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Landfill leachate impacts on groundwater quality from specific distances at the abloradjei landfill site in Accra, Ghana

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ABSTRACT

The study investigated the impact of landfill leachate on groundwater quality for communities surrounding the landfill site at Abloradjei in the Greater Accra Region of Ghana. Four (4) boreholes at various distances, R1-50m, R2-100m, R3-250m and R4-400m, away from the position of the Abloradjei landfill site were monitored for three months. The results from the physicochemical water quality monitoring parameters of the boreholes from the various distances: R1-(17*NTU*), R2-(8*NTU*), R3-(42*NTU*) and R4-(12*NTU*) and *pH* at R1-6.44, R2-6.10, R3-6.33 and R4-6.78 fell outside the specified WHO (2004) Standard Guideline limit of drinking water. The results of bacteriological analysis of the water samples: R1-(3276 Cfu/100ml), R2-(884Cfu/100ml) and R3-(676Cfu/100ml), R4-(1404Cfu/100ml) also showed an inference of growth indicating some sort of possible contamination and hence the water was not safe for drinking.

Introduction

Rapid urban growth resulting from large increases in the numbers of urban dwellers in major cities of the developing world has led to an increase in waste generation. Areas close to landfill sites are now the preferred options for urban settlement, which is generating a competing land use issue problems (Tengrui *et al.*, 2007). In most developing nations, almost 100 per cent of municipal solid waste is managed by transporting them to these created landfill sites. Landfill operations are most feasible in developing countries because land is vastly available and moderately inexpensive (Longe & Balogun, 2010). Slimy liquid containing many dangerous chemicals called "leachate", leak from the wet solid wastes accumulated and buried in landfills (Lopez *et al.*, 2004; Zhang *et al.*, 2007).This fluid contains significant quantities of pollutants which usually percolate to the underlying soil layers under the effect of different mechanisms, and may enter into the underground water table or surface water.

Studies by Lee and Jones-Lee (1993); Christensen *et al.*, (2001); Tengrui *et al.*, (2007) and Ogundiran and Afolabi, (2008) have identified municipal landfill leachate to be highly concentrated with complex effluents which contain both dissolved organic matters and inorganic compounds. According to Tchobanoglous *et al.* (1993), leachate formation creates a non-uniform and intermittent percolation of moisture through the waste mass, which results in the removal of these soluble compounds from the waste and their dissolution and suspension in the leachate. Landfill leachate, recognized as a potential source of groundwater and other surface water contamination, contains high amounts of organic compounds, ammonia, heavy metals, a complex variety of materials, and many other hazardous chemicals (Alslaibi *et al.*, 2010; Christensen *et al.*, 2001; and Schrab *et al*., 1993).

In recent times, the impact of leachate on groundwater and other water resources has attracted a lot of attention because of its overwhelming environmental significance. Leachate migration from wastes sites release pollutants from sediments which pose high risks to people who have their sources of water directly from groundwater resources (Ikem *et al.* 2002). As noted by Longe & Balogun (2010), improper management and disposal of solid waste at landfill sites has the potential to expose communities around such sites to many environmental and health hazards. In many developing countries, several unregulated landfills exist adjacent to large cities release harmful contaminants to the underlying aquifer (Singh *et al.*, 2009). These landfill sites are potential sources of groundwater pollution (Paras *et al*, 2007). Despite the evolution of landfill technology from open, uncontrolled dumps to highly engineered facilities designed to eliminate or minimize potential adverse impacts of the waste on the surrounding environment, generation of contaminated leachate remains an inevitable consequence of the practice of waste disposal in landfills in many of these countries (Mu, Aysun, & Mineku, 2006).

Groundwater pollution is by far the most significant concern arising from landfill leachate migration. Christensen and Kjeldsen (1989) asserted that a combination of physical, chemical and microbial processes in the waste, transfers pollutants from the waste material to the percolating water. According to Tchobanoglous *et al*, (1993), leachate formation creates a non-uniform and intermittent percolation of moisture through the waste mass, which results in the removal of these soluble compounds from the waste and their dissolution and suspension in the leachate. Thus, landfill leachate can be generated by excess water percolating through the waste layers in a landfill.

Landfill leachate therefore presents a very complex mixture that may contain a large number of xenobiotic organic compound. These compounds are usually found in low concentrations (µg L-1), but all the compounds in combination may cause severe biological effects as many of the identified

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compounds are highly toxic or even carcinogenic (Baun *et al*, 2000).

Landfill leachate poses great threat to both groundwater and surface water which can be fatal to humankind. However, the scale of this threat depends on the composition and quantity of leachate and the distance of a landfill from the water sources (Slomczynska & Slomczynski, 2004). Leachate that percolates through the base of the landfill and enters the groundwater system has the potential of affecting the quality of water of which many people depend for their survival (Mohd *et al*, 2011). Consequently, monitoring the quality of groundwater is essential for environmental safety and as such analyzing physicochemical properties including trace element content are crucial for public health (Kot *et al*., 2000).

The Abloradjei landfill site, which is one of the largest landfill sites in the Accra Metropolis, has become a nuisance and therefore a major environmental concern because of poor management of the site and its potential to cause leachate which subsequently can pollute groundwater for the surrounding communities. However despite these threats, little studies have been conducted to examine the effect of waste disposal sites on ground water quality in the area. Therefore, this study seeks to analyze the physicochemical and bacteriological properties of groundwater quality and its suitability for the communities adjacent the Abloradjei Landfill site.

Methodology

Study Area

The Abloradjei Landfill site is located in the Ga East Municipal Assembly (GEMA) in the Greater Accra Region (Figure 1). The Municipality has a land area consisting of gentle slopes interspersed with plains in the west. The Akwapem range rises steeply above the western end and lies generally at 375-420m north of Aburi and fall to 300m southward. This makes the area rich in ground water resources (GEMA Report, 2010). Thus, the nature of drainage pattern has called for most households within GEMA to depend on hand dug wells and boreholes for their water supply.

With the increasing influx of people into Accra and the subsequent rapid urbanization, huge amounts of human and industrial waste are generated at an alarming rate. It is estimated that the site receives an average of 249 tons of waste daily (GEMA Report, 2010). According to the report, this landfill site serves three Assemblies namely; Adentan Municipal, Accra Metropolitan and Ga West Municipal (Figure 1). In spite of this huge volume of waste disposed off daily, no proper engineered final disposal site has yet been designed for the area. As a result, the rate of waste generation and management in the Municipality has become a matter of great concern.

In order to ascertain the level of contamination of groundwater from the landfill site, the area around the landfill site was carefully demarcated into four major distances (Figure 2): radius R1 (50 meters away from the site), radius R2 (100 meters away from the site), radius R3 (250 meters away from the site) and radius R4 (400 meters away from the site) respectively (Figure 2).

This was ascertained by delineating the area covered by the landfill site from satellite image on Google Earth and saved as KML file, imported into ArcGIS 10 platform and converted into a shape (SHP) file. A buffer of various distances was generated in ArcGIS 10 on which the selection of boreholes was established. Based on the buffer map generated, A Global Positioning System (GPSmap 62sc) was used to record the spatial locations (X, Y, coordinates) of each borehole to ensure that they are within the defined radius as stated (Figure 2).

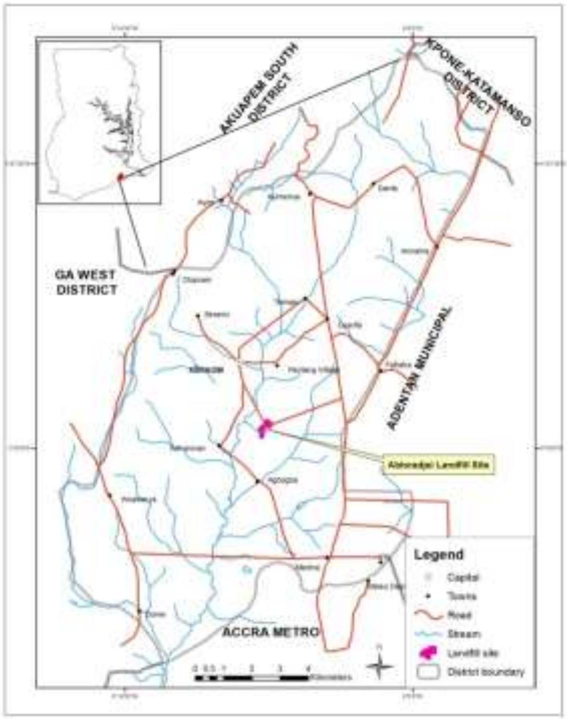

Figure 1: Ga East Municipal Assembly showing location of Landfill site

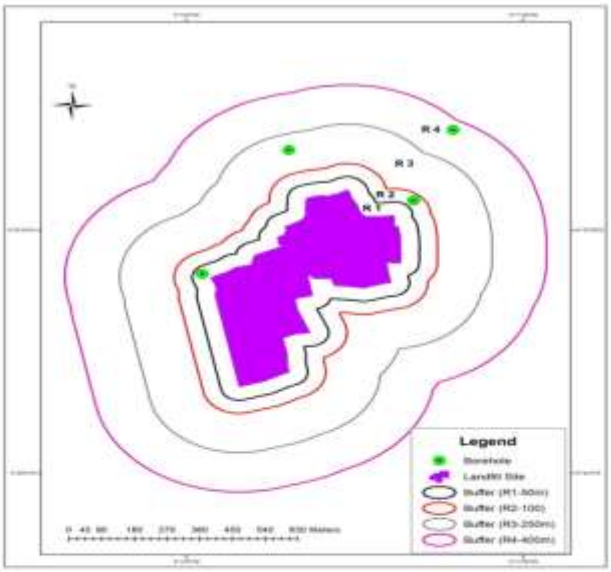

Figure 2: Borehole Distances from the Abloradgyei LandFill site

Water Sampling and Laboratory Test

In each section, 4 boreholes with the average depth of 40 metres in the basement formation were used as the sampling points for groundwater quality testing. For each borehole, 15 liters of the groundwater samples were collected in 500ml sterilized polyethylene bottles, stored at the temperature of 4°C and analyzed.

The analysis covered physical, chemical, and bacteriological parameters of the water samples from each borehole. The physical parameters tested included: odour, taste, colour, turbidity and temperature. Chemical parameters analyzed were pH, dissolved oxygen (DO), total hardness (TH), total iron, nitrate, nitrite, chloride, calcium and heavy metals such as copper, zinc, and lead. The pH was determined using a Mettler Toledo (Schwerzenbach, Switzerland) pH meter by direct measurement, analog mercury thermometer was used for temperature measurements, and a Hach 2100A turbidimeter was used for turbidity determination.

Samples were also analyzed in the water laboratories for total dissolved solids, total hardness, iron, nitrate (NO_3), nitrite (NO_2), calcium, and chloride using standard methods for the examination of water (APHA, 2005). The concentrations of heavy metals such as copper, zinc, and lead in the water samples were determined with flame atomic absorption spectrophotometer. The bacteriological analysis involved the determination of total and faecal coliforms, *Escherichia coli* (E-Coli) and Total Hetrotrophic (THB) bacteria by membrane filtration method. HiCrome Coliform Agar was used for the simultaneous detection of E-coli and total coliforms in water samples. Twenty seven (27g) of the Hicrome Agar was suspended in 1 litre distilled water. This was heated to boiling to dissolve the medium completely. It was then sterilized by autoclaving at 121ºC for 15 minutes. All results obtained were compared with the World Health Organization standards (WHO, 2004).

Results & Discussion

Physical Characteristics of Underground Water Samples at Various Distances

The physical characteristics analysis involved the appearance, colour and turbidity as presented in Table 1 below. The results indicated that the temperatures of all the boreholes (R1, R2, R3 and R4) at the various points were above the WHO, (2004) standard of 4^{o}C for domestic water, hence indicating the presence of foreign bodies.

The term colour was used to mean true color that is the color of water from which turbidity has been removed. The results revealed that, the water samples from R1 (50m away from dumpsite) were clear, R2 (100m away from dumpsite) was turbid, R3 (250m away from dumpsite) was coloured while R4 (400m away from dumpsite) was clear. This indicated that, leachate from dumpsite has high potential in determining the colour of underground water to about 150m within range. The changes in colour with regards to distance might be due to the presence of organic and inorganic matter, such as bacteria metals, iron, manganese or highly coloured industry waste. The presence of colour was an indication of pollution and confirmed leachate infiltration into the wells (Ogedengbe & Akinbile, 2004; Mohamed *et al*. 2009). However, when the colour of the water samples were measured, it was revealed that the water samples at the various radii was within the WHO standards (15Hz) except for Radius 400m which recorded the 20Hz and above the maximum permissible levels. Despite these changes in colour with distance, there was no odour found in any of the water samples.

Turbidity of the water samples according to the laboratory report indicated that, underground water from a distance of 50km (R1) was little higher (17 NTU) than the WHO standards (15NTU); decreased in R2 (8 NTU), increased exponentially again in water sample at R3 and subsequently declined to (12 NTU) at R4 which were all above the WHO standards. A high turbid level in the underground water sampled determined the type of micro-organisms for example; viruses, parasites, and bacteria which could be present in the water and these agents could have health implications on domestic water use. High turbidity found in the various water samples (R1, R2, R3, and R4) might mean that the boreholes were unlined, hence the high values.

It might be suggested that soil particles might have found their way into the boreholes from the unstable side walls thereby increasing the water turbidity. A similar trend had been reported by were also reported by Akinbile (2012).

Chemical Characteristics of Underground Water Samples at Various Distances

The chemical analysis indicated that the pH was high in R1 (6.44), dropped to 6.10 at R2 rose again to 6.33 at R3 and later nearly acidic at distance 200km and above. This shows that, leachate from landfill site could raise the pH of underground water sources to even a distance as far as 400km. The pH of drinking water is not a health concern, but acidic water, which has a low pH rating, can leach some metal from plumbing system, causing health problem. The pH of the various water samples were within the WHO, (2004) standards. Conductivity on the order hand declined with regards to distance of source of contamination: R1 (2420µS/cm), R2 (1663µS/cm), R3 (1034 µS/cm) and R4 (1513 µS/cm). These values were all above the WHO standards of quality water conductivity levels (≤1000 µS/cm).

The total dissolves solids (TDS) of the water samples was high (1331mg/l) which was also beyond the maximum permissible levels at distance of 50m away from the dumpsite but subsequently the values declined with respect to distance: R2 (915 mg/l), R3 (569 mg/l) except R4 (832 mg/l). All were found to be within the WHO (2004) permissible levels. However, the high TDS found at R1 might be due to its proximity to the landfill site, but the increase in TDS at R4 could be as a result of other environmental factors present. Again, the results showed that total hardness also decreased with distance from pollution point R1 (460mg/l), R2 (256mg/l), R3 (13 mg/l) and R4 (118 mg/l). This meant that leachate from landfill sites has high potential in altering the hardness of underground water sources and perhaps its usage.

The results also showed that chloride levels at various boreholes were above (WHO, 2004) maximum permissible levels of drinking water. Chloride levels were seen to decrease with regards to distance or borehole proximity. Chemical properties such as Ammonium, Fluoride, and Phosphate were all within (WHO, 2004) maximum permissible levels of quality drinking water. However, it could be deduced from the Table 2 above that the values of parameters such as Fluoride and Phosphate changed with distance to landfill sites. The concentration of Ammonium on the contrary recorded same values at various distances.

Test for Selected Heavy Metal Concentration in Water Samples

In order to ascertain the quality of drinking water and determine the extent of pollution as well as determine the health risks associated with landfill sites on underground water, selected heavy metals were measured and analyzed. Table 3 below presents the concentration of heavy metals recorded at each distance.

Laboratory result of the various water samples indicated that copper concentrations at various boreholes (R1, R2, R3 and R4) from the landfill site were the same (<0.002mg/l) and were within the WHO (2.0mg/l) threshold for water quality. The values of Lead concentration in all the samples (<0.005mg/l) were also found to be within maximum permissible level (0.01mg/l) of drinking water (WHO, 2004).

Even though zinc levels changed with distance - R1 (0.015 mg/l), R2 (0.011 mg/l), R3 (0.007 mg/l), and R4 (0.013 mg/l), the values recorded at each borehole was within the maximum permissible levels of drinking water. Cadmium concentration in all water samples (<0.002mg/l) were also found to be the same at the various distances from landfill site.

Table 1: Physical characteristics of Underground Water Samples from Communities

Physical Parameters	Temperature	Appearance	Odour	Hz	NTU	ph	Conductivity	TDS	TH
WHO Standards	4°C	-	inoffensive	15	0-5	6.5-8.5	≤1000	1000	500
Unit	°C	-	-	NTU	PH	µS/cm	mg/1	mg/1	mg/1
R-1	26.5	Clear	-	10.0	17.0	6.44	2420	1331	460
R-2	27.5	Turbid	-	5.00	8.00	6.10	1663	915	256
R-3	26.5	Coloured	-	20.0	42.0	6.33	1034	569	131
R-4	24.0	Clear	-	5.00	12.0	6.78	1513	832	118

Hz – Colour (pt.Co): NTU – Turbidity: pH – TDS – Total Dissolved Solids: TH – Total Hardness

Table 2: Chemical Constituents of Underground Water Samples from Communities

Physical Parameters	pH	Conductivity	TDS	TH	Cl	NO_3	NO_2	NH_4-N	F-	Na	PO_4-P
WHO Standards	6.5-8.5	≤1000	1000	500	≤250	10	1.0	0.00-1.5	1.5	125	3.5
Unit	pH	µS/cm	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1
R-1	6.44	2420	1331	460	526	0.160	0.085	<0.001	0.225	286	0.112
R-2	6.10	1663	915	256	387	0.113	0.047	<0.001	0.265	158	0.169
R-3	6.33	1034	569	131	254	0.079	0.079	<0.001	0.169	74.7	0.118
R-4	6.78	1513	832	118	318	0.066	0.066	<0.001	0.586	77.9	0.106

pH TDS – Total Dissolved Solids: TH – Total Hardness: Cl – Chloride: NO_3 – Nitrate: NO_2 – Nitrite: NH_4-N – Ammonium Nitrogen: F- - Flouride: Na – Magnesium: PO_4-P – Phosphate

Table 3: Heavy Metal Concentration in Underground Water Samples from Communities

Physical Parameters	Cu	Fe	SO_4	Pb	Cd	Ca	As	Zn
WHO Standards	2	0.3	500	0.01	0.003	200	0.01	4
Unit	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1
R-1	<0.020	<0.020	50.3	<0.005	<0.002	69.7	<0.001	0.015
R-2	<0.020	0.184	46.6	<0.005	<0.002	41.2	<0.001	0.011
R-3	<0.020	2.68	31.7	<0.005	<0.002	22.6	<0.001	0.001
R-4	<0.020	0.626	50.8	<0.005	<0.002	15.9	<0.001	0.013

Cu –Copper: Fe –Iron: SO_4 –Sulphate: Pb –Lead: Cd –Cadmium: Ca –Calcium: As –Arsenic: Zn – Zinc

Table 4: Bacteriological Characteristics of Underground Water Samples from Communities

Bacteriological Characteristics	tvc/ml	tvc/ml	E.coli	THB
WHO Standards	0	0	0	0
Unit	Cfu/100ml	Cfu/100ml	Cfu/100ml	Cfu/ml
R-1	744	186	20	3276
R-2	837	0	0	884
R-3	1302	372	279	679
R-4	1488	465	279	1404

tvc/ml - Total Coliforms: tvc/ml - Faecal coliform: E.coli - Escherichia Coli : THB - Total Heterotrophic Bacterial

The values recorded were however, slightly below maximum permissible level (0.03mg/l) of drinking water (WHO Guideline, 2004).

Iron content, on the order hand, varied from well proximity to landfill sites. For example, while R1 recorded (0.010 mg/l) of iron and this was below the maximum threshold (0.3mg/l). The rest, even though increased, were still within the threshold. Iron concentration at R3 (2.68 mg/l), and R4 (0.626 mg/l) were on the other hand outside the maximum permissible levels. The arsenic levels in all the water samples were the same (<0.001mg/l) and also within the WHO standards (0.07mg/l) for quality drinking water.

Bacteriological Analysis of Underground Water Samples at Various Distances

The essence of this test was to detect and enumerate the indicator organisms such as bacteria present in order to help predict the general sanitary condition of water and possible health risks associated with them. The first character tested under this category was the total coliforms. The result showed that total coliforms count were present in all samples even though from lower to higher with regards to distance R1(744Cfu/100ml), R2(837Cfu/100ml), R3(1302Cfu/100ml) and R4(1488Cfu/100ml). This indicated that faecal contamination in all the water samples was very high and above the (WHO, 2002) maximum concentration and thus the water was unsafe.

The faecal coliforms in the water at R1, R3 and R4 were all above the WHO (2002) maximum concentration except at R2 which recorded zero (0) concentration for quality water. It could however, be observed that, the faecal coliforms increased in concentration from landfill site. The presence of faecal coliforms at R1, R3 and R4 indicated high pollution of underground water sources and therefore risky for use by humans without any further treatment. Escherichia Coli (E-Coli) is a form of bacteria which is rendered very dangerous especially when found in water. This is due to its long life span characteristic. The presence of E.coli can result in cholera, typhoid and dysentery when water is used without further processing. The E.Coli values recorded were R1 (20 Cfu/100ml), R3 (279Cfu/100ml) and R4 (279Cfu/100ml) respectively whereas no E.Coli was recorded at R2. The result showed high inference of bacteria growth in all the water sources sampled except R2 which was within the WHO guideline or standard for E. Coli concentration.

It could be deduced that bacteria growth as a result of leachate has little impact in areas closer to point of pollution but high impact on distant areas between 100m–400m. Nevertheless, other possible sanitation factors such as presence of rubbish dump or toilet facility could lead to high bacteria growth. This scenario might be used to explain why there was high occurrence of E.Coli's at R3 and R4.

The concentration of other bacterial growth such as total heterotrophic was noticeable. The values of heterotrophic bacterial recorded declined with distance from the landfill site; R1 (3276 Cfu/100ml), R2 (884Cfu/100ml) and R3 (676Cfu/100ml), but slight increment at R4 (1404Cfu/100ml). The presence of heterotrophic bacterial at R1 may be due its proximity to landfill site.

Conclusion

The presence of the landfill sites had the potential to contaminate chemical composition of underground water from the monitoring boreholes at the various distances (R1, R2, R3 and R4). Comparison of the quality of water in the various sites indicated that leachate from landfill site had polluted groundwater since the parameters measured including the physiochemical and bacteriological were all above the permissible levels. This could have negative health effects on households who depend on groundwater for their household water supply. Using unsafe water may lead to several waterborne diseases, and chronic health problems. Based on the outcome of the research, it is recommended that the Authorities in Ghana should have concrete policies with the siting of landfill sites since it has the ability to contaminate groundwater resources and subsequent health implications on adjacent communities. As evidenced from the study, landfill sites should be sited outside human settlements since leachate could travel as far as 400m as shown by this study.

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References

Akinbile, CO. "Environmental Impact of landfill on groundwater quality and Agricultural soils in Nigeria", *Soil and Water Research,* 2012, 7(1): 18-26.

Alslaibi, TM., Mogheir, & YK., Afifi, S. "Analysis of landfill components in estimating the percolated leachate to groundwater using the HELP model". *Water Science & Technology,* 2010, *62*(8), 1727–1734.

APHA, Standard Method for the Examination of Water and Wastewater. *American Public Health Association*, 2006, Washington D.C.

Baun, A. et al. "Toxicity of Organic Chemical Pollution in Groundwater down Gradient of a landfill", *Environmental Science,* 2000, *34,* 1647– 1652.

Christensen, TH., et.al "Biogeochemistry of landfill leachate plumes'. *Applied Geochemistry,* 2001, *16,* 659–718.

Christensen, TH., & Kjeldsen, P. Basic biochemical processes in landfills. In:Sanitary landfilling: Process, Technology and Environmental Impact. Christensen, T.Hoo Cossu. R. and Stegmann. R. (eds.), Academic Press Ltd., London, 1989, pp. 29- 49.

Daskalopoulos, E., Badr, O. and Probert, SD. "An Integrated Approach to Municipal Solid Waste Management". *Res. Cons. Rec*., 1998, *24*(1), 33-50.

Lee, GF., &. Jones-Lee, A. Groundwater pollution by municipal landfills. Leachate Composition, detection and water quality significance. Proceeding of the 4th International Landfill Symposium, Sardinia, Italy, 1993, pp: 1093-1103.

Ga East Sanitation Strategy and Action Plan (2010), Ga East Municipal Assembly (GEMA Report), Abokobi, Ghana.

Ikem, A. et al. "Evaluation of groundwater quality characteristics near two waste sites in Ibadan and Lagos, Nigeria". Water, Air, and Soil Pollution, 2002, *140,* 307–333.

Singh, SK., & Jhamnani, B."Groundwater contamination due to Bhalaswa Landfill site in New Delhi. *International Journal of Environmental Science and Engineering*, 2009, *1*(3), 121-125.

Kot, B., Baranowski, R., & Rybak, A. (2000) Analysis of mine waters using X-ray fluorescence. *Polish Journal of Environmental Studies*, *9*(5), 429-431.

Longe EO., & Balogun MR. Groundwater Quality Assessment near a Municipal Landfill, Lagos, Nigeria. *Research Journal of Applied Sciences, Engineering and Technology,* 2010, *2,* 39–44.

Lopez, A., et al. "Fenton's pre-treatment of mature landfill leachate", *Chemosphere,* 2004, *54* (7), 1005-1010.

Mohd, RT., et al "Groundwater Quality a Two Landfill sites in Selangor, Malaysia". *Bulletin of the Geological Society of Malaysia*, . 2011, *57,* 13–18.

Mohamed, A.F., et al. Groundwater and Soil Vulnerability in the Langsat Basin Malaysia. *European Journal of Scientific Research,* 2009, *27,* 628-635.

Mu, F., Aysun, O. & Mineku, R. "Characterization of the leachate an Urban landfill by Physicochemical Analysis and Solid Phase Micro extraction- GC/M" *Environmental Monitoring and Assessment,* 2006, *121,* 439–459.

Ogdengbe, K., & Akinbile, CO.) "Impact of Industrial Pollutants on Quality of Ground and Surface Waters at Oluyole Industrial Estate, Ibadan, Nigeria". *Nigerian Journal of Technological Development,* 2004, *4,* 139–144.

Ogundiran, O. O., Afolabi, TA." Assessment of the Physicochemical Parameters and Heavy Metals' Toxicity of leachates from Municipal Solid Waste Open Dumpsite". *International Journal Environment Science & Technology*, 2008, *5*(2), 243-250.

Paras, R., et.al "Assess of Pollution near Landfill Site in Nagpur, India by Resistivity Imaging and GPR". *Environmental Monitoring Assessment,* 2007, *31,* 489–500

Schrab, GE, Brown, KW, & Donnelly, KC. "Acute and genetic toxicity of Municipal landfill leachate. *Water, Air, and Soil Pollution*, 1993, *69,* 99–112.

Somczyska, B., & Somczyski, T. "Physicochemical and toxicological characteristics of leachates from MSW landfills. *Polish Journal of Environmental Studies*, 2004, *13*(6): 627-637.

Tchobanoglous, G, Theisen, H, & Vigil, S. (1993) Integrated Solid Waste Management: Engineering Principles and Management Issues, McGraw-Hill Inc., New York, USA.

Tengrui, L., et al. "Characteristics of nitrogen removal from old landfill leachate by sequencing batch biofilm reactor. *Journal of Applied Sciences,* 2007, *4,* 211–214.

World Health Organization – WHO, Guidelines for Drinking Water Quality. Third Edition, Volume1, 2004.

World Health Organization - WHO, Drinking Water Guidelines: Bacteriological Parameters. Vol. 13 Geneva, Switzerland: 2002.

Zhang, H., Choi, H., & Phuangb, C. "Treatment of landfill leachate by Fenton's Reagent in a continuous stirred Tank Reactor. *Journal of Hazardous Materials*, 2007, *136*(3), 618–623.