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Landfill Leachate Characterization and Its Treatment by Biological Agents in Southwest Coastal Region of Bangladesh

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Abstract

This study was conducted with a view to characterizing the leachates collected from four sampling spots located in the southwest coastal region of Bangladesh for a period of two years, from January 2008 to December 2009. Five treatments each with 3 replications were used and both physical and chemical properties of leachates were studied.

The result seems that there is a significant variation in the composition of leachate at different locations and more complex situation were observed when the landfill situated at closest location to the saline zone.

Keywords: Landfill leachate, physico-chemical characteristics, biological treatment, Coastal Area, Saline zone.

Introduction

Inefficient management and disposal of solid waste is one of the most immediate and serious environmental problems confronting municipal authorities in developing countries like Bangladesh which causes degradation of the environment in the developing world. Landfills have served for many decades as ultimate disposal sites for all manner of wastes: residential, commercial, and industrial, both innocuous and hazardous. Poorly-designed or poorly-managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin, and generation of liquid leachate. Leachate can be defined as, the liquid that results when water comes in contact with a solid and extracts material, either dissolved or suspended, from the solid. On a composting facility site this refers to, liquid that has percolated through and drained from feedstock or compost and has extracted dissolved or suspended materials. Leachate from industrial and agricultural sources contain harmful substances for organisms which might enter human and other animal body through food materials grown using water which come into direct contact of these leachates [1]. Groundwater may also be affected by landfill leachates [2], [3],[4], [5],[6], [7]. Typical young leachate may have a chemical oxygen demand (COD) 36 times higher than raw sewage [8]. Depending on the location and the availability of land, up to 95% of generated solid waste of developing countries is disposed to the crude landfills directly [9]. The landfill solid waste produces poisonous leachate and has the possibility of contamination to surrounding ecosystem, environment and human health [10]. Past disposal of hazardous and solid waste in soils has resulted in ground-water contamination. At many of these waste sites, remediation of contaminated ground water involves extracting the ground water, then treating it *ex-situ*. In addition, modern land disposal facilities generate leachate that requires collection and treatment. Bangladesh is undergoing a rapid urbanization at a rate of 5% per year and experienced with mushrooming factories [11]. All of these are contributing a significant amount of solid waste of different origins (household, vegetable and other market, commercial, chemical, hospital and other wastes). In the major cities in Bangladesh, per capita production of solid waste 0.5 kg/day

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but only 0.2 kg of waste per capita is carried to the final disposal [12]. Therefore the wastes collected are dumped in a crude dumping site and after that no action is taken for the ultimate fate of the wastes. From the solid waste 'leachate' is produced and mix with surface and ground water and pose the threat to the environment. These types of activities are almost same all over the country and there is necessity for proper researches. But in Bangladesh a few researches have been conducted on this issue [13], [14], [15] which are not enough to understand the present scenario. Water has the ability to purify itself, which attaches its impurities and environmental factors which help the impurities in its ability to afford the source and treatment [16]. This rate is not enough to deal with the present situation in Bangladesh and but treatment of leachate may be an excellent solution to this problem. Thus the present was conducted which reveals leachate characterization and its treatment by using some locally available flora and fauna. The primary objective of the study was to characterize the conventional landfill leachate, both physically and chemically.

Materials and Methods

Study area and duration: To select the sampling sites and data collection a reconnaissance survey has been conducted in different areas of the KCC and Jessore town areas. The sites were selected based on the representative criteria. Sampling spots were Rajbandh, Gollamari, Nirala areas of Khulna district and Moilakhana in Jessore district (Fig. 1). This study was conducted for a period of two years, from January 2008 to December 2009.

Sampling framework: Field survey was carried out in the study areas for sampling. Each sampling site was divided into several parts and samples were collected randomly from those divisions for minimization of error. Samples were collected very conventionally using mug, gallon and funnel. Randomly collected samples were brought to the laboratory for further in depth analyses. Samples were prepared for the biological treatments by diluting them to five times with supplied tap water. These were divided into five divisions and kept in five open pots named '*Charhi*' (an open end rounded earthen pot) for treatment.

Four biological treatments along with one control were used to treat the conditioned (diluted) leachate (Table 1). These were kept under observations for 15 (fifteen) days in the laboratory and following parameters were studied- color, odor, temperature, pH, EC, TDS, sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{++}), magnesium (Mg^{++}), chloride (Cl^{-}), bicarbonate (HCO_3^{-}), carbonate (CO_3^{--}), ortho-phosphate (HPO_4^{--}), sulphate (SO_4^{--}), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD).

Data analyses: The data were analyzed using computer software Statistical Packages for Social Science (SPSS) version 15.00 and Microsoft Excel 2007.

Results

Effects of conditioning on the composition of leaches

The chemical composition of landfill leachate would vary greatly depending on the age of landfill and the history of events proceeding the time of sampling. The composition of the leachate also depends on the geographical location of the area. From this study it was clear that, some variation occurred depending on the location of sampling. The changes in different chemical parameters by the conditioning are presented in Table 2.

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pH: The value of pH has been increased in all the samples after conditioning (Table 2). Before conditioning, the highest value of pH (7.78±0.03) was recorded in the samples collected from Rajbandh and the lowest value (7.08±0.25) was found in samples collected from Jessore. Whereas, after conditioning, the highest value (8.57±0.35) was recorded in the samples from Nirala and the lowest value (7.76±0.41) was recorded in the samples collected from Jessore.

Bicarbonate is an intermediate version of carbonate and carbonic acid. All the pH was in the range of 7.00 to 8.69. According to the relationship between carbon dioxide and the three forms of alkalinity at various pH levels, within that range a very little or no carbon dioxide could be present in the sample and a very little or no carbonate present there. So conversion of bicarbonate was restricted by the pH level of the samples showed a reasonable effect for bicarbonate rather than others.

EC: The value of EC has been decreased in all the samples after conditioning (Table 2). Before conditioning, the highest value of EC (14.37±0.96 ms) was recorded in the samples collected from Gollamari and the lowest (5.64±0.50 ms) in the samples collected from Jessore. After conditioning, the highest (6.77±0.96 ms) EC was recorded in the samples from Gollamari and the lowest (5.13±0.86 ms) in the samples from Jessore.

TDS: Like pH, TDS values were also decreased after conditioning of the samples (Table 2). The highest value of TDS was found in the samples collected from Gollamari, both before (7.19±0.10 g) and after (4.72±0.18 g) conditioning. On the other hand, the lowest value was recorded in the samples from Jessore, both before (3.93±0.13 g) and after (3.5±0.23 g) conditioning.

Temperature: A little reduction in temperature was recorded in all the samples after conditioning (Table 2). Before conditioning, the highest and lowest values were recorded 27.5±0.28 ^{o}C (Jessore) and 26.8±0.21 ^{o}C (Nirala) respectively. Whereas, after conditioning, the highest and lowest values were measured 25.3±0.18 ^{o}C (Jessore) and 24.9±0.13 ^{o}C (Nirala) respectively.

Leachate color: Due to conditioning of leachate, its color has been changed to somewhat light. Black colored leachates were changed to brownish after the treatment in Gollamari and Nirala. The color of leachate collected from Jessore was reddish which turned into light reddish after conditioning (Table 2).

Odor of the leachate: After conditioning, the odor of the leachates was reduced to a considerable extent. Strong odor has been removed after conditioning (Table 2).

Sodium: Marked reduction in sodium was recorded after conditioning of leachate except for Gollamari where a little reduction took place (Table 2). Before conditioning, the highest amount of Na (7000±435.89) was recorded in the samples collected from Jessore. After conditioning, the lowest amount of Na (1600±360.56) was recorded in the samples collected from Rajbandh. Among treatments, duckweed reduced the amount of sodium significantly (Fig. 2).

Potassium: No changes in the potassium content were found before and after conditioning. This clearly indicated that the treatments used in the present study had no effects on the potassium contents (Table 2). Treatments had no great effect potassium in the present study.

Calcium: Both increase and decrease in the amount of calcium was recorded in the samples before and after conditioning (Table 2). After conditioning, increased amount of Ca was recorded in the samples collected from Rajbandh and Gollamari. Whereas. decreased amount of Ca was found in the samples collected from Nirala and Jessore.

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For calcium, most effective treatment was jute fiber but the duckweed was also reduced the amount of calcium a little (Fig. 3). A huge increment of calcium was found for the snail treatment. This is may be due to the decay of the shell of the snail, which is made of calcium carbonate. Water hyacinth also reduced calcium in a smaller amount.

Magnesium: Like Ca, amount of Mg also showed variation before and after the conditioning of leachates (Table 2). In the leachates collected from Rajbandh and Jessore its amount had been increased after conditioning; whereas, the amount was reduced in the other two samples from Gollamari and Nirala. No great effects on magnesium was found of the treatments.

Sulphate: The highest amount of sulphate was detected in the samples collected from Jessore, 200±57.66 and 201±44.53, before and after conditioning respectively (Table 2). In the samples collected from other three spots, sulphate content was found very low, ranged from 3.9 to 10.9 ppm before conditioning and 1.10 to 9.9 ppm after conditioning.

During treatments, the amount of sulphate was increased (mainly due to jute fiber) to an amount of double or triple (Fig. 4). It was because of the conversion of other forms of sulpher into sulphate in aerobic condition on the presence of aerobic bacteria. In spite of that occurrence, duckweed and water hyacinth showed a positive effect on sulphate than others *i.e.* it reduced the production of sulphate comparatively to the other treatments (Fig. 3).

Ortho-phosphate: The amount of ortho-phosphate has been reduced to a great extent after the conditioning of the leachates (Table 2). Before conditioning, the lowest amount (6 ppm) was recorded in the samples collected from Rajbandh which reduced to 0.8 ppm after the conditioning of the samples. Again before conditioning, the highest quantity (70±13.23 ppm) of ortho-phosphate was recorded in the samples collected from Nirala and it reduced to 22±4.58 ppm after conditioning of the leachates. In case of treatment's effects on ortho-phosphate, it was greatly reduced by the water hyacinth, In other case the concentration was increased.

Chloride: The chloride content has been increased in all the samples after the conditioning except for samples collected from Gollamari where it decreased from 2800±264.58 ppm to 2100±229.13 ppm (Table 2). A remarkable increase in chloride amount in the samples collected from Jessore was found where the amount of chloride increased by 5 times after the conditioning, from 300±52.68 ppm to 1500±180.28 ppm. In the leachate of Jessore the amount of chloride was significantly lower than that of other sampling points in Khulna. This was found because the Khulna city was nearer to coastal region than Jessore. No special effect of any treatment on chloride was found. All the treatments acted more or less the same. Only due to the evaporation chloride was found more in concentration at the end of the experiment.

Dissolved oxygen (DO): Low level of DO was found in all the leachate samples before conditioning (Table 2). The highest DO was found 4.2±0.26 mg/l in the samples collected from Rajbandh and the lowest DO level (2.43±0.12 mg/l) was recorded in the samples collected from Nirala.

BOD and COD: In the samples collected from Gollamari, Nirala and Jessore, a little variation was found the BOD levels (Table 2). Whereas, a small amount of BOD (53±3.61 mg/l) was found in the leachate samples collected from Rajbandh. The lowest (436±13.08 mg/l) and highest (1344±93.58 mg/l) amount of COD was found in the samples collected from Rajbandh (Table 2).

Biological treatment of landfill leachate

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Biological treatment method is one of the most well-known methods which are used all over the world due to its reduced environmental impact rather than the chemical use for treatment and also to save money. In the experiment the used treatments are found free of cost and locally available.

Duckweed treatment: Survival capacity of the duckweed was found higher in the leachates collected from Rajbandh and Gollamari areas than that of other two areas (Table 3). After 4-6 days of conditioning, the duckweeds in the leachates from Nirala and Jessore became weak and between 8 and 10 days their death started. It took 14 days to die majority of the duckweed in the leachates of Nirala and Jessore whereas this duration was little longer in leachates from other two sources.

Water hyacinth treatment: Like duckweed treatment, water hyacinths also became weak earlier in the leachates from Nirala and Jessore (Table 3). Delayed starting of death was recorded in samples collected from Gollamari which was on the fourteenth day. However, after 15 days most of the water hyacinths died.

Snail and jute fiber treatments: On the tenth days of conditioning, snail started to die in all the leachate samples (Table 3). After fifteen days, the mortality rate was not more than 10% in all the samples. In all the leachate samples, the jute fiber that was provided did not rot after fifteen days.

Discussion

There were no previous research efforts found on the present topic in Bangladesh and thus it was not possible to compare the findings of the present study with others. However slightly relevant researches were evaluated. Physical treatment *i.e.* the conditioning of the samples had positive effects on the leachate compositions. Due to this, the samples became less concentrated and might have loosen the complexity of the characteristics of the leachates. Conditioning had also a significant positive effect on the color and odor of the samples. Conditioning lightened the color and odor and it also reduced the TDS of the samples. Similar statements were also made by Salequzzaman *et al.*, [17].

From the analysis of the result it was found that a very common thing was happened in every case. And it has been cited before as a limitation of the experiment, it was the reduction of sample from the system through direct evaporation (for all treatments) and evapotranspiration (without control and snail treatments). It affected the experiment result vigorously. The estimated evaporation rate was 90 ml/day. Except a very few cases all other showed an incremental result. The event was more prominent for control because of there was no surface cover for the leachate sample, which was for the duckweed, water hyacinth and jute treatments. Furthermore, it was proved that the more days passed over, the more evaporation occurred and the more the concentration increased. Again as the most of the treatment agent were collected from the costal periphery some of the parameter like chloride increased naturally due to geographical conditions. Another limitation that affects the treatment system was the dilution water. From the characteristics of the dilution water it was found that, the concentration of chloride was much higher than normal water which increases the concentration of chloride in the treatments. However, despite of the limitation, some variation were also observed for all parameters among treatments. Another effect within the treatment system was the amount of samples which

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were reduced within the 'chari' due to direct evaporation and evapotranspiration. It was a limitation of the experiment.

Leachate production from landfill sites is inevitable. Leachate is a potential hazardous waste; pose a potential pollution problem for local ground and surface waters. Similar results also mentioned by several researchers [2], [3], [4], [5], [6], [7].

As leachate is a potential hazardous waste from landfill sites. If not dealt with properly they can also cause health problems to the surrounding community people and as well as the agricultural crops and environment too [18]. Biological treatment is currently in use for leachate treatment; however COD removal efficiency is often low and biologically-refractory organics remain in the effluent, making the technology potentially inadequate. Pretreatment as a part of conditioning for sewer disposal, is essential. In this research, four studies of landfill leachate samples have extensively been studied and found with high COD and BOD contents. For COD, the value ranges from 436 mg/l to 1344 mg/l and for BOD, 308 mg/l was the highest value. The samples of Khulna were highly concentrated in salty substances in the form of chloride and sodium. The highest chlorine content was found 2800 ppm. But the sample of Jessore was less concentrated in salty substances than that of other three sampling sites of Khulna. Similar results were also recorded by Salequzzaman *et al.* [19]. Presence of this high concentrated salt such as sulphate is dangerous to the surrounding ecosystem. In spite of various limitations of the experiment, the treatments used in the experiment acted positively to reduce different constituents from the complex sample of leachate, although increasing prohibition in some factors. Based on the findings of the present study, more research efforts are recommended on the collection and treatments using different techniques of landfill leachate.

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Table 1: Treatments used in the present study

Treatments	*Remarks*
Control	Only leachate sample
Duckweed	Three mugs of duckweed + leachate
Water hyacinth	Ten water hyacinths of almost same size + leachate sample
Apple snail	Fifteen snails + leachate sample
Jute fiber	500 g fiber + leachate sample

Table 2: Composition of leachate before and after conditioning

Parameters	*Sampling point*							
	Rajbandh		*Gollamari*		*Nirala*		*Jessore*	
	Before	*After*	*Before*	*After*	*Before*	*After*	*Before*	*After*
pH	7.78±0.03	7.98±0.11	7.39±0.14	8.34±0.13	7.40±0.13	8.57±0.35	7.08±0.25	7.76±0.41
EC (ms)	6.42±0.13	5.21±1.10	14.37±0.96	6.77±0.96	7.05±0.58	5.44±0.44	5.64±0.50	5.13±0.86
TDS (g)	4.49±0.27	3.62±0.18	7.19±0.10	4.72±0.18	4.9±0.15	4.6±0.15	3.93±0.13	3.5±0.23
Temperature (^{0}C)	27.3±0.22	25.0±2.5	27.0±1.73	25±2.65	26.8±0.21	24.9±0.13	27.5±0.28	25.3±0.18
Color	Brownish	Light brownish	Black	Brownish	Black	Brownish	Reddish	Light reddish
Odor	Less strong	Less strong	Strong	Less strong	Strong	Less strong	Strong	Less strong
Sodium	4000±458.26	1600±360.56	3400±200	3200±529.15	4200±264.58	1800±132.29	7000±435.89	3400±529.15
Potassium	240±18.03	240±15.00	110±18.03	110±21.79	240±36.06	240±45.83	140±21.79	140±5.00
Calcium (ppm)	470±26.46	545±21.79	380±20.00	590±21.22	620±45.83	580±36.06	640±36.06	630±26.46
Magnesium (ppm)	270±26.46	501±31.51	420±42.72	390±21.89	768±57.86	485±70.89	576±32.60	690±49.12
Carbonates	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Bicarbonate (ppm)	1000±200	380±20	800±360.56	390±10	1480±105.83	505±13.23	2000±526.78	2800±264.58
Sulphate (ppm)	10.9±0.18	6.1±0.1	9.01±0.23	9.9±1.49	3.9±0.44	1.1±0.2	200±57.66	201±44.53
Ortho-Phosphate (ppm)	6.0±2.0	0.80±0.20	30.63±4.60	3.16±0.08	70±13.23	22±4.58	51.5±2.59	20.0±5.0
Chloride (ppm)	1300±264.58	1500±200.50	2800±264.58	2100±229.13	1950±150.0	2050±173.21	300±52.68	1500±180.28
Dissolve Oxygen (mg/l)	4.2±0.26	-	2.60±0.10	-	2.43±0.12	-	3.38±0.04	-
BOD (mg/l)	53±3.61	-	308±2.65	-	289±6.56	-	280±10.0	-
Chemical Oxygen demand (mg/l)	436±13.08	-	1344±93.58	-	921±11.53	-	756±30.64	-

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Table 3: Effects leachates on the various treatments

Treatment	***Treatment issues (days)***	***Leachate collecting sites***			
		Rajbandh	***Gollamari***	***Nirala***	***Jessore***
Duckweed	Became week	6-7	6-7	4-6	4-6
	Start of death	10	10	8-10	8-10
	Majority died (80% or more)	15	15	14	14
Water hyacinth	Became week	8-10	8-10	7-8	7-8
	Start of death	13	14	13	13
	Majority died (80% or more)	15	15	15	15
Snail	Start of snail death	10	10	10	10
	Few snail died (10% or less)	15	15	15	15
Jute	Jute fiber not rotten till	15	15	15	15

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Fig. 1: Map of study area showing the sampling points

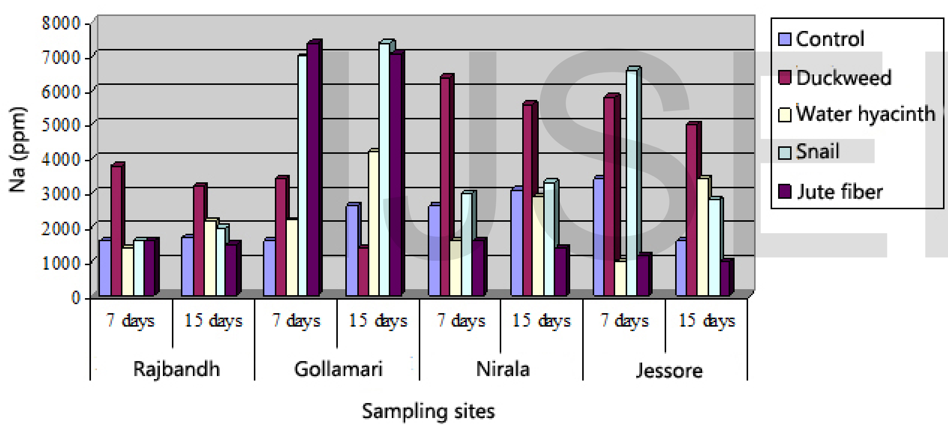

Fig. 2: Effects of various treatments on sodium content of the leachate

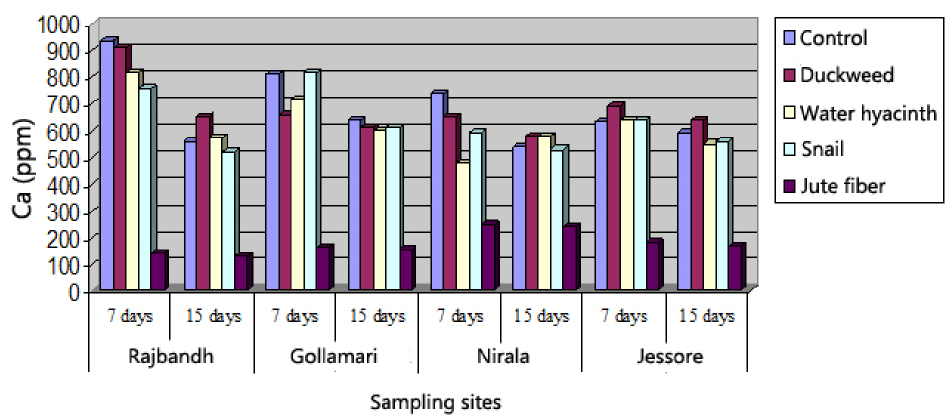

Fig. 3: Effects of various treatments on calcium content of the leachate

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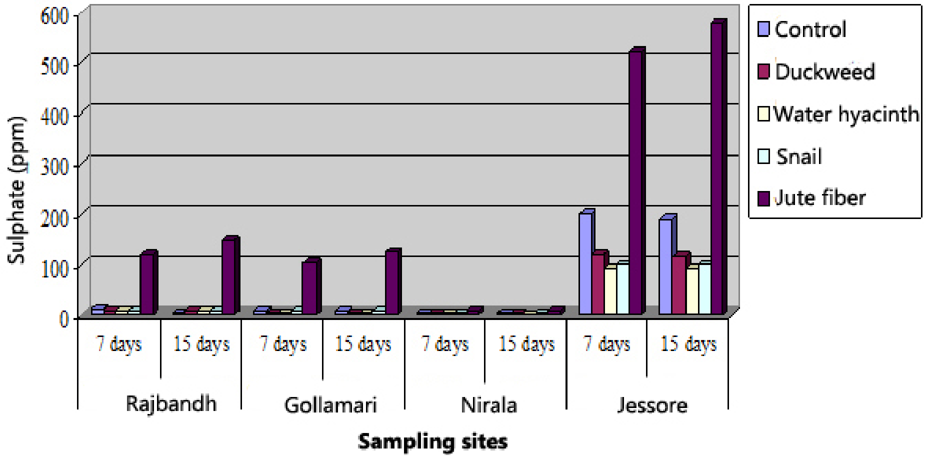

Fig. 4: Effects of various treatments on sulphate content of the leachate

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