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Characterization of Solid Waste Leachate and Its Impact on Surface Water Quality: A Case Study at Rajbandh, Khulna, Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author NH designed the study, field work done by FM while MNNL helped in collecting data under the supervision of SIM. FM and SIM wrote the first draft of the manuscript whereas SIM and SCS performed the statistical analysis. FM, SIM, SCS, MAR and NH was involved in the visualization of the results. Also, MAR prepared the study area map and details in GIS. All authors read and approved the final manuscript.

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ABSTRACT

The present study was carried out to characterize leachate from waste dumping site and its impact on surrounding surface water quality at Rajbandh in Khulna. For this purpose, surface water samples (10) and leachate samples (5) were taken from the site during two season the monsoon season and post monsoon respectively. The samples were taken during the daytime from 9 a.m. to 1 p.m because at midday the temperature rises and the physico-chemical parameters of the water are modified. Some physico-chemical parameters such as pH, Electrical conductivity (EC), Total dissolved Solids (TDS), Dissolve Oxygen (DO), Chloride (Cl^-), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Sodium (Na+), Potassium (K^+), Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Iron (Fe^{2+}), Phosphate (PO_4^{3-}), Sulfate (SO_4^{2-}), Nitrate (NO_3^{2-}) were analyzed in the laboratory in accordance with standard laboratory procedure. As well as some heavy metals such as Cadmium, Chromium, Lead, Manganese, Iron and Zinc were also analyzed in the laboratory. It is observed that, the physicochemical characteristics of surface water and leachate samples vary

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among the parameters in two seasons throughout the study period. The concentration of TDS and EC were found to be high in leachate compare to surface water samples that might be caused due to the existence of high-level various anions and soluble salts with other inorganic components. In monsoon the TDS values ranged from 3227 ± 2357 for leachate and 737 ± 498 for surface water samples whereas in post-monsoon the variation followed by 4640 ± 1790 and 803 ± 232 for surface water and leachate respectively. In case of EC for leachate it varied from 3630 ± 1397 and 4900 ± 1734 for monsoon and post-monsoon seasons correspondingly but varied from 1473 ± 498 in monsoon and 1627 ± 473 in post-monsoon for surface water samples. The high concentration of BOD (3.91 ± 1.54 in monsoon and 6.25 ± 3.27 in post- monsoon) and COD (117.80 ± 58.31 in monsoon and 229.39 ± 166.55 in post-monsoon) value were found in surface water samples compared to leachate samples. In case of Cr for leachate it varied from 0.081 ± 0.029 and 0.070 ± 0.026 for monsoon and post-monsoon seasons correspondingly. As well as the concentration of Cd (0.023± 0.006 in monsoon and 0.087±0.068 in post monsoon) and Pb (0.35±0.109 in monsoon and 0.025±0.013 in post monsoon) varied greatly during both season. The concentration of heavy metals such as Pb, Zn, Cr and Mn in surface water samples was also greater than 0.001mg/l. Further for leachate COD was very strongly correlated with TDS and cadmium. Magnesium was significantly correlated with potassium. For surface water sample TDS was significantly correlated with EC and pH. Chloride was significantly correlated with Cd and pb was correlated with calcium. This study recommended that the authority should take proper steps for the management of waste as well as give emphasis on the leachate collection.

Keywords: Municipal solid waste; landfill; leachate; surface water quality; heavy metal; seasonal variation.

1. INTRODUCTION

Leachate is a liquid containing innumerable organic and inorganic compounds which are formedprimarily by the percolation of precipitation through an open landfill or through the cap of a completed site [1,2]. It ishigh-strength wastewater entering landfills and exists in the disposal site when it is decomposed. Its composition varies greatly from site to site depending on several factors such as the age of the landfill, waste generation rate, treatment process, types of waste and the decomposition rate, etc. [3]. The world is urbanizing at an unprecedented rate as a result the generation of municipal solid waste (MSW) become faster. For instance, MSW generation increased from 0.68 to 1.3 billion tons, and per capita generation increased from 0.64 to 1.2 kg/day, which become almost double within 10 years. It is one of the major concerns all over the world whereas land filling is the cheapest, simplest, most cost-effective method of disposing of waste in both developed and developing countries [4]. Like Malaysia and Nepal, Bangladesh is highly dependent on landfilling as the main disposal method in managing this continuous increase in solid waste generation annually. In 1995 urban Bangladesh generated 0.49 kg/person/ day waste which is estimated to increase to 0.6 kg by 2025 due to the rapid and high growth of the urban population [5]. In Khulna city, rapid urbanization occurred due to intensive commercial and industrial activities and has put tremendous pressure on its existing solid waste management. Besides this in Khulna, the daily generation of Municipal solid waste (MSW) is estimated as 520 Mg, of which food and vegetable wastes are the main components (79% on average). The major source of generated MSW is from residential areas, commercial areas, institutional areas, street sweeps, and others whereas residential areas contribute 85.87% of the total generation of waste, commercial areas contribute 11.60%, in the case of institutional areas it is 1.02%, 0.55% in street sweeps and 0.96% in other areas. About 50% of the total generated waste is disposed of daily at the dumping site and the rest remains uncollected and unmanaged [6]. Moreover, in Khulna city, there are seventeen primary solid waste disposal sites and one ultimate waste disposal site namely Rajbandh. As a result, almost all municipal solid waste is dumped in the Rajbandh landfill site, where a large amount of leachate is produced every day. Poor waste collection systems and inadequate transportation systems are responsible for the accumulation of MSW at every nook and corner of Khulna cities. During the rainy season, the dumped solid wastes receive water, and the by-products of its decomposition move into the water through the waste deposition. Moreover, it has a large number of adverse impacts on water quality, human health as well as the surrounding environment. For many decades landfills are served as the ultimate disposal site for a municipal area. Poorly-constructed or inadequately managed disposal sites can create a number of adverse environmental impacts such as wind-blown litter, the attraction of vermin, and the generation of liquid leachate. Population explosion, rapid urbanization, industrial and technological expansion, energy utilization and wastes generation from domestic and industrial sources have rendered many water resources related issues [7]. Several studies have recorded the precedent of groundwater and surface water contamination near waste dumpsites [8,9]. The present study is designed to characterize the leachate and impact of solid waste leachate on surface water quality, analyzing the Physico-chemical parameters and heavy metals of leachate and surface water sample in the laboratory. Leachate characterization, surface water quality analysis, and the seasonal variation of the major ions in surface water were explained. To improve landfill leachate management and protect water resources from contamination the result will be helpful.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at the Rajbandh Waste disposal site. It is located on the north side of the Khulna-Satkhira highway and is approximately 8 km far from the city center [10]. It is a suburb in Khulna division and situated in north of koija bazar and northwest of Thikarabad. In general, 17 primary disposal sites and 1ultimate disposal site (Rajbandh) are found in Khulna city. Geographically, Khulna lies between 22°47'16" to 22°52'0" north latitude and 89°31'36" to 89°34'35" east longitude [11].The climate in Khulna is humid and warm, affected by pre-monsoon, monsoon, and post-monsoon circulation, and frequent heavy rains and tropical cyclones. The average annual precipitation in Khulna is 1605 mm. Moreover, about 87% of the average annual precipitation occurs from May to October. The months with the greatest precipitation are July, August, and June with 890 mm of precipitation. Most precipitation occurs in July with an average precipitation of 332 mm. The highest precipitation was observed in July and the lowest in December with a precipitation difference of 324mm [12].The location of Rajbandh disposal site is presented in Fig. 1.

2.2 Leachate Collection and Characterization

To identify the effect of leachate on surface water, 5 leachate samples were collected at different points of the ultimate disposal site. Leachates were collected twice during two seasons (monsoon and post-monsoon). At each time, a total of 5 liters of samples were collected from 5 sampling points by opening a 0.5 m hole. The temperature of each bottle was maintained at 4°C before the required test [13]. The samples were collected in July and November (monsoon and post-monsoon) in the daytime from 9 am to 1 pm. The temperature is increasing at noontime and the Physico-chemical parameters of water are changed [14].

2.3 Surface Water Collection

To understand the effect of leachate on surface water,10 surface water samples were collected from 10 different spots around the ultimate disposal site (Rajbandh). Water samples were collected by using the grab sampling technique. Surface water samples were collected in 500ml plastic bottles at 15-30 cm below the water surface and 40-80 cm from the water reservoir [15]. Before sample collection, the sample bottles were rinsed with the water (that is taken as sample water) three times. After that, the water sample was collected safely within 200 meters of the leachate collection point. After the collection of the water sample, the bottles were sealed with an appropriate label [16].Try to avoid aeration during sampling. Then the water samples were carefully transported to the laboratory for relevant physical and chemical analysis. Site specifications for sampling points are presented in Table 1.

2.4 Laboratory Analysis

The parameters analyzed for surface water and leachate include pH, Electric conductivity (EC), Total Dissolved Solids (TDS), Dissolve Oxygen (DO), Chloride (Cl^-), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Sodium (Na^+), Potassium (K^+), Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Iron (Fe^{2+}), Phosphate (PO_4^{3-}), Sulfate (SO_4^{2-}), Nitrate (NO_3^{2-}), Cadmium (Cd^{2+}), Chromium (Cr^{3+}), Lead (Pb^{2+}), Manganese (Mn^{2+}) and Zinc (Zn^{2+}) in the laboratory according to internationally accepted procedure and standard methods [17]. Table 2 represents various methods and instruments which are used for laboratory analysis of different parameters.

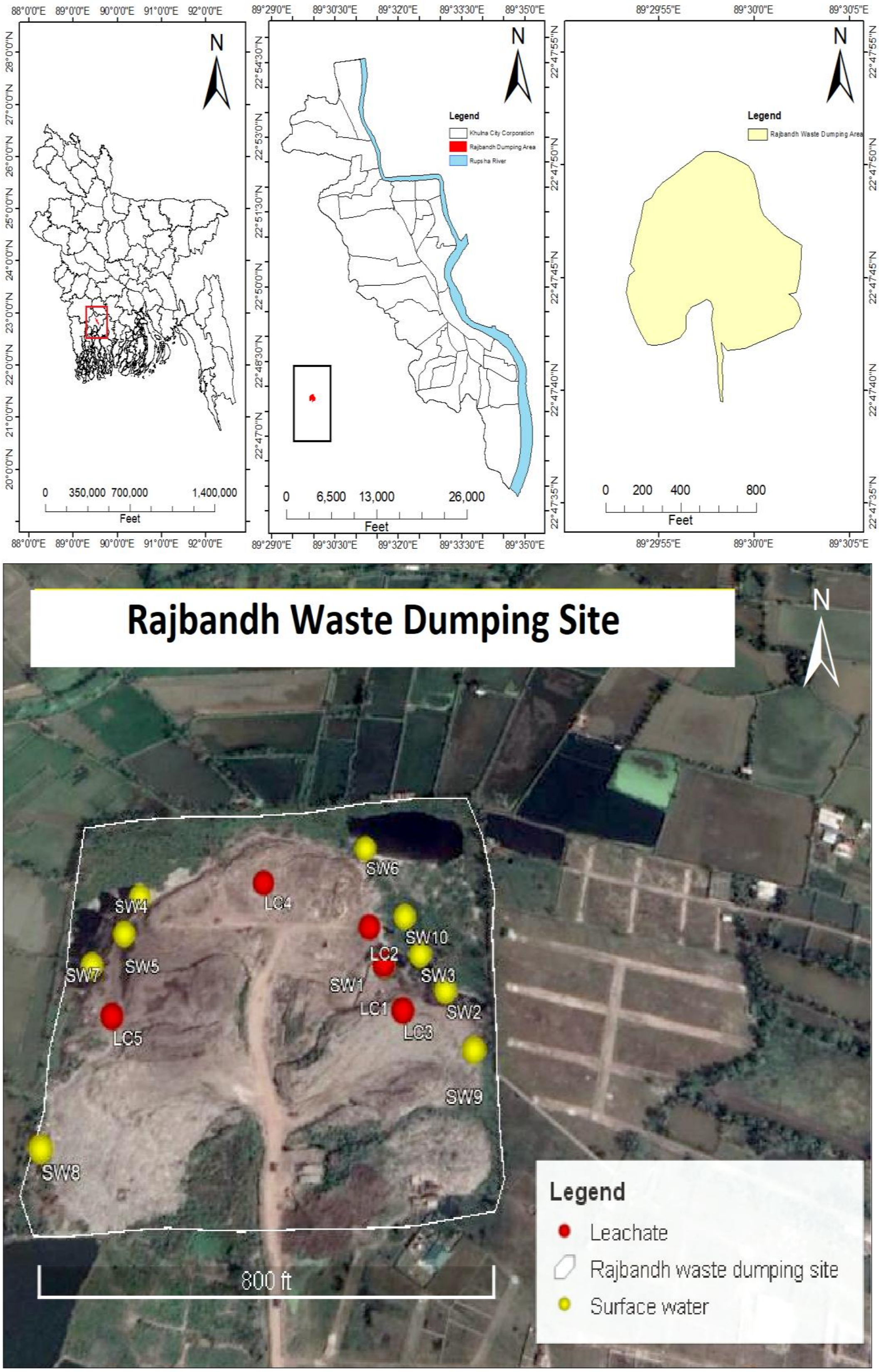

Fig. 1. Study area map with sample locations

Table 1. Site specification for sampling

Type		Latitude and Longitude	Notation
Leachate(5)	Leachate 1	$22^0$79'20.5"N $89^0$50'23.2"E	LC1
	Leachate 2	$22^0$79'16.3"N $89^0$47'21.6"E	LC2
	Leachate 3	$22^0$79'72.3"N $89^0$50'31.1"E	LC3
	Leachate 4	$22^0$79'44.5"N $89^0$49'49.5"E	LC4
	Leachate 5	$22^0$79'26.7"N $89^0$49'38.5"E	LC5
Surface water(10)	Surface water 1	$22^0$79'30.7"N $89^0$49'87.8"E	SW1
	Surface water 2	$22^0$79'32.5"N $89^0$49'74.5"E	SW2
	Surface water 3	$22^0$79'69.2"N $89^0$50'33.3"E	SW3
	Surface water 4	$22^0$79'72.3"N $89^0$50'31.1"E	SW4
	Surface water 5	$22^0$79'47.2"N $89^0$50'24.5"E	SW5
	Surface water 6	$22^0$79'46.1"N $89^0$49'38.0"E	SW6
	Surface water 7	$22^0$79'16.3"N $89^0$48'67.0"E	SW7
	Surface water 8	$22^0$79'46.7"N $89^0$49'38.5"E	SW8
	Surface water 9	$22^0$79'36.6"N $89^0$50'15.5"E	SW9
	Surface water 10	$22^0$79'26.1"N $89^0$48'25.8"E	SW10

Source: field survey, 2019

Table 2. Details of methods/ instruments used in analysis of Parameters

Parameters	Methods/ Instruments
pH	ORP meter (HANNA instruments, Hi 2211)
Electric conductivity(EC)	Portable Multi-parameter Meter (BANTE INSTRUMENTS, 900P)
Total dissolved Solids (TDS)	Portable Multi-parameter Meter (BANTE INSTRUMENTS, 900P)
Dissolve Oxygen (DO), Biological Oxygen Demand (BOD_5)	Dissolved oxygen meter (LT, Lutron DO-5519)
Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Chloride (Cl^-)	Titration method
Sodium (Na^+), Potassium (K^+)	Flame photometric method PFP7 Flame Photometer (JENWAY)
Chemical Oxygen Demand (COD), Iron (Fe^{2+}), Sulfate (SO_4^{2-}) Nitrate (NO_3^{2-}), Cadmium (Cd), Chromium (Cr), Lead (Pb), Manganese (Mn)	Ultra-violate Spectrophotometer, Screening Method (UNICO, 4802 UV/ VIS DOUBLE BEAM SPECTROPHOTOMETER

Source: APHA-1994

2.5 Data Processing and Statistical Analysis

After the collection of information from the field and laboratory, initially, data were processed and analyzed manually later placed on the Microsoft office 2013 and Microsoft excel 2013. After that Statistical Package for Social Sciences (SPSS 25.00 version) was used to explore multiple inter-relationships among all the physico-chemical parameter and heavy metals. Pearson's correlation was carried out by using SPSS.

3. RESULTS AND DISCUSSION

3.1 Leachate Characterization

The results obtained from the physico-chemical analysis of leachate from waste dumpsite are presented in Table 3. The pH values for the five leachate samples observed ranged from 8.27 to 8.6, with a mean value of 8.38 in the monsoon season whereas during the post-monsoon the pH value ranged from 7.39 to 8.53, with the mean value of 8.01. The pH value of the leachate was alkaline that representing the biological stabilization of the organic components [18].The leachate LC5 with a pH of 8.6 is, therefore, more alkaline than the other four samples in case of monsoon as well the leachate LC2 with a pH of 8.53 is, therefore, more alkaline than the other four samples during post-monsoon season.

The electrical conductivity (EC) values for the five leachate samples show different values, in which LC5 has the highest value of 5560 μS/cm, while the lowest value of 1569 μS/cm was recorded for the LC2 leachate samples during monsoon. Besides the highest value of 6600μS/cm was recorded for the LC4 and the lowest value of 2790μS/cm was found for LC2 leachate samples during Post-monsoon. Therefore the concentration of EC was high indicating the presence of inorganic materials or components in the leachate samples.

Among the five leachate samples,there is effective variation in the values of total dissolved solids (TDS), of which during the monsoon LC2 has the highest value of 7845 mg/l, and the lowest value of 170 mg/l was observed in LC1. On the other hand in post-monsoon, the highest value of 6970 mg/l was recorded for LC3 samples whereas the lowest value was found for LC1 samples. The values of DO were relatively different for all leachate samples and the highest value was found in monsoon for the sample LC4. There is a little variation in the value of BOD during monsoon but in post-monsoon, the highest value was observed in LC1. The concentration of COD in the leachate ranged from 19.38mg/l to 135.62mg/l, with a mean value of 75.18 mg/l in monsoon as well as the concentration of COD in the leachate ranged from 21.13mg/l to 205.37mg/l, with a mean value of 86.03 mg/l during post-monsoon.

In monsoon season the value of Cl^- ranged between 21.27mg/l and 85.08mg/l, LC2 has the lowest value and LC3 has the lowest value of 85.08mg/l. But in post-monsoon this value ranged from 166.62 mg/l to 584.93 mg/l, with mean value of 336.07 mg/l. Other anions analyzed include sulphates (SO_4^{2-}) and phosphates (PO_4^{3-}) and nitrate (NO_3^-). The values of sulphate are also variable as the value of LC3 is 12.51mg/l, which is the leachate with the highest value and LC1 the least, with a value of 3.07mg/l in monsoon. The values of sulphate ranged from 1.30mg/l to 8.30mg/l in post-monsoon with a mean value of 5.51mg/l. There is a slight variation in the value of phosphate and nitrate during both seasons. However, the presence of phosphate and nitrate in leachate is dangerous as its presence in water increases eutrophication and correspondingly promotes the growth of algae [19]. Prolong erosional deposition, leakage or leaching from nearby sewage might be the cause of loading variation of some parameters like sulfate and nitrate etc. [20].Various cations analyzed including sodium, potassium, calcium, magnesium were presented in this Table 3.

The heavy metals content of the leachate samples obtained from the laboratory analysis includes lead (Pb), zinc (Zn), iron (Fe2+), chromium (Cr) and manganese (Mn) are also represented in table 3. The concentration of Pb was small,but it is attributed to the availability of Pb related wastes such as paints, chemicals fromphotography processing andbatteries in the dumpsite [21].Incase of Cr for leachate it varied from 0.081 ± 0.029 and 0.070 ± 0.026 for monsoon and post-monsoon seasons correspondingly. As well as the concentration of Cd (0.023± 0.006 in monsoon and 0.087±0.068 in post monsoon) and Pb (0.35±0.109 in monsoon and 0.025±0.013 in post monsoon) varied greatly during both season. The presence of Cr in the leachate samples may have produced from the emission of automobile vacate from diesel tanker vehicles. The different heavy metals found were an indication that the Rajbandh waste dumpsite receives a diversity of wastes that reflect the origin of Pb, Zn, Fe, Cr and Mn [1].Heavy metals exist in batteries, electronic goods, pesticides, industrial effluents and painting waste increase the poisonous health and environmental effects due to percolation of leachate when dumped with municipal wastes in dumpsites [22, 23].

3.2 Surface Water Quality Analysis

The seasonal variations of physical and chemical attributes of surface water sample are shown in Fig. 2 and Fig. 3 respectively. The Physico-chemical characteristics of surface water samples during monsoon and post-monsoon seasons are also presented in annex (Table A and Table B).The value pH of the surface water samples was in the range of 8.2 to 9.43 with a mean value of 8.75 during monsoon. And the highest pH values of 9.34 were observed in SW6 in post-monsoon. The obtained EC ranged from 835 to 2500μS/cm for surface water samples during the period of monsoon, whereas the surface samples have values that varied from 893-2710μS/cm during post-monsoon. The EC values were high and they must have been caused by the outflow of leachate into surface water bodies enhanced by precipitation. In monsoon, the concentrations of TDS in surface water varied between 410 and 1274 mg/l in the study area, whereas in post-monsoon those values ranged between 494 and 1360 mg/l. Therefore, the high level of TDS may be responsible for the reduction in the palatability of water, inflict gastro-intestinal inconveniences in humans, and may also cause a laxative effect, particularly upon transits [19]. The concentration of COD in the surface water samples was higher indicating the presence of organic matter in samples.

The value of Na+ ions in the surface water samples varied from 5.53 to 15.65mg/l during monsoon and the highest value was recorded for SW1; the high value may have been influenced by leachate. The consumption of water with a high concentration of Na+ ions is inimical to people with cardiac, renal, and circulatory diseases [19].On the other hand, the values for the surface water in post-monsoon were relatively higher, ranging from 7.12- 20.98 mg/l, with SW4 having the maximum value. The highest value of K+ was found in SW3 during both seasons. A high concentration of Ca^{2+} was found in SW10 and SW5 during monsoon and post-monsoon respectively.

Table 3. Physicochemical characteristics and heavy metal content of leachate

Parameters	Monsoon					Post-monsoon				
	LC1	LC2	LC3	LC4	LC5	LC1	LC2	LC3	LC4	LC5
pH	8.34	8.34	8.37	8.27	8.60	8.41	8.53	7.62	7.39	8.10
EC	2940	1569	3340	4740	5560	6550	2790	2830	6600	5730
TDS	1470	7845	1670	2370	2780	3450	6623	6970	2648	3511
DO	3.52	4.59	3.06	5.1	3.75	2.4	3.32	3.05	3.97	2.71
BOD	1.48	1.27	1.94	0.86	1.54	3.59	2.76	3.45	2.68	3.34
COD	19.38	135.62	89.13	50.38	81.38	65.88	205.37	27.13	50.38	81.38
Na^+	13.63	9.68	15.72	19.34	23.47	32.89	21.55	32.84	37.75	34.14
K^+	7.37	6.35	4.65	6.15	5.29	33.18	46.44	32.61	28.04	19.03
Ca^{2+}	16.97	7.12	12.54	15.8	14.13	7.53	1.76	5.21	7.31	5.79
Mg^{2+}	22.21	22.85	22.54	21.94	22.01	19.32	19.19	19.17	18.85	18.43
Cl^-	46.09	21.27	85.08	53.18	77.99	301.33	166.62	584.93	287.15	340.32
SO_4^{2-}	3.07	6.62	12.51	7.07	9.95	1.30	8.40	7.29	3.96	6.62
NO_3^-	2.09	0.65	2.46	0.86	1.27	2.00	0.38	2.27	0.74	0.91
PO_4^{3-}	0.69	0.66	1.12	1.33	1.4	0.27	1.05	0.98	1.59	1.54
Cr	0.022	0.13	0.029	0.025	0.028	0.045	0.201	0.028	0.031	0.129
Fe	0.04	0.055	0.106	0.114	0.091	0.030	0.051	0.081	0.102	0.086
Pb	0.073	0.099	0.108	0.132	0.153	0.241	0.257	0.142	0.193	0.212
Mn	0.266	0.332	0.313	0.567	0.294	0.045	0.034	0.022	0.012	0.013
Zn	0.159	0.064	0.044	0.071	0.093	0.081	0.086	0.031	0.051	0.071

Source: Field Survey, 2019(All units are in mg/l except conductivity which is μS/cm and pH); Note: EC = Electrical conductivity, TDS =Total dissolved solids (TDS), DO = Dissolved oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, LC=Leachate

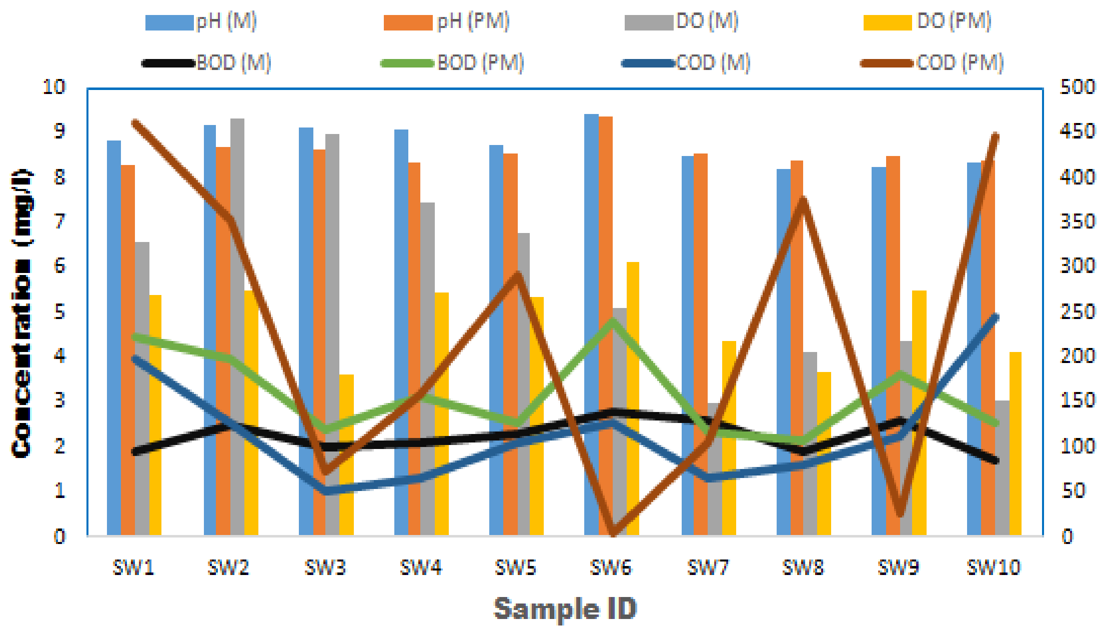

Fig. 2. Seasonal variation of physical attributes in SW samples

Note :(*SW = Surface Water, DO = Dissolved oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, M=Monsoon, PM=Post monsoon)*

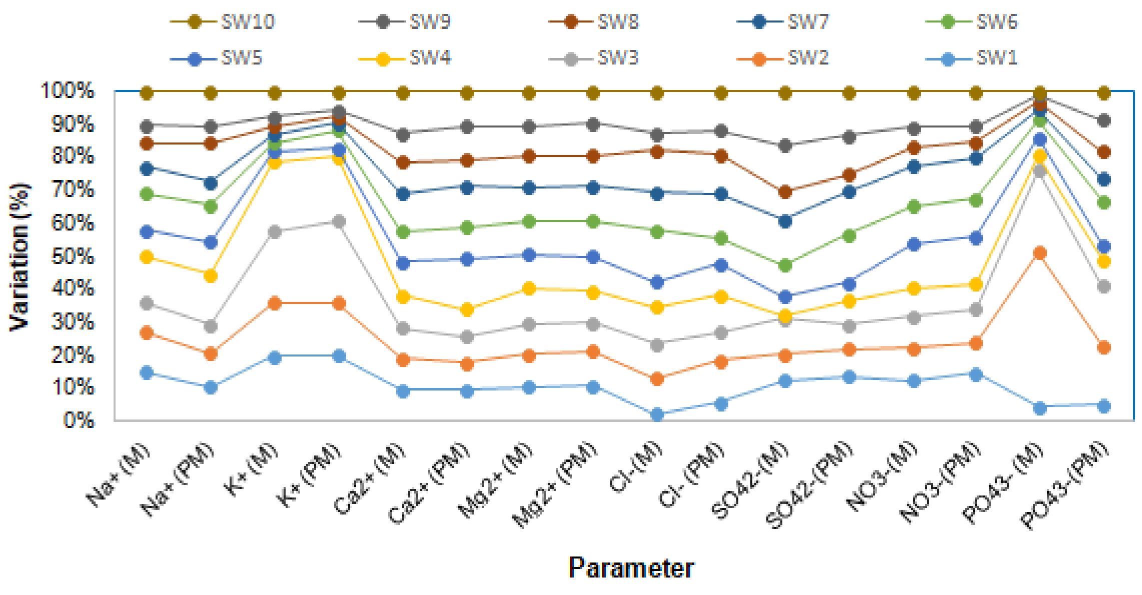

Fig. 3. Seasonal variation of chemical attributes of SW samples in monsoon and post-monsoon season

(Note: SW = Surface Water, M=Monsoon, PM=Post monsoon)

The content of Mg^{2+} in the surface water ranged from 18.7mg/l to 22.1mg/l during monsoon and showed little variation in post-monsoon as compared to monsoon. There is a low concentration of NO_3^- in the sample during both seasons which indicates some level of pollution by leachate. The range of the concentration of sulfate and phosphate varied from monsoon to post-monsoon. The concentrations of Cl^- were in the range of 53.18 to 372.23mg/l and a significant proportion was found in SW6 during the period of monsoon. Whereas the value obtained for the post-monsoon season varied from 212.7- 496.3 mg/l, with a mean value of

Table 4. Pearson's correlation analysis Leachate samples (Average values of two seasons)

Parameters	pH	EC	TDS	DO	BOD	COD	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cd	Cr	Fe	Pb	Mn
pH	1																		
EC	-.291	1																	
TDS	.401	-.891*	1																
DO	-.440	.097	.153	1															
BOD	.272	-.134	-.156	-.979**	1														
COD	.543	-.672	.927*	.275	-.336	1													
Na^+	-.549	.887*	-.861	-.014	.066	-.773	1												
K^+	.316	-.816	.740	.204	-.234	.626	-.945*	1											
Ca^{2+}	-.389	.834	-.990**	-.168	.168	-.942*	.785	-.640	1										
Mg^{2+}	.269	-.913*	.687	-.143	.159	.448	-.890*	.906*	-.581	1									
Cl^-	-.472	.036	-.319	-.540	.693	-.578	.454	-.481	.296	-.089	1	.							
SO_4^{2-}	-.183	-.381	.465	-.054	.179	.337	-.004	-.157	-.553	.011	.492	1							
NO_3^-	-.130	-.053	-.373	-.783	.856	-.640	.172	-.168	.428	.224	.782	-.034							
PO_4^{3-}	-.525	.485	-.210	.451	-.373	-.085	.656	-.666	.085	-.756	.183	.523	-.427	1					
Cd	.714	-.412	.744	.117	-.223	.920*	-.568	.344	-.791	.161	-.590	.291	-.658	.018	1				
Cr	-.804	.365	-.265	.389	-.241	-.293	.668	-.601	.171	-.572	.475	.571	-.124	.904*	-.310	1			
Fe	.534	.267	.153	.355	-.513	.512	-.071	-.043	-.214	-.385	-.796	-.187	-.822	.237	.727	-.188	1		
Pb	-.747	.322	-.211	.899*	-.830	-.159	.295	-.026	.207	-.275	-.231	-.145	-.470	.487	-.324	.559	.042	1	
Mn	.670	.292	-.275	-.281	.095	-.071	-.114	.080	.326	-.047	-.535	-.821	-.004	-.562	.130	-.779	.463	-.345	1

***. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed)*

Table 5. Pearson's correlation analysis surface water samples (Average values of two seasons)

	pH	EC	TDS	DO	BOD	COD	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cd	Cr	Fe	Pb	Mn
pH	1																		
EC	.844**	1																	
TDS	.840**	.991**	1																
DO	.599	.444	.399	1															
BOD	.636*	.555	.579	.453	1														
COD	-.403	-.082	-.047	-.108	-.192	1													
Na^+	.334	.658*	.586	.408	.145	.355	1												
K^+	.258	.369	.316	.671*	.034	.091	.564	1											
Ca^{2+}	-.275	-.248	-.207	-.393	-.298	.182	-.304	-.515	1										
Mg^{2+}	.234	.380	.392	.099	.509	.301	.332	-.160	.481	1									
Cl^-	.132	.009	-.017	-.292	-.326	-.102	.124	-.255	.081	-.100	1								
SO_4^{2-}	-.165	-.055	.054	-.533	.194	.158	-.407	-.264	.217	.176	-.191	1							
NO_3^-	.327	.442	.475	.167	.170	.243	.201	.103	.596	.711*	-.165	.206	1						
PO_4^{3-}	.519	.184	.194	.608	.207	-.116	.024	.462	-.469	-.290	.213	-.167	-.077	1					
Cd	-.569	-.511	-.566	-.466	-.588	.208	.104	-.229	.172	-.093	.648*	-.222	-.378	-.246	1				
Cr	.207	.037	.106	-.151	.510	-.295	-.452	-.205	-.446	-.193	-.173	.566	-.268	.259	-.446	1			
Fe	-.610	-.717*	-.686*	-.281	-.331	.495	-.330	-.483	.358	-.002	.191	-.034	-.252	-.054	.536	-.205	1		
Pb	-.026	-.109	-.109	.177	-.174	.077	-.137	-.285	.670*	.284	-.168	-.397	.441	-.234	-.125	-.564	.306	1	
Mn	.251	.228	.175	.025	.347	.010	.439	-.107	-.156	.471	.546	-.171	-.030	.071	.446	.020	.038	-.316	1

*** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).*

375.77 mg/l. Among the heavy metals analyzed, the observed value of Fe^{2+} in the surface water samples ranged from 0.041- 0.142mg/l and 0.101-0.153 mg/l in monsoon and post-monsoon respectively. The corresponding values of Pb, Zn, Cr and Mn in surface water samples were also greater than 0.001mg/l. The very low concentrations of heavy metals recorded in the study underpin the roles played by the occurrence of organic soils and clayey soils underneath the municipal waste dumpsite in the sorption of heavy metals [24].

3.3 Statistical Analysis

Some of the parameters were found to have statistically significant correlation with each other. According to Table 4 in leachate samples, COD was very strongly correlated with TDS. Magnesium was significantly correlated with potassium. Cadmium was also well correlated with COD. According to Table 5 in surface water samples, TDS was significantly correlated with EC and pH. Chloride was significantly correlated with Cd and pb was correlated with calcium.

4. CONCLUSION

From the study, it is observed that the physicochemical characteristics of surface water and leachate samples vary among the parameters in two seasons throughout the study period. The concentration of TDS and EC were found to be high in leachate compare to surface water samples which might be caused due to the existence of high-level various anions and soluble salts with other inorganic components. The high concentration of BOD (3.91 ± 1.54 in monsoon and 6.25 ± 3.27 in post-monsoon) and COD (117.80 ± 58.31 in monsoon and 229.39 ± 166.55 in post-monsoon) values were found in surface water sample compared to leachate samples. BOD varied from 1.42 ± 0.35 and COD varied from 75.18 ± 39.03 in the monsoon while BOD and COD varied from 3.16 ± 0.37 to 86.03 ± 62.31 respectively in post-monsoon that representing the proportion of waste evolved from the biological processes. The concentration of heavy metals (cadmium, iron, lead, manganese, and zinc) was found in percolate to the surrounding surface water of the Rajbandh disposal site. COD, Cadmium, Chromium, Lead, and Manganese were above the permissible limit recommended by Bangladesh standards in surface water and cause strong contamination of water and surrounding agricultural land. From the study, it is observed that there is no systematic waste dumping system as well as improper management of solid waste, which creates a tremendous impact on the quality of surface water. During the period of monsoon, leachate runoff occurred in this area as a result conditions become worse. In the study, it is easily concluded that surface water around the disposal site is not safe or appropriate for domestic purposes. However, it is highly recommended that the authority should take proper steps for the management of waste that is dumped in the study area as well as give emphasis on the leachate collection. Further authority can take action for the development of a proper waste disposal system.

DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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ANNEX (Data)

Table A. Physico-chemical characteristics and heavy metal concentration in surface water (SW) samples in monsoon

Sample ID	pH	EC	TDS	DO	BOD	COD	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cr	Fe	Pb	Mn	Zn
SW1	8.8	2028	1027	6.57	1.9	197.62	15.65	3.14	6.08	21.93	53.18	9.51	2.57	0.04	0.013	0.017	0.065	0.002	0.065
SW2	9.17	1427	719	9.31	2.5	127.87	12.41	2.61	5.95	20.41	248.15	6.07	2.10	0.43	0.018	0.017	0.133	0.002	0.084
SW3	9.13	1486	744	8.98	2.0	50.38	9.37	3.42	6.01	19.44	248.15	8.29	2.03	0.23	0.011	0.017	0.041	0.002	0.053
SW4	9.08	1863	940	7.45	2.1	65.88	14.52	3.39	6.1	22.1	265.88	0.85	1.78	0.04	0.023	0.015	0.055	0.002	0.081
SW5	8.7	1041	518	6.74	2.3	104.63	8.28	0.52	6.65	21.39	177.25	4.41	2.84	0.05	0.017	0.015	0.142	0.002	0.065
SW6	9.43	2500	1274	5.1	2.8	127.87	11.67	0.38	5.73	21.43	372.23	7.29	2.42	0.05	0.013	0.018	0.056	0.002	0.08
SW7	8.46	1118	558	2.98	2.6	65.88	8.54	0.39	7.4	21.14	265.88	10.51	2.54	0.03	0.025	0.017	0.080	0.002	0.077
SW8	8.2	985	458	4.1	1.9	81.38	7.68	0.42	6.02	19.73	301.33	6.51	1.24	0.02	0.021	0.017	0.098	0.002	0.072
SW9	8.23	835	410	4.35	2.6	112.38	5.53	0.46	5.55	18.79	124.08	10.84	1.22	0.02	0.016	0.018	0.098	0.002	0.059
SW10	8.33	1448	723	3.04	1.7	244.12	10.74	1.25	8.1	22.1	301.33	12.62	2.34	0.01	0.023	0.016	0.112	0.002	0.069
Min	8.20	835	410	2.98	1.70	50.38	5.53	0.38	5.55	18.79	53.18	0.85	1.22	0.01	0.01	0.02	0.04	0.00	0.05
Max	9.43	2500	1274	9.31	2.80	244.12	15.65	3.42	8.10	22.10	372.23	12.62	2.84	0.43	0.03	0.02	0.14	0.00	0.08
Mean	8.75	1473.10	737.10	5.86	2.24	117.80	10.44	1.60	6.36	20.85	235.75	7.69	2.11	0.09	0.02	0.02	0.09	0.00	0.07
SD	0.44	524.47	274.68	2.30	0.37	61.46	3.17	1.37	0.80	1.19	93.44	3.46	0.55	0.13	0.00	0.00	0.03	0.00	0.01

Source: Field Survey, 2019 (All units are in mg/l except conductivity which is µS/cm and pH)

Note: SW = Surface Water, EC = Electrical conductivity, TDS =Total dissolved solids (TDS), DO = Dissolved oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand

Table B. physico-chemical characteristics and heavy metal concentration in surface water (SW) samples in post-monsoon

Sample ID	pH	EC	TDS	DO	BOD	COD	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	NO_3^-	PO_4^{3-}	Cr	Fe	Pb	Mn	Zn
SW1	8.26	1634	810	5.40	4.47	461.10	14.38	3.10	6.55	22.08	212.70	8.18	2.84	0.09	0.013	0.017	0.123	0.002	0.007
SW2	8.69	1674	828	5.47	3.94	352.61	13.95	2.45	5.82	21.75	478.58	4.85	1.88	0.32	0.018	0.016	0.123	0.002	0.001
SW3	8.61	1903	943	3.64	2.39	73.63	12.05	3.87	5.64	17.44	319.05	4.41	2.00	0.33	0.015	0.016	0.119	0.002	0.004
SW4	8.34	1806	723	5.45	3.13	158.87	20.98	3.05	5.82	19.52	425.40	4.41	1.52	0.14	0.020	0.014	0.131	0.002	0.003
SW5	8.55	1755	870	5.36	2.56	290.61	13.47	0.40	10.86	21.97	354.50	3.41	2.78	0.08	0.015	0.015	0.108	0.009	0.001
SW6	9.34	2710	1360	6.14	4.82	3.88	15.60	0.84	6.73	22.00	301.33	8.73	2.27	0.24	0.011	0.018	0.101	0.002	0.002
SW7	8.53	1212	593	4.34	2.33	104.63	9.48	0.34	8.66	21.96	496.30	7.85	2.48	0.12	0.016	0.017	0.129	0.002	0.007
SW8	8.36	1165	571	3.65	2.13	375.86	16.20	0.26	5.63	18.64	443.13	2.96	0.92	0.15	0.023	0.016	0.153	0.002	0.005
SW9	8.46	893	494	5.48	3.60	27.13	7.12	0.34	7.13	20.78	283.60	7.07	0.97	0.17	0.015	0.017	0.144	0.002	0.007
SW10	8.39	1515	839	4.13	2.55	445.60	14.71	0.89	7.53	19.64	443.13	8.18	2.10	0.16	0.019	0.016	0.139	0.002	0.001
Min	8.26	893	494	3.64	2.13	3.88	7.12	0.26	5.63	17.44	212.70	2.96	0.92	0.08	0.01	0.01	0.10	0.00	0.00
Max	9.34	2710	1360	6.14	4.82	461.10	20.98	3.87	10.86	22.08	496.30	8.73	2.84	0.33	0.02	0.02	0.15	0.01	0.01
Mean	8.55	1626.70	803.10	4.91	3.19	229.39	13.79	1.55	7.04	20.58	375.77	6.01	1.98	0.18	0.02	0.02	0.13	0.00	0.00
SD	0.31	498.52	244.07	0.88	0.96	175.56	3.77	1.40	1.66	1.67	94.83	2.21	0.67	0.09	0.00	0.00	0.02	0.00	0.00

Source: Field Survey, 2019 (All units are in mg/l except conductivity which is µS/cm and pH)

Note: SW = Surface Water, EC = Electrical conductivity, TDS =Total dissolved solids (TDS), DO = Dissolved oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand

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