Probable Risk Assessment of Surface and Groundwater in the Surrounding Areas of Waste Landfill Site at Khulna in Bangladesh

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Abstract

Landfills are a possible threat to the character of the environment, although the entire extent of this threat has not always been scientifically corroborated. The present study aims at assessing the characteristics of leachate and its probable risks on human health through surface and ground water in and around the waste landfill site located at Rajbandh, Khulna, Bangladesh. This study was carried out during the periods of both dry season and rainy season in the year 2016. In the laboratory, the relevant parameters required for assessing health risks were assessed through the standard methods. In this study field, non-carcinogenic risk assessment of selected metals in surface and ground water was then valued using the Hazard Quotient ($HQ_{ing/Derm}$) and Hazard Index ($HI_{ing/Derm}$) following USEPA methodology. The answer brings out that the child's were more vulnerable to adverse health hazards than adults around the landfill site.

Keywords: *Waste Landfill, Landfill Leachate, Possible Health Risks, Hazard Quotient, Hazard Index.*

1 Introduction

Solid waste generation in Khulna city, Bangladesh is estimated to roughly 450 t/d in 2013 (Alam and Hassan, 2013). These wastes are dumped in landfill site 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 (Aderemi et al., 2011; Sizirici and Tansel, 2010). The solid waste in the 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 carcinogens and non-carcinogens chemicals which may seep from the landfill site into underground aquifers and thus polluting much needed urban water resources (Shenbagarani, 2013). 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 (Lee and Jones-Lee, 1994). However, due to the generating huge amount of waste, most of the developing countries has dumped their waste in the open disposal sites which posses serious impacts to the surrounding area. In addition, contamination of underlying groundwater is one of the major problems regarding open dumping sites (Butt and Oduyemi, 2003; Butt et al., 2008).

The selected landfill site is located at Rajbandh, Khulna with an area of 5 acres, is 8 km far from the city centre and situated along the North-side of Khulna-Satkhira highway as shown in Figure 1. Actually, it is known as New Rajbandh, the second ultimate open disposal site of waste in city area, just 700 m away from the older one, known as old Rajbandh of 20 acres land (Islam et al., 2009). The new Rajbandh consists of 5 cells where paddy plantation and fish cultivation were continued till the waste deposition started. Despite the partial filling of waste in the older one, the city authority started to dump waste n the new Rajbandh since January 2007 and first two cell cells along the Khulna-Satkhira Highway were started to fill. The site of the sanitary is located at the north-west cell is also shown in the Fig.1.

The performance of geo-environmental structures such as landfill liners, covers, impoundments of vertical barriers depends mainly on the basic characteristics of the soils (Azim et al., 2011). The geotechnical characteristics of the sub-soils were determined in the laboratory using conventional test methods after collecting

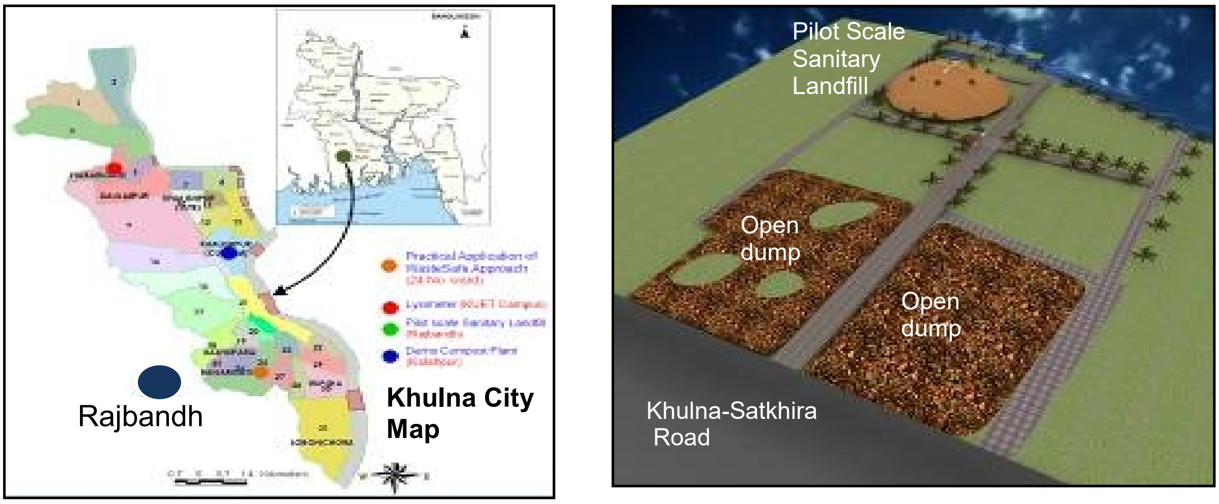

Figure 1. Location and layout of sanitary landfill at Rajbandh as shown with respect to Khulna city map (Source: Islam et al., 2009)

the soil samples through a sub-soil exploration by wash boring method up to a depth of 17 m. The existing ground surface exists at a depth of 1 m from road level, while the ground water table is encountered at a depth of 2 m. The soils predominated in the site till the executed depth with the presence of significant portion of organics in the depth of 2 to 3.5 m. Result shows that in the depth of 0-2 m, the average value of liquid limit, plastic limit and the plasticity index are 53 %, 33 % and 20, while in the subsequent layers, these values vary from 36-71 %, 22-37 % and 13 to 41, respectively.

The Rajbandh sanitary landfill broadly lies within the geological framework of Khulna city characterized by multiple aquifers overlain by thick clay aquitard of varying thickness (Islam et al. 2009). 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. 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 (Islam et al. 2009). The main aquifer is found at depth of about 60-70 m. The areas immediately bordering the all sides of landfill site is lowlands and extensively used for fisheries and cultivation. The amount of wastes dumped in site per year, leachate production rate and quality, and project activities has changed significantly over the last three years (Alamgir et al. 2008). Additionally, this paper is to give an overview of the risk assessment methodology with particular emphasis on the areas where numerical Monte Carlo Simulation (MCS) can be helpful. Health risk assessment is based on the integration of fundamental knowledge of a number of disciplines, like environmental science, medicine, public health, toxicology or physiology**.**

2 Materials and methods

2.1 Sampling of leachate and water samples

Three leachate sample, three surface water and five groundwater sample was collected from the surrounding area of landfill site. Moreover, the locations with GPS, sampling distances from landfill and depth of tube well from the existing ground level for ground water samples of are provided in Table 1.

Table 1. Site specification for sampling of leachate and water samples

Notation	Sampling locations	Sample type	Sampling Distance (m)	Depth of tube well (m)	Locations (GPS)
L1	Leachate-1	Leachate	--	--	90º21.116′E & 24º43.195′N
L2	Leachate-2	Leachate	--	--	24º43.208′N & 90º21.118′E
L3	Leachate-3	Leachate	--	--	25º40.216′N &

					90º18.111′E
SW1	Surface water-1	Surface water	30	--	27º43.221′N & 90º28.118′E
SW2	Surface water-2	Surface water	120	--	27º42.962′N & 90º28.012′E
SW3	Surface water-3	Surface water	300	--	23º42.952′N & 90º28.112′E
GW1	Ground water-1	Ground water	50	40	23º43.223′N & 90º27.118′E
GW2	Ground water-2	Ground water	150	120	23º42.962′N & 90º27.012′E
GW3	Ground water-3	Ground water	250	120	23º42.961′N & 90º27.013′E
GW4	Ground water-4	Ground water	350	40	23º42.12′N & 90º27.15′E
GW5	Ground water-5	Ground water	500	120	23º42.872′N & 90º27.112′E

2.2. Laboratory investigations

The metal concentrations of Calcium (Ca^{+}), Potassium (K^{+}), Sodium (Na^{+}) and Magnesium (Mg^{2+}) were determined by a flame atomic absorption spectrophotometer (VARIAN; AA/2400). Moreover, the heavy metal concentrations of Copper (Cu^{2+}), Cadmium (Cd^{2+}), Chromium (Cr^{2+}), Lead (Pb^{2+}), Nickel (Ni^{2+}), Iron (Fe^{3+}), Zinc (Zn^{2+}) and Manganese (Mn^{4+}) were analysed using a spectrophotometer (HACH; DR/2400) in accordance with the standard method (APHA, 1998).

2.3. Risk assessment methodology

The human health risk assessment methodology pertaining to water ecosystems has been described elsewhere (Li and Zhang, 2010; US.EPA, 1989; US.EPA, 2004; Wu et al., 2009). Human beings may expose to metals from water through three main pathways including direct ingestion, inhalation through mouth and nose, and dermal absorption through skin exposures; ingestion and dermal absorption are common for water exposure (US.EPA, 1989; US.EPA, 2004; Wu et al., 2009). In the present study, the numeric expressions for risk assessment were obtained from the US.EPA Risk Assessment Guidance for Superfund (RAGS) methodology (US.EPA, 1989). Equation for estimating incidental ingestion exposure through the contamianted water as follows

$$CDI_{ing} = \frac{C_W * CR * ABS_S * ET * EF * ED}{BW * AT} \quad ....(1)$$

Where, CDI_{ing}= chronic dialy intake for ingestion, Cw= metal concentration in water (mg/L), CR=contact rate (L/hrs), ABSs=absorption factor (%), ET= exposure time (hrs/event), EF=exposure frequency (days/year), ED=exposure duration (years), BW=body weight (kg), AT=average time (days). Iadditionall, equation for estimating dermal exposure with contamianted water as follows:

$$CDI_{derm} = \frac{C_W * SA * ABS_S * CF * PC * ET * EF * ED}{BW * AT} \quad ....(2)$$

Where, CDI_{derm}= chronic dialy intake from dermal contact with metals in water, Cw= concentration of estimated metals in water (mg/L), SA=skin surface area avialable for contact (cm^2), CF=volumetric conversion factor for water (L/cm^3), PC=metal specific dermal permaebility constant (cm/hrs), ABSs=absorption factor.

Potential non-carcinogenic risks for exposure to contaminants were assessed by comparison of the calculated contaminant exposures from each exposure route with the reference dose (RfD) (Table 6) in order to produce the hazard quotient (HQ), defined as follows

$$HQ_{ing/derm} = \frac{CDI_{ing/derm}}{RfD_{ing/derm}} \quad ....(3)$$

Where $HQ_{ing/derm}$ is hazard quotient via ingestion or dermal contact (unitless) and $RfD_{ing/derm}$ is oral/dermal reference dose (mg/kg-day). The RfD_{ing} and RfD_{derm} values were obtained from the literature elsewhere (Li and Zhang, 2010; US.EPA, 1989; Wu et al., 2009; Liang et al., 2011).

The hazard quotient (HQ) is a numeric estimate of the systemic toxicity potential posed by a single element within a single route of exposure. To evaluate the overall potential for noncarcinogenic effects posed by more than one element, the computed HQs for each element are integrated and expressed as a hazard index (HI) (US.EPA, 1989)

$$HI=\sum_{i=1}^{n} HQ_{ing/derm}.................(4)$$

Where $HI_{ing/derm}$ is hazard index via ingestion or dermal contact (unitless). When HQ/HI exceeds unity, there may be a concern for potential human health risks caused by exposure to non-carcinogenic elements (US.EPA, 1989).

3 Results and discussions

Table 1. Metal and heavy metal concentrations in landfill leachate and maximum discharge standards

Designation	Period	Concentrations in leachate parameters of landfill (mg/L)										
		Ca^{+}	K^{+}	Na^{+}	Mg^{2+}	Cd^{2+}	Cr^{2+}	Pb^{2+}	Ni^{2+}	Zn^{2+}	Cu^{2+}	Fe^{2+}
L1	Dry	365	1339	2335	312	0.13	0.05	0.80	0.52	1.14	1.11	39
	Rainy	285	1311	2139	305	0.11	0.04	0.51	0.062	0.68	0.85	37
L2	Dry	468	2451	2371	353	0.10	0.05	0.38	0.052	0.74	0.90	43
	Rainy	339	2289	2206	327	0.10	0.03	0.44	0.047	0.64	0.90	25
L3	Dry	304	1306	2198	301	0.06	0.05	0.35	0.083	0.53	1.21	29
	Rainy	239	1187	2285	287	0.06	0.05	0.29	0.057	0.36	0.79	24
DoE Bangladesh[a]		--	--	--	--	--	0.5	0.1	1	5	0.5	2

[a]Jannatul, 2013 (Standard set by DoE (Bangladesh) on ECR, for Effluent (Wastewater, inland surface water) (1997)); [b]Kumar and Alappat 2003; [c]Meier et al., 2002 (Maximum discharge standard for landfill leachate from selected countries) and [d]Azim et al. 2011 (Typical range for commonly used indicator parameters for leachate (SWANA 1991)).

Table 2. Metal and heavy metal concentrations in surface and ground water samples of landfill site

Designation	Sampling Period	Mean concentrations (mg/L)										
		Ca^{+}	K^{+}	Na^{+}	Mn^{4+}	Cd^{2+}	Cr^{2+}	Pb^{2+}	Ni^{2+}	Zn^{2+}	Cu^{2+}	Fe^{2+}
SW1	Dry	28	130	20	33.5	0.001	0.77	0.02	0.33	0.17	0.48	4.3
	Rainy	34	167	24	35.2	0.003	0.88	0.04	0.55	0.19	0.54	4.8
SW2	Dry	18	110	17	20.2	0.004	0.5	0.02	0.44	0.14	0.38	4.8
	Rainy	19	177	22	29.6	0.005	0.63	0.03	0.42	0.16	0.54	3.8
SW3	Dry	16	150	12	15.2	0.005	0.42	0.03	0.54	0.14	0.07	3.3
	Rainy	13	167	17	15.2	0.007	0.57	0.04	0.60	0.14	0.09	2.8
GW1	Dry	60	22	11	31.9	0.001	0.03	0.05	0.043	1.4	0.72	4.0
	Rainy	65	23	12	35.1	0.003	0.04	0.04	0.062	1.5	0.95	4.6
GW2	Dry	53	24	9	18.6	0.005	0.04	0.05	0.046	1.0	0.65	4.8
	Rainy	50	20	10	29.5	0.004	0.03	0.03	0.046	1.1	0.81	3.8
GW3	Dry	38	20	16	13.9	0.006	0.04	0.05	0.089	0.5	0.61	3.3
	Rainy	37	27	21	15.3	0.006	0.05	0.05	0.060	0.7	0.71	2.5
GW4	Dry	29	17	21	3.4	0.007	0.02	0.02	0.054	0.4	0.45	3.2
	Rainy	31	20	23	5.3	0.005	0.05	0.05	0.042	0.5	0.53	2.0
GW5	Dry	25	12	9	4.4	0.006	0.02	0.03	0.057	0.4	0.39	2.5
	Rainy	30	13	10	4.9	0.005	0.04	0.05	0.041	0.5	0.44	3.8
DoE[a]		75	12	200	--	0.005	0.05	0.05	0.1	5	1	
WHO[b]			15	200	150	0.005		0.05		4.0	1.5	1

[a]Azim et al. 2011. (DoE 1992, Bangladesh drinking water quality standard); [b]Olafisoye et al. 2011. (WHO, Drinking water quality standard)
Notation: Ca^{2+}=Calcium; K^{+}=Potassium; Na^{+}=Sodium; Mg^{2+}=Magnesium, Cd^{2+}=Cadmium; Cr^{2+}=Chromium; Pb^{2+}=Lead; Ni^{2+}=Nickel; Zn^{2+}=Zinc; Cu^{2+}=Copper and Fe^{2+}=Iron

Table 3. Non-carcinogenic health risk assessment summary for the selected metals in GW1 for Adult and Child via ingestion and dermal routes

Metals	Adult (CTE)				Child (CTE)			
	Dry		Rainy		Dry		Rainy	
	HQ_{ing}	HQ_{derm}	HQ_{ing}	HQ_{derm}	HQ_{ing}	HQ_{derm}	HQ_{ing}	HQ_{derm}
Cr^{2+}	2.24E-03	3.26E-02	1.26E-02	1.83E-01	1.19E-02	9.75E-02	6.67E-02	5.49E-01
Zn^{2+}	1.04E-03	5.70E-04	5.87E-03	3.21E-03	5.53E-03	1.71E-03	3.11E-02	9.60E-03
Cd^{2+}	4.47E-04	1.63E-03	2.52E-03	9.16E-03	2.37E-03	4.88E-03	1.33E-02	2.74E-02
Ni^{2+}	4.81E-04	1.30E-03	2.70E-03	7.29E-03	2.55E-03	3.88E-03	1.43E-02	2.18E-02
Cu^{2+}	4.03E-03	3.66E-03	2.26E-02	2.06E-02	2.13E-02	1.10E-02	1.20E-01	6.17E-02
Pb^{2+}	7.99E-03	1.94E-02	4.49E-02	1.09E-01	4.24E-02	5.81E-02	2.38E-01	3.27E-01
Fe^{2+}	1.62E-02	1.16E-03	9.12E-02	6.54E-03	6.78E-03	3.48E-03	3.81E-02	1.96E-02
Mn^{4+}	3.02E-02	9.27E-03	1.70E-01	5.22E-02	1.58E+00	4.05E+00	8.87E+00	2.28E+01
$HI_{ing/derm}$	*6.26E-02*	*6.95E-02*	*3.52E-01*	*3.91E-01*	*1.67E+00*	*4.23E+00*	*9.39E+00*	*2.38E+01*

Table 4. Non-carcinogenic health risk assessment summary for the selected metals in SW3 for Adult and Child via ingestion and dermal routes

Metals	Adult (RME)				Child (RME)			
	Dry		Rainy		Dry		Rainy	
	HQ_{ing}	HQ_{derm}	HQ_{ing}	HQ_{derm}	HQ_{ing}	HQ_{derm}	HQ_{ing}	HQ_{derm}
Cr^{2+}	1.76E-01	2.56E+00	2.39E-01	3.48E+00	9.34E-01	7.68E+00	1.27E+00	1.04E+01
Zn^{2+}	5.87E-04	3.21E-04	5.87E-04	3.21E-04	3.11E-03	9.60E-04	3.11E-03	9.60E-04
Cd^{2+}	1.26E-02	4.58E-02	1.76E-02	6.41E-02	6.67E-02	1.37E-01	9.34E-02	1.92E-01
Ni^{2+}	3.40E-02	9.16E-02	3.77E-02	1.02E-01	1.80E-01	2.74E-01	2.00E-01	3.05E-01
Cu^{2+}	2.20E-03	2.00E-03	2.83E-03	2.58E-03	1.17E-02	6.00E-03	1.50E-02	7.72E-03
Pb^{2+}	2.70E-02	6.54E-02	3.59E-02	8.72E-02	1.43E-01	1.96E-01	1.91E-01	2.61E-01
Fe^{2+}	2.52E-01	5.40E-03	3.34E-01	4.58E-03	3.15E-02	1.62E-02	2.67E-02	1.37E-02
Mn^{4+}	3.29E-01	2.49E-02	4.28E-01	2.49E-02	4.23E+00	1.09E+01	4.23E+00	1.09E+01
$HI_{ing/derm}$	*8.34E-01*	*2.80E+00*	*1.10E+00*	*3.77E+00*	*5.60E+00*	*1.92E+01*	*6.02E+00*	*2.21E+01*

4 Conclusions

The risk of pollution of surrounding lowland (used for agriculture and fisheries) areas in landfill site is particularly high during the wet season, when the flow of drainage water/leachate would be much higher. So management of landfill leachate should be made more carefully in the studied area especially during rainy season. Here, it should be noted that in the same study area, there is also an open dumping site for waste, so, the surrounding surface water bodies, underlying soil layer and ground water table is easily contaminated by this open dumping facility. The present study showed the diverse variations of parameters in surface and ground water in both the dry and rainy seasons. Deviations were observed by surface and ground water samples from water quality standards indicating surface and ground water pollution.

Moreover, health risk levels were found to be higher in rainy season than that of dry season, demonstrating more risk for Adult and Child in rainy season. For Adult and Child, Mn^{4+}, Cr^{2+}, Pb^{2+}, Fe^{2+}, and Cd^{2+} emerged as the most important pollutants leading to non-carcinogenic concerns via ingestion route and dermal contact of surface and ground water in both the dry and rainy seasons. However, Childs were more vulnerable to adverse health risks than Adults. The results demonstrated that the inputs of Mn^{4+}, Cr^{2+}, Pb^{2+}, Fe^{2+}, and Cd^{2+} should be reduced and managed on priority basis in the area. It is also suggested that the metals pollution should be considered as a vital part for future planning and management strategies for restoration of water quality of the selected landfill area. Additionally, the values of correlation coefficient will help in selecting proper treatment to minimize surface and ground water pollution as well as reduces the range of uncertainty associated with decision making for risk assessment.

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