groundwater contamination, 3 sampling points were selected within 0.30 km radius of the landfill site from where the groundwater samples were taken. Samples were collected in clean 500 mL plastic bottles after the extraction of water either from a hand pump or a tube well. The water was left to run from the source for about 4 min to equate the minimum number of well volume and to stabilize the electrical conductivity (Mor *et al*., 2006). Since the landfill was not equipped with a leachate collection system, the leachate accumulating at the base of the landfill was sampled randomly from three different locations within the landfill and was mixed prior to analysis. The samples for microbiological analysis were aseptically taken in 50 mL sterile universal containers. Then the collected samples were shifted to the laboratory of the WASA, Dhaka, preserved in cool temperature for the testing. The testing of different parameters was done within the next 48 h which is recommended for better result in minimizing the quality change. All the samples were analyzed for relevant physico-chemical and biological parameters according to internationally accepted procedures and standard methods (APHA-AWWA-WPCF, 1994). The parameters analyzed on the surface and ground water and leachate samples include, Total Suspended Solid (TSS), turbidity, pH, electrical conductivity, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), chloride, nitrate, fluoride, arsenic, metal analysis and fecal Coliform bacteria count. Data was analyzed using MS Excel.

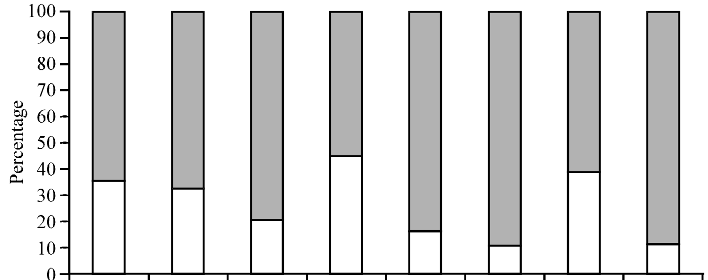
RESULTS AND DISCUSSION

Analysis of leachate quality at Rowfabad dumping site: During rainy season, the leachate can be flushed out from the confined storage place to surrounding water bodies which can pollute the surface water. Heavy rainfall during the monsoon is very conducive for generation of leachates at the dumping sites. Leachates have the potential of slowly moving downwards and eventually reaching the aquifer.

Table 1 represents the pH, electric conductivity, turbidity and TSS of leachates in Rowfabad dumping site with seasonal variation. The pH, electric conductivity and TSS of the leachate in winter season were higher than that in the rainy season (Table 1). The finding of present study is with the agreement of DCC and JICA (2004); where it has been observed that concentration of pH, electric conductivity and TSS in leachate sample (collected from Matuail landfill site, Dhaka) is lesser in rainy season sampling.

Chemical parameters of leachate analysis have been presented in Table 2. Concentration of DO was found very lower (0.8 mg L^{-1} in winter and 0.2 mg L^{-1} in rainy season), while BOD (550 mg L^{-1} in winter and 216 mg L^{-1} in rainy season) and COD (745 mg L^{-1} in winter and 430 mg L^{-1} in rainy season) were higher in the leachate sample. The finding is in consistent with the agreement of (DCC and JICA, 2004); where it has been observed that the concentration of DO was very lower (0.15 mg L^{-1}); while, BOD and COD were higher (660 and 766 mg L^{-1}, respectively) in the leachate sample collected from Matuail Landfill site, Dhaka (Table 2).

The concentration of Iron (Fe) was relatively higher than other metals in both seasons. It was observed in general that concentration of different parameters except Zinc (Zn) was lesser in the



	Cd (mg L⁻¹)	Pb (mg L⁻¹)	Cr (mg L⁻¹)	As (mg L⁻¹)	Cu (mg L⁻¹)	Zn (mg L⁻¹)	Fe (mg L⁻¹)	Mn (mg L⁻¹)
Winter season	0.09	0.027	1.999	0.09	0.65	2.5	7.25	2.12
Rainy season	0.05	0.013	0.519	0.073	0.13	0.31	4.61	0.27

Fig. 2: Percentage amount of metals in leachate with seasonal variation

Table 1: Seasonal variation of physical parameters in leachate at Rowfabad dumping site

Physical parameters	Winter season	Rainy season
pH	60.30	60.27
Electrical conductivity (μS cm^{-1})	77.69	58.73
Turbidity (NTU)	131	136
TSS (mg L^{-1})	376	270

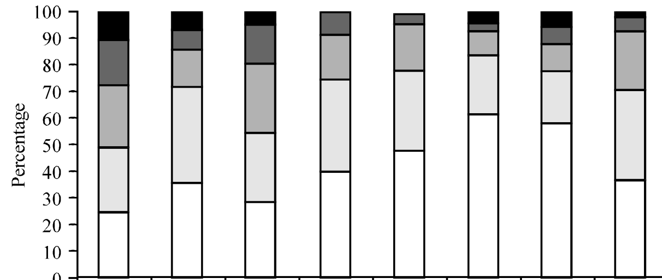
Table 2: Seasonal variation of chemical parameters in leachate at Rowfabad dumping site

	Chemical parameters (mg L^{-1})				
Seasonal variation	BOD	COD	DO	NO_3-N	Cl
Winter	216	430	0.8	115	104
Rainy	550	745	0.2	62.5	24

rainy season sampling compared to winter season, this may perhaps be due to dilution of the sample with rain water (Fig. 2). The finding of the present study is with the agreement of DCC and JICA (2004); where it has been observed that concentration of different parameters in leachate sample is lesser in the rainy season sampling.

Analysis of surface water quality at Rowfabad dumping site: Surface water samples collected from locations around the Rowfabad dumping site were found to be contaminated from the leachates flowing into them. The pH, electric conductivity, turbidity and TSS of surface water at different distance near the Rowfabad dumping site with seasonal variation are shown in Table 3. The pH, electric conductivity, turbidity and TSS of the surface water in the winter season are higher than that in the rainy season. It also depicts that pH, electric conductivity and turbidity were lower along with the distance; this may perhaps be due to dilution of the sample (Table 3). The finding is consistent with DCC and JICA (2004).

Table 4 represents some chemical parameters of surface water analysis for both rainy and winter season. It showed that the normally concentration of all parameters at near distance was relatively higher. It also depicts that the concentration widely reduced along with the seasonal variation. It shows that the concentration of all parameters (except DO) at near distance was relatively higher. Concentration of DO was found very lower; 2.35 mg L^{-1} at 100 m distance and 4.1 mg L^{-1} at 500 m distance in winter season and 3.8 mg L^{-1} at 100 m distance and 4.6 mg L^{-1} at 500 m distance in rainy season (Table 4).



	Cd (mg L^{-1})	Pb (mg L^{-1})	Cr (mg L^{-1})	As (mg L^{-1})	Cu (mg L^{-1})	Zn (mg L^{-1})	Fe (mg L^{-1})	Mn (mg L^{-1})
■ 500 m	0.030	0.001	0.20	0.02	0.006	0.0100	0.46	0.001
■ 400 m	0.045	0.001	0.53	0.40	0.020	0.0079	0.57	0.002
□ 300 m	0.063	0.002	1.00	0.82	0.090	0.0200	0.84	0.009
□ 200 m	0.064	0.005	1.00	1.66	0.160	0.0500	1.60	0.014
□ 100 m	0.067	0.005	1.07	1.91	0.250	0.1400	4.80	0.015

Fig. 3: Percentage amount of metals in surface water sample near dumping site in rainy season

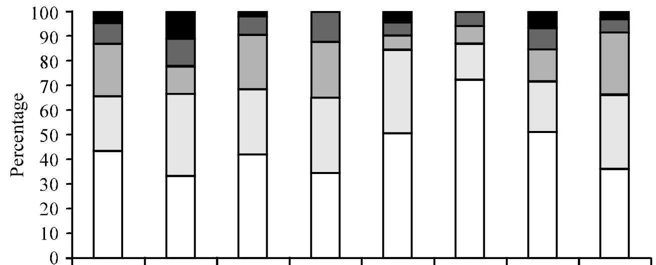
Table 3: Seasonal variation of physical parameters in surface water sample near dumping site

	Away from disposal site (m)									
	100		200		300		400		500	
Physical parameter	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
pH	7.24	7.12	7.21	7.11	7.20	7.11	7.20	7.1	7.20	7.08
Electrical conductivity (µS cm^{-1})	692	327	145.8	139.7	143	127.8	140	124	121	119
Turbidity (NTU)	56	130	36	61	21	49	17	22	17	21
TSS (mg L^{-1})	240	140	101	100	63	51	61	50	43	45

Table 4: Seasonal variation of chemical parameters in surface water sample at different distances from dumping site

	Away from disposal site (m)									
	100		200		300		400		500	
Chemical parameters (mg L^{-1})	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
BOD	20.80	11.20	15.20	11.00	10.00	8.00	9.00	6.00	6.00	2.0
COD	68.00	23.00	42.00	21.00	13.00	7.00	11.00	4.50	9.00	3.0
Fluoride	3.59	1.97	1.76	1.23	0.95	0.64	0.66	0.23	0.12	0.1
DO	2.35	3.80	3.20	4.40	3.40	4.40	3.43	4.60	4.10	4.6
Nitrate	6.30	4.30	3.80	2.80	2.90	2.90	2.20	2.20	1.90	1.9
Chloride	5.50	4.50	4.40	4.00	1.20	1.20	1.10	1.20	1.00	1.1

Figure 3 and 4 illustrate the percentage amount of metals in surface water sample close to dumping sites. In Fig. 4 the smaller values of the metals are may be due to the surface flow of the excessive rain during the survey period. It shows that the normally concentration of all parameters at near distance was relatively more. It also depicts that the concentration widely reduced along with the seasonal variation.



	Cd (mg L^{-1})	Pb (mg L^{-1})	Cr (mg L^{-1})	As (mg L^{-1})	Cu (mg L^{-1})	Zn (mg L^{-1})	Fe (mg L^{-1})	Mn (mg L^{-1})
■ 500 m	0.003	0.001	0.04	0.02	0.007	0.001	0.41	0.001
▣ 400 m	0.005	0.001	0.13	0.40	0.010	0.007	0.55	0.002
▣ 300 m	0.013	0.001	0.41	0.82	0.010	0.010	0.81	0.009
□ 200 m	0.014	0.003	0.46	1.06	0.060	0.020	1.30	0.011
□ 100 m	0.027	0.003	0.77	1.21	0.090	0.100	3.20	0.013

Fig. 4: Percentage amount of metals in surface water sample near dumping site in winter season

Table 5: Seasonal variation of concentration of physical and biological parameters of ground water near dumping site

Physical and biological parameters	Winter season	Rainy season
pH	6.7	6.46
Electrical conductivity (µS cm^{-1})	331	703
Turbidity (NTU)	6.8	8.1
TSS (mg L^{-1})	1	2
Faecal coliform (Count/100 mL)	15	71

Table 6: Seasonal variation of concentration of chemical parameters in ground water near dumping site

	Seasonal variation	
Chemical parameters (mg L^{-1})	Winter	Rainy
BOD	0.4	0.1
COD	44	35
Fluoride	1.49	1.16
DO	2.45	1.5
Nitrate	2.9	1.8
Chloride	5.5	3.5

Analysis of ground water quality at Rowfabad dumping site: Leachates have the potential of slowly moving downwards and eventually reaching the aquifer used by the city for its water supply, thus contaminating this precious resource. Electric conductivity was high (703 µS cm^{-1}) in rainy season. Thus, high conductivity is a symbol of high ionic load and indicates that organic and inorganic matter has washed into water. The presence of faecal coliform in ground water (15/100 mL in winter season and 71/100 mL in rainy season) was alarming (Table 5). The water qualities in most cases are close and more than the drinking water standards of Bangladesh and WHO permissible limits.

Concentration of BOD, COD, DO, fluoride, chloride and nitrate in ground water during winter and rainy season sampling represent that the concentration of DO was very lower (2.45 mg L^{-1} in winter and 1.5 mg L^{-1} in rainy season), while COD (44 mg L^{-1} in winter and 35 mg L^{-1} in rainy season) was higher in ground water (Table 6).

Table 7: Seasonal variation of metal concentration in ground water near dumping site

	Metal concentration (mg L^{-1})							
Seasonal variation	Cd	Pb	Cr	As	Cu	Zn	Fe	Mn
Winter	0.04	0.007	0.092	1.7	0.015	0.50	3.26	0.12
Rainy	0.02	0.005	0.019	0.9	0.011	0.07	2.61	0.07

Ground water near the landfill sites is highly contaminated by metal which is shown in Table 7. The higher concentration of iron (3.26 mg L^{-1} in winter and 2.61 mg L^{-1} in rainy season) and arsenic (1.7 mg L^{-1} in winter and 0.9 mg L^{-1} in rainy season) in ground water were found alarming. The presence of some toxic metal, i.e., chromium, lead, cadmium, etc., in ground water samples were also alarming. The present finding is in consistent with DCC and JICA (2004) where, it has been observed that higher concentration of metals than standard limits.

Remedial measures for reducing surface and groundwater contamination: The study revealed that the leachate generated from the landfill site is affecting the surface water quality through surface runoff and ground water quality in the adjacent areas through percolation into the subsoil. So, it is unavoidable to take necessary steps to prevent further contamination from leachate. In this regard leachate management through effective control of leachate generation, its treatment and subsequent recycling throughout the waste should be taken into consideration by the Chittagong City Corporation. Landfill site should be constructed in such a way so that leachate can be collected for recycling or treatment. This collected leachate can be distributed throughout the waste by means of spraying the leachate across the landfill surface. Some of the water may be lost through evaporation and therefore, leading to reduction in the volume of the leachate for ultimate treatment.

Following activities can be taken for proper management of leachate:

- Surface run off of leachate during rainy season can be reduced through construction of embankment surrounding leachate collection pond and the landfill
- Limit the infiltration of the water through the landfill cover by providing impermeable clay cover
- Extraction of the leachate collected at the base can be done and it can be recycled, so that a reduced amount of will enters the aquifer lying below
- Increasing the evapo-transpiration rate by providing vegetation cover over the landfill can also reduce leachate production

CONCLUSION

Municipal landfills are considered a grave threat to their surrounding urban environments and a major source of pollution especially ground water contamination. From the study it has observed that improper practices of solid waste management carried out at the Rowfabad landfill site and the inappropriateness of the leachate collection system and its treatment or recycling exert tremendous impact on the surface and ground water quality. Study findings revealed that the groundwater is unacceptable for drinking water purposes and therefore puts emphasis on the call for to get better on solid waste management practices and construct appropriately engineered sanitary landfill sites to restrict the contamination of groundwater. It is strongly suggested that the Chittagong City Corporation should take necessary initiatives for the control of surface and ground water contamination and for the protection of the environment and public health as well through improved techniques for solid waste management, leachate collection, its recycling or treatment and surface and ground water monitoring.

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