

Full Length Research Paper

Assesement of the quality of leachate at Sarbah landfill site at Weija in Accra

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Physico-chemical and bacteriological characteristics of Sarbah dump site at Weija, Accra were investigated to ascertain the leachate quality for possible treatment. The leachate was observed to be alkaline in nature and had high concentration of the following biological oxygen demand (BOD), chemical oxygen demand (COD) and oil and grease. Samples of leachate were collected from different sites close to the landfill. On average the leachate contained high turbidity (840 NTU), colour (4,000 Hz), suspended solids (493 mg/l) and total dissolved solids (16725 mg/l), but no dissolved oxygen. Heavy metal such as Cd, Zn, Pb, Mn, Cr, Hg and Cu and their contamination were within the Environmental Protection Agency of Ghana (EPA) guideline limits except Fe which was relatively high. The study showed the possibility of leachate contamination of nearby water body. The leachate was found to be contaminated with micro-organisms and some of which have public health implications. The major pathogens isolated in the leachates from Sarbah dump site were total coliform (TC), faecal coliforms (FC), *Escherichia coli*, *Salmonella* spp, *Vibrio* spp, *Bacillus* spp, Yeast and Moulds. TC and FC were predominant in all the sites and their levels were above the EPA permissible limits. The highest levels were recorded at site I, TC (26 x 10⁶ CFU/ 100 ml); FC (33 x 10⁵ CFU/ 100 ml)] and the lowest observed at site IV, TC (18.6 x 10² CFU/ 100 ml)] ; (FC (38.4 x 10 CFU/ 100ml). Specific bacteria pathogens, *E. coli* (22.4 x 10⁵ CFU/100 ml), *Salmonella* (41 x 10³ CFU/100 ml), *Vibrio* spp (12 x 10 CFU/100 ml) were present at site I but absent at site II. The dominant biological pollutants in the leachate could expose the residence around the dump site to the risk of the following diseases; malaria, intestinal worms, upper respiratory infections, typhoid fever, dysentery, salmonellosis, cholera and gastroenteritis.

Key words: Leachate, landfill, physic-chemical, bacteriological.

INTRODUCTION

Landfilling is one of the less expensive methods of disposal of solid waste playing an important role in integrated solid waste management (Peng, 2013). It is reported that about 90% of municipal solid waste (MSW)

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is disposed in open dumps and landfills in a crude manner creating problems to public health and the environment (Sharholy et al., 2008). Inefficient management of these dumpsites causes uncontrolled gas and liquid emissions. The emitted liquid known as 'Leachate' may contain several organic and inorganic contaminants which have detrimental effects on water, and soil environment (Kolsch and Ziehmman, 2004). Proper treatment and safe disposal of the leachate is one of the major environmental challenges worldwide especially in developing nations (Butt et al., 2014; Mukherjee et al., 2014).

Within a landfill, complex sequence of physical, chemical, and biologically mediated events occurs as have been reported by Pastor and Hernández (2012). As a consequence of these processes, refuse is degraded or transformed. As water percolates through the solid waste, contaminants are leached from the solid waste. The mechanics of contaminant removal outlined by Aziz et al. (2010); Eggen et al. (2010) and Hennebert et al. (2013) include leaching of inherently soluble materials, leaching of soluble biodegradation products of complex organic molecules, leaching of soluble products of chemical reaction and washout of fines and colloids. The characteristics of leachate produced are highly variable, depending on the composition of the solid waste, precipitation rate, site hydrology, compaction, cover design, waste age, sampling procedures, and interaction of leachate with the environment as well as landfill design and operation (Nartey et al., 2012).

Leachate could cause increase in turbidity of water resulting in reduced photosynthesis and production of dissolved oxygen (Pillay, 1992). Aberration in the haematology of fish raised in leachate-contaminated waters has also been documented (Van-Vuren, 2006). It was found that leachate nonetheless could clog fish gills lowering their growth rate (Emenike et al., 2012). Toxicity effect of leachate to human living in such leachate polluted areas has also been reported by Fauziah et al. (2013). Some of the detrimental effect of leachate polluted water could be bacterial related diseases such as diarrhoea, severe bacillary dysentery, typhoid fever, other intestinal diseases as well as genitourinary tract and blood infections. According to the WHO there are 4.5 billion cases of intestinal infections every year, of which 1.9 million end in death.

Landfill can be classified into three groups based on age: young, medium and old. Normally land filling that commences within five years is termed young age landfill. It consists of large amount of biodegradable matters and higher COD value of 20000 mg/L. The 5 to 10 years old landfill site is known as medium age landfill and it consists of COD values in range between 3000 to 15000 mg/L. After 10 years, the landfill contains very less amount of biodegradable matters and its COD is lesser than 2000 mg/L. At this age, it is designated as old landfill (Renou et al., 2008). The characteristics of the landfill

basic parameters such as COD, BOD, Ratio of BOD/COD, colour, pH, alkalinity, oxidation reduction potential and heavy metal (Kjeldsen, 2002).

The objective of this study was to assess the quality of leachate from the Sarbah landfill site in Accra for possible treatment.

MATERIALS AND METHODS

Sampling of leachate

Leachate samples were collected from man-made septic reservoir, storm drains and Densu River. Total of four grab samples were taken from different points assigned as site I, II, III and IV. Site I is the main collection point of entry of leachate into an underground reservoir located downhill about 100 m from the landfill site constructed to directly receive leachate from the landfill. Site II is located about 300 m from the landfill site and was in front of a building. Site III is a runoff from a storm drain into the Densu River, while site IV is the Densu River receiving leachate from landfill. The Densu River is a source of drinking water treated and distributed by Ghana Water Company Limited (GWCL) to Accra West and its surrounding communities.

Analysis of samples

Samples collected from the various sites were analysed in-situ and also in the laboratory for specific parameters.

On-site measurement of water quality

Direct field measurements of pH using Schott Gerate pH meter, temperature with Oakton Electrical Thermometer and conductivity with a conductivity meter were performed immediately after the samples were collected. Other parameters required to be analysed in the laboratory were kept in sampling bottles placed in a bigger container having ice cubes and temperature insulating mechanism.

Laboratory analysis

Prior to the laboratory analysis the samples were kept in a refrigerator at -4°C to keep the identity of the samples intact. Laboratory analyses were conducted to ascertain the quality of the leachate samples taken from the various points using the standard method for the examination of water and waste water (APHA, 1998) for the physico-chemical analysis. Some of the parameters analysed include COD, $\text{NH}_4^+ -\text{N}$, $\text{NO}_3^- -\text{N}$, $\text{NO}_2^- -\text{N}$ and TN. Heavy metals were determined using Atomic Absorption Spectrophotometer (Schimadzu model AA-6650 flame system).

Microbiological analysis was also conducted using the Membrane Filtration (MF) Technique to determine the microbes present in the samples.

RESULTS AND DISCUSSION

Physico-chemical quality

Physico-chemical parameters in leachate from Sarbah landfill in Accra is represented in Table 1. Samples of the leachates collected exhibited alkaline characteristics

Table 1. Physico-chemical quality.

Parameter	Unit	Site I	Site II	Site III	Site IV (Densu River)	EPA guideline value
pH		8.97	7.36	8.71	7.91	6-9
Conductivity	$\mu\text{S/cm}$	3330	1850	960	510	1500
Turbidity	NTU	840	257	25	21	75
Apparent Colour	Hz	4000	1250	400	50	100
Temperature	$^{\circ}\text{C}$	29.9	31.0	29.6	30.4	< 3 $^{\circ}\text{C}$ above ambient
Total Suspended Solids	mg/L	493	295	20	26	50
Total Dissolved Solids	mg/L	16,725	787	470	234	1000
Sulphate	mg/L	94.1	20.9	20.1	26.0	50
Ammonium Nitrogen ($\text{NH}_4\text{-N}$)	mg/L	41.0	12.0	2.78	0.501	1.5
Nitrate –Nitrogen ($\text{NO}_3\text{-N}$)	mg/L	5.00	0.700	21.6	0.108	10
Nitrite ($\text{NO}_2\text{-N}$)	mg/L	1.06	0.220	0.940	0.060	-
Phosphate-Phosphorous ($\text{PO}_4\text{-P}$)	mg/L	16.3	0.850	0.600	0.019	2
Chloride	mg/L	4.864	357	159	77.4	250
sulphide	mg/L	<0.005	<0.005	<0.005	<0.005	1.5
DO	mg/L	0.00	0.30	1.10	5.40	-
BOD	mg/L	220	100	36		
COD	mg/L	6,672	544	170		
Oil/Grease	mg/L	32.0	26.0	19.0		
Cadmium	mg/L	<0.002	<0.002	<0.002	<0.002	<0.1
Total Iron	mg/L	5.00	28.1	0.486	0.483	10
Zinc	mg/L	0.764	0.208	0.021	0.031	5
Lead	mg/L	0.035	<0.005	0.021	0.031	5
Manganese	mg/L	0.132	1.55	0.022	0.360	-
Chromium	mg/L	0.809	0.085	0.065	0.071	0.1
Mercury	mg/L	<0.001	<0.001	<0.001	<0.001	0.005
Copper	mg/L	0.094	<0.012	0.012	<0.020	5

indicating the landfill had been exploited for a period of time. The pH of the leachate ranged from 7.36 to 8.97 indicating suitable methanogenic activities of methane formers and was in the range reported by Abu-daabes et al. (2013). Leachate generated in the initial stage of waste decomposition (up to 5 years) on many landfills have pH 3.7-6.5 that reflects the presence of carboxylic acid and bicarbonate ions. With time the leachate becomes neutral or weakly alkaline (pH 7.0-7.6) whereas landfill exploited for a long period of time gives rise to alkaline leachate (pH 8.0-8.5) as have been observed by El-Salam and Abu-Zuid (2015) and Talalaj (1998).

The conductivity of the leachate ranged from 510 $\mu\text{S cm}^{-1}$ at site IV to 3330 $\mu\text{S cm}^{-1}$ at site I. The conductivity decreased as one moved away from the landfill as can be seen from Site III which was far from the main landfill and this could be due to dilution with storm or rain water. Conductivity levels at Site I and Site II were above the EPA guideline value of 1500 $\mu\text{S cm}^{-1}$ and therefore unsatisfactory. A high conductivity value indicates the presence of excess concentration of various ions or nutrients present in the leachate. Nutrients such as ammonia, nitrogens, nitrate, nitrite and phosphate

concentrations were found higher in concentrations at the various sites. Site I had ammonia-nitrogen level of 41.0 mg l^{-1} , nitrate-nitrogen level of 5.00 mg l^{-1} , nitrite-nitrogen level of 1.06 mg l^{-1} and phosphate-phosphorous level of 16.3 mg l^{-1} . These values were higher than their respective EPA guideline values. The higher ammonia-nitrogen was responsible for the unbearable stench produced and attracted a lot of flies into the area. The high nutrient content in the leachate could cause eutrophication in the receiving water body.

The total suspended solids concentration varied between 20 and 493 mg l^{-1} while the total dissolved solids ranged from 470 to 16,725 mg l^{-1} . The leachate from site I which was directly from the landfill had higher total dissolved solid value than the EPA guideline values of 50 and 1000 mg l^{-1} for TSS and TDS, respectively and therefore not satisfactory. High turbidity and colour may also be as a result of high suspended particles in the leachate. Turbidity ranged from 25 to 840 NTU in the leachate, while colour varied between 400 to 4000 Hz. Turbidity and colour in the leachate also exceeded the EPA guideline values and therefore not acceptable.

Heavy metals are also important parameters which

Table 2. Microbiological characteristics of leachate.

Microorganisms	Unit	Sampling locations				Maximum permissible levels for irrigation	EPA guideline values
		Site I	Site II	Site III	Site IV		
Total Coliform	cfu/100 ml	26 x 10 ⁶	6 x 10 ⁵	244 x 10 ⁵	18.6 x 10 ²	<1000	<400
Faecal Coliform	cfu/100 ml	33 x 10 ⁶	1 x 10 ⁴	26 x 10 ⁴	38 x 10 ⁴	<10	10
<i>E. coli</i>	cfu/100 ml	22.4 x 10 ⁵	0	1 x 10 ⁵	36.9 x 10 ²	<10	<10
<i>Salmonellaspp</i>	cfu/100 ml	41 x 10 ³	0	9 x 10 ³	10.4 x 10	<10	<10
Yeast	cfu/ml	15	0	14	0	0	0
<i>Clostridium spp</i>	cfu/100 ml	0	0	0	0	<10	<10
<i>Vibrios spp</i>	cfu/100 ml	12.0 x 10	0	23.3 x 10 ²	14	<10	<10
<i>Bacillus spp</i>	cfu/100 ml	5	0	8	4	<10	<10
Mould	cfu/100 ml	20.4 x 10	12	50	13	<10	<10
Helminth Egg	L ⁻¹	0	0	0	0	-	<1

have adverse effect on human health; hence their levels of contamination are of great concern. The results of the heavy metals investigation in the landfill showed iron (Fe) to be the most predominant metals in the landfill leachate (0.486 – 28.1 mg l⁻¹), its oxidized form Fe (III) gave the brown colour observed from in most landfills leachates. However, mercury (Hg) and Cadmium (Cd) were below their respective direction limits of <0.001 and <0.002 respectively. Chromium (Cr) level of 0.809 mg l⁻¹ was detected in the main leachate from the landfill, site I, which was above the EPA guideline limit of 0.1 mg l⁻¹. Zinc (Zn), lead (Pb) and Copper (Cu) were observed in the samples, but their levels were within the EPA guideline. Similarly low levels of heavy metals have been reported in leachates from Jordan by Abu-daabes et al.(2013)

Organic matter

An indication of the organic content of the leachate can be assessed from the Biochemical Oxygen Demand (BOD) and the Chemical Oxygen Demand (COD) level (Tchobanoglous, 2003). Leachate was observed to have high BOD and COD levels. BOD level (200 mg l⁻¹) and the COD level (6, 672 mg l⁻¹) were higher than the EPA guideline value of 50 and 250 mg l⁻¹ for BOD and COD respectively and therefore unsatisfactory. However the BOD and COD were far less than the BOD of 3847 mg l⁻¹ and COD 67.719 mg l⁻¹ reported by Chaudhari and Murthy (2010) in Gujarat State of India. Similarly, very high COD range of 13,900–22.350 mg l⁻¹ was observed from a landfill in Riyadh, Saudi Arabia by Al-Wabel et al. (2011) while BOD of 83.243–326 mg l⁻¹ was measured from a landfill in Pulau Burung Landfill Site, Malaysia by Aziz et al. (2010). High concentrations of BOD and COD will deplete the oxygen resources of the receiving waste body. The dissolved oxygen in the main leachate (site I) was zero. However, the Dissolved oxygen (DO)

improved a little bit in sites I and II due to dilution. The low DO is capable of inducing stress to the fish with prolong exposure (Table 1).

Bacteriological quality

The results of bacteriological quality of leachate sampled from the Sarbah landfill are presented in Table 2. At all the sites, total and faecal coliform levels far exceed the EPA maximum permissible limits both for irrigation and for the discharge of wastewater into the environment. The highest level recorded was at site I, 26.0 x 10⁵ CFU/100 ml for total coliform and 6.0 x 10⁵ CFU/100 ml for faecal coliform and the lowest levels was at site IV. Samples from the Densu River at site IV generally recorded the lowest levels of pathogenic organism; 18.6 x 10² CFU/100 ml total coliforms; 38.4 x 10² CFU/100 ml faecal coliforms; 36.88 x 10² CFU/100 ml *E. coli*; 10.4 x 10 CFU/100 ml *salmonella* spp; 14.0 CFU/100 ml *vibro* spp but the levels were still higher than the EPA recommended levels. Human activities around the river could also contribute to pollution; however the impact of the leachate cannot be undermined. Higher biological pollutions in leachates have been reported by many researchers; for instance, Threedeach et al. (2012) reported of values in range between 2.2x10⁴ and 9.4x10³CFU/100ml *Ecoli* spp.

Helminth eggs and *Clostridium* were absent with appreciably low levels of mould, yeast, and *Bacillus* spp. Leachate produced from the landfill is not safe to be in the environment. Their reduced level could be due to the sun effect on the leachate.

Effect of the leachate on the quality of the Densu River

The Densu River is the only water body in the vicinity

where the Sarbah landfill is located. The river has its source from Weija and extends from the South of Weija to the northern-most part of Weija and beyond. The river is the source of drinking water to many parts of Accra in the Greater Accra Region and the Eastern Regional parts of Ghana. It also serves as economic haven of the communities around the river with fishing as a major activity. Thus the Densu River affects the livelihood of people in and around the capital city of Accra, Ghana.

Generally, the high conductivity, turbidity, colour and suspended solids in the leachate influence the quality of the Densu River. Relatively high conductivity ($510 \mu\text{Scm}^{-1}$), turbidity (21 NTU) colour (50 Hz), total dissolved solids (243 mg l^{-1}) and suspended solids (26 mg l^{-1}) were observed in the sample collected from Densu River. BOD, COD, oil and grease levels in Densu River were 6.0, 8.6 and 31.0 mg l^{-1} respectively. Nutrients and metals levels in the river were within WHO and EPA limits. High levels of *total and faecal coliforms*, *E. coli* and *salmonella spp.* were observed in the water. The contamination of the water with micro-organisms by the leachate is potential threat to aquatic ecosystems and public health especially those who drink directly from the river without treating it (Eggen et al., 2010). The pollution level of the river body also contributes to the high cost of treating the river for domestic and industrial uses compared to other water sources use to serve far East of Accra as observed by Ghana Water Company Limited, responsible for treating and distributing water.

Management and proposed treatment options for the leachate from Sarbah

Leachate management in rainy seasons is quite a problem for a country like Ghana which has a major rainfall regime of April-July and a minor season from October –December. Within these periods, leachate emanating from the landfill visibly runs off the street through the routes where the samples were taken to the Densu River. Currently, bigger reservoirs are constructed at four different locations to impound the leachate and periodically collected with trucks for discharge. Further management considerations that can be adopted include: evaporation of the leachate during dry season from constructed ponds which would be covered during the rainy seasons. Leachate collected from the reservoir could be emptied into the evaporation pond. The leachate can also be recirculated into the landfill, but care should be taken since this has the potential to contaminate underground water, the surrounding environment and build up COD, BOD and heavy metals. The leachate can as well be recycled using treatment facilities having fixed bed system and activated charcoal packed chamber for trapping microbes and chemical pollutants.

Treatment of the leachate could be in a form of pretreatment which may involve neutralizing the acidity by pH adjustment, screening and sediment removal.

Physical, chemical and biological treatments could be employed on a separate process or in combination. Some of these processes include sand filtration, sedimentation, flocculation, anaerobic digestion, the use of oxidative/ aeration pond, facultative pond, activated sludge system and reverse osmosis. The treatment processes such as the use of aeration pond, facultative pond and activated sludge remove ammonia through nitrification, COD and BOD.

BOD:COD ratio informs the biodegradability of the leachate, higher ratios are possible during the early stage of the landfill where the acidogenic activities are higher, but the ratio reduces as the landfill ages indicating that recalcitrant materials which are difficult to degrade are left showing a state of stability (El-Salam and Abu-Zuid, 2015). According to Ehrig and Scheelhaase (1993), a leachate may be treated biologically when the BOD: COD ratio is about 0.5; below this ratio the leachate cannot be treated biologically. High levels of metals, chlorides, sulphides, some nutrients make application of biological processes very difficult. In the Sarbah landfill, the BOD:COD ratio ranges from 0.03 – 0.22, although the levels of biological pollution are high; the attention should be on physical and chemical treatment, although some biological treatment could still be considered.

Conclusion

The study has provided the physico-chemical and bacteriological characteristics of Sarbah landfill leachate. The physico-chemical characterization of the leachate from Sarbah landfill indicated that the leachate is alkaline in nature and has high BOD, COD and oil and grease levels with potential effect on the environment and ground water resources. The leachate contained high turbidity, colour suspended as well as dissolved solids. The leachate exerted negative impact on Densu River water quality. The river water was also contaminated with micro-organisms, some of which have public health implication.

The level of coliforms, *E. coli*, *Salmonella* and *Vibrio spp.* exceeded the EPA recommended limits for irrigation and for waste water discharged into the environment. Surrounding communities would be at serious health risk of contracting various gastrointestinal diseases such as typhoid fever, diarrhoea, cholera, dysentery, etc if the leachate enters their drinking water sources. Management activities employed involve impounding the leachate in a reservoir and allowing it to evaporate in an evaporation pond. However, this alone may not be enough; physico-chemical treatment methods should be explored.

Conflict of Interests

The authors have not declared any conflict of interests.

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