Leachate Quality Characteristics and Groundwater Contamination around Active and Closed Landfills in Lagos, Nigeria

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Abstract
Landfilling is widely applied as a disposal method for solid wastes in most developed and developing countries. However, in many developing nations many landfills are not properly managed, and pose a serious threat to the environment due to leachate run-off. The risk of groundwater contamination by leachate is considered a significant environmental concern associated with landfilling. This study evaluated the quality characteristics of leachates from four landfills (two closed and two active landfills) in Lagos, Nigeria. The quality characteristics of groundwater samples near the landfills were also assessed. Leachate and groundwater samples were analyzed for some physicochemical properties, trace and major elements. The obtained results revealed that the total hardness in the leachates from all the landfills exceeded the regulatory limits in Nigeria. COD values in all the leachates were above the limit set by the Lagos State Environmental Protection Agency (LASEPA) which is an indication of gross organic pollution of the leachates. Generally, the concentrations of trace and major elements in the leachates were low. The presence of high concentrations of Pb in raw leachates of Abule-Egba (1.037 mg/L) and Olusoshun (1.680 mg/L) is a matter of concern because Pb is known to be one of the highly toxic environmental pollutants. Moreover, the total hardness level in groundwater near Soluos 3 landfill (190 mg/L) exceeded the limits by the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO). Trace metals concentrations in the groundwater samples were generally low. Finally, the leachate quality characteristics of the closed and active landfills in this study and the associated groundwater quality characteristics did not follow any specific pattern but might have been largely influenced by the composition and type of solid wastes disposed at each of the landfill sites.
Keywords: Leachate, groundwater, landfill, physicochemical characteristics, trace and major elements, Lagos

1.Introduction

Disposal of solid wastes is a challenge for many communities in the developed and developing countries because of the risks to human, health and the general environment. Many of the current problems associated with solid waste management have come from increased waste generation resulting from increasing urban population. Landfilling is widely applied as a disposal method for municipal solid waste in most developed and developing countries due to such advantages as simple disposal procedure, low cost and landscape restoring effects on pits from mineral workings (Davis and Cornwell, 2008; Bashir et al.,2010). However, many landfills are not properly managed, and pose a serious threat to the environment due to leachate run-off (Kurniawan et al.,2006; Wiszniowski et al., 2007; Mangimbulude et al.,2009).The disposal sites are capable of releasing large amounts of harmful chemicals to nearby water sources and air via leachate and landfill gas respectively (Christensen *et al.*, 2001). Leachate is produced when liquid originating from rain, melted snow or waste itself percolates through a landfill and picks up organic and inorganic materials from decomposing solid wastes (Lo,1996, Kanmani and Gandhimathi 2013a). When refuse is buried in a landfill, a complex series of biological and chemical reactions occur as the refuse decomposes mainly as a result of the activities of microorganisms.

The existence of wide variations in leachates composition has been largely demonstrated (Johansen and Carlson,1976; Bookter and Ham,1982; Robinson and Luo,1991; Christensen et al.,2001, Robinson, 2007). The chemical composition of leachate is influenced by many factors such as the initial composition of the waste, the amount of the waste, moisture content of the solid waste, local factors as climate and hydro geological conditions of landfill and finally the age of the landfill (Johansen and Carlson,1976; Kouzeli-Katsiri et al.,1999; Kulikowska and Klimiuk,2008).The risk of groundwater and surface water contamination by leachate is considered to represent the most significant environmental concern related to the landfilling of waste (Kjeldsen and Christophersen, 2001; Ikem et al., 2002; Daka et al.,2007; Awofolu et al.,2007; Salem et al.,2008; Odukoya and Abimbola,2010). The detailed characterization of leachate quality can provide a substantial contribution to the better understanding of leachate production and diverse operations in landfill. This can lead to a more efficient management of landfill sites including treatability options of leachates (Tatsi and Zouboulis, 2002; Aziz et al., 2010). An understanding of leachate composition is also critical for making projections on the long-term impacts of landfills on the neighbouring ground water and surface water reserves (Kjeldsen et al., 2002; Bahaa-eldin et al.,2010).

Percolation of leachate through soil can affect underlying aquifer and surface water surrounding the landfill. Contamination of surface and ground water by landfill leachate raises serious public health and environmental concerns (Sulemana et al. 2015). Groundwater monitoring is an important aspect of sustainable landfill management. It conforms to the normative principle of sustainability which includes the precautionary principle and equity (Bosselmann et al. 2008). Continuous groundwater monitoring can also help in sustainable landfill management in order to detect any pollution from its outset and thus provides the opportunity to remediate the pollution before it becomes pandemic. The chemical composition of groundwater is a measure of its suitability as a source of water for human and animal consumption, irrigation, and for industrial and other purposes (Babiker et al. 2007; Kanmani and Gandhimathi 2013b). Therefore, monitoring the quality of water is important because clean water is necessary for human health and reliability of aquatic ecosystems.

The current disposal practices of solid wastes in Nigeria are not totally safe for humans and the environment; the waste disposal sites are neither properly designed nor constructed. Assorted solid wastes are indiscriminately disposed at the dumpsites without segregation. In Nigeria, one of the major concerns about solid waste management is related to the pollution potential of uncontrolled leachate migration from landfills into local groundwater and the challenge to the attainment of the United Nations' Sustainable Development Goal on clean water and sanitation by 2030 (Ajibola, 2016). Lagos is the commercial capital of Nigeria with a population of more than 21 million people. Because of the high human population, the state generates a large volume of waste daily which are often disposed of into landfills under the management of the Lagos State Waste Management Authority (LAWMA). The landfills receive a wide spectrum of wastes ranging from organic to inorganic and hazardous wastes.

This study was undertaken to evaluate the qualities of leachates from four landfills in Lagos, Nigeria and possible groundwater contamination near the landfill sites. The aim was to assess the quality characteristics of leachates from two active landfills (Soluos 3 and Olusoshun) and two closed landfills (Soluos 2 and Abule-Egba) in Lagos with a view to evaluating the possible contamination of groundwater resources near the landfills due to leachate migration. Therefore, raw and runoff leachates were collected from the active and closed landfills and analyzed for physicochemical parameters, trace and major elements. Groundwater samples were also collected near the landfill sites and analyzed. The results were compared across the different landfill sites and with relevant regulatory standards.

2. Materials and Methods

2.1 Sites description:

Lagos with a population of about 21 million people is the commercial capital of Nigeria. About nine million metric tonnes of wastes were deposited into various landfill sites in Lagos in 2014 (LAWMA). Olusoshun, Abule-Egba and Soluos landfills are located in Lagos, South-Western Nigeria (Fig. 1). Lagos is located on longitude 3º 24' E and latitude 6º 27' N. Four landfill sites (two closed and two active sites), under the management of the Lagos Waste Management Authority (LAWMA), were considered for this study: Olusoshun (active site), Soluos 2 (closed site), Soluos 3 (active site) and Abule-Egba (closed site). Olusoshun landfill is located at Ojota, Lagos State, Nigeria. It began operation in 1992. The size of the landfill is about 42.7 hectares. Therefore, the lifespan of the landfill is 24 years. Waste deposited on the landfill is predominantly solid wastes from surrounding industrial factories, gasoline station, automobile repair workshop and waste transported to the landfill. The landfill shares same boundary with Oregun, Ketu and Ojota communities. It receives approximately 40% of the total wastes deposits in Lagos. Solous landfill is ranked the second largest after Olusoshun dumpsite. Solous landfill is sub-divided into two sections namely Solous 2 (closed site) and Solous 3 (an active site). Solous 2 covered about 7.8 hectares with average lifespan of 5 years and Solous 3 covered about 5 hectares of land with an average life span of 5 years and receives an average waste of about 2,250m^2 per day (LAWMA website). Abule-Egba landfill, which began operation in 1992, is located along Oshodi–Sango road in the Alimosho Local Government area, in the North Western part of Lagos State, Nigeria. The land size is about 10.2 hectares with a lifespan of about 24 years from the date of its establishment in 1992. Its geographical location is 6.87ºN, 3.38ºE. It received 250,000 tonnes of waste annually. Abule-Egba landfill has been inactive (closed) since 2008. Generally, the geology of the study areas falls within coastal plain sand of Dahomey Basin and is characterized by coarse, unsorted sands and clay lenses mixed together in varying proportions at varying depth. Depth to water ranges from land surface to about 10m for first acquifer (Odukoya and Abimbola, 2010).

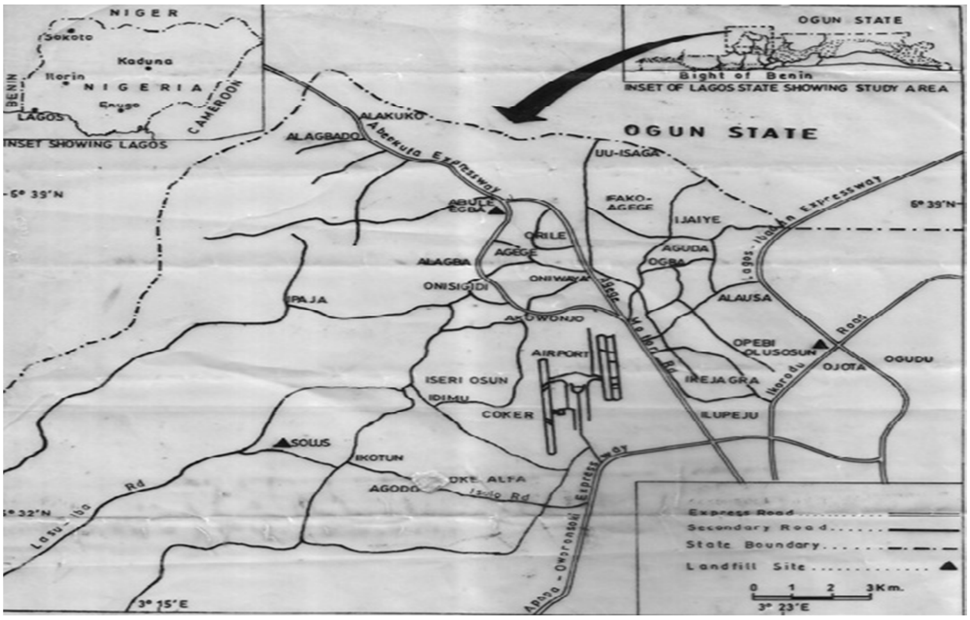

Fig 1: Map extract of Lagos showing the location of the Landfill Sites

2.2. Sampling and Analysis

In an effort to determine the quality characteristics of leachates from the landfills, raw leachates samples were collected in July 2015 from four landfill sites in Lagos namely; Soluos 2 (closed site), Soluos 3 (active site), Abule-Egba (closed site) and Olusoshun (active site). Collection of run-off leachate samples was possible for only Olusoshun and Abule-Egba landfill sites. Groundwater samples were also collected from dug wells near the landfill sites. The leachate and groundwater samples were collected in plastic bottles previously cleaned by soaking in 10% nitric acid, rinsed with distilled water and afterwards rinsed with the leachate or groundwater to be sampled. The raw leachate samples were designated as RLS2, RLS3, RLA and RLO for Soluos 2 landfill, Soluos 3 landfill, Abule-Egba landfill and Olusoshun landfill respectively. The Run off leachate samples were designated as ROO and ROA for Olusoshun and Abule-Egba respectively. Similarly, the groundwater samples were designated as GWS2, GWS3, GWA and GWO for Soluos 2 landfill, Soluos 3 landfill, Abule-Egba landfill and Olusoshun landfill respectively. Collected samples were transported to the laboratory, filtered and stored at 4ºC until analysis.

The pH was recorded on site at the time of sampling with a digital pH meter. The physicochemical analyses were carried out according to the standard methods for the Examination of Water and Wastewater (APHA 2012). The parameters determined include total dissolved solids, total suspended solids, total hardness, total alkalinity, chloride, phosphate, chemical oxygen demand (COD), trace and major elements (Cadmium, Lead, Nickel, Zinc, Copper, Manganese, Calcium, Sodium and Potassium). COD was determined by the reactor digestion method using dichromate reagent vials. Trace and major elements were determined with an Atomic Absorption Spectrophotometer (Thermo Fisher Scientific iCE 3000 Series).

3. Results and Discussion

3.1 Physicochemical Characteristics of Leachates

Quality characteristics of leachates are often influenced by many factors such as biochemical changes, physicochemical processes including dissolution, adsorption, dilution, precipitation and volatilization (Emenike et al. 2012). The composition of leachates may also vary as a function of landfill age (Kulikowska and Klimiuk,2008). The results of physicochemical analysis and determination of trace and major elements in the raw and run-off leachate samples are presented in Tables 1 and 2.

The pH values of the raw and run-off leachates ranged from 6.84 to 7.95. Leachate samples from the two active sites (Soluos 3 and Olusoshun) had lower values than the closed landfill sites (Soluos 2 and Abule-Egba). This is an indication of short acidic phase for the active sites and methanogenic phase for the closed sites. Similar results were obtained by other researchers (Kanmani and Gandhimathi 2013(a), Abd-El-Salam and Abu-Zuid, 2015). The high values for the closed sites showed that already there was already a decrease in the concentration of free volatile acids due to anaerobic decomposition (Kanmani and Gandhimathi 2013(b)). Alkaline pH is normally encountered at landfills after 10 years operations began (El-Fadel et. al 2002).

Total hardness of the raw leachates ranged from 2075 to 4960 mg/L. Maximum value of hardness was observed for Abule-Egba site. However, for the run-off leachates, hardness was higher in Olusoshun (250 mg/L) than Abule-Egba (185 mg/L). Hardness in all the leachate samples exceeded the LASEPA and FEPA regulatory limits. Total alkalinity of the raw leachates ranged from 21 to 174 mg/L. Soluos 3 had the lowest value of alkalinity. The alkalinity levels in all the samples were within the WHO limit.

Table 1: Physicochemical Quality Characteristics of Leachates of Active and Closed Landfills in Lagos.

Parameter	RLS2	RLS3	RLA	RLO	ROO	ROA	LASEPA	FEPA	WHO
pH	7.5±1.4	6.8± 1.6	7.9±1.2	7.1±1.5	7.2±1.1	7.8±1.4	5.5-9	6-9	6.5-8.5
TDS	3255±621	705±132	2000±458	2175±573	2175±482	1000±254	2100	2000	1000
TSS	745±150	295±62	1815±532	1905±494	825±227	355±93	100	30	-
Hardness	4500±724	2075±528	4960±846	2935±645	250±54	185±32	-	-	100
Alkalinity	70±12	21±4	174±28	117±34	68±18	11±3	-	-	200
Chloride	3998±726	1000±241	175±48	249±89	224±53	124±42	250	600	250
Phosphate	23.0±5.0	1.0±0.2	42±7.9	1.6±0.4	3.4±0.7	0.8±0.2	-	5	-
COD	1171±142	247±53	3647±548	3962±616	1532±128	205±47	200	-	-

Note: LASEPA- Lagos State Environmental Protection Agency
FEPA-Federal Environmental Protection Agency
WHO- World Health Organization

Chloride levels ranged from 175 mg/L to 3998 mg/L in raw leachates with Soluos 2 containing the highest concentration. Run-off leachates from both Olusoshun and Abule-Egba contained comparable levels of chloride. The chloride contents in raw leachates from Soluos 2 and Soluos 3 exceeded both the LASEPA and FEPA regulatory limits whereas chloride contents in raw and run-off leachates of Abule-Egba and Olusoshun were below the discharge limits for effluents. Chloride is a conservative contaminant and is not affected either by the biochemical processes taking place in the landfill body or by natural decontamination reactions in which the leachates are involved during their penetration in the vadose zone (Fatta et al. 1999). High chloride contents in leachates were also observed by other researchers (Tatsi and Zouboulis, 2002; Abd El-Salam and Abu-Zuid, 2015). Since chlorides represent inert, non-biodegradable compounds, they can also be used to assess the extent of contamination of nearby water resources, provoked by contact with the leachate (Lo, 1996). While the concentrations of chlorides in raw and run-off leachates could not be considered as potential threats to the nearby water resources, the high concentrations of chloride in leachates from Soluos 2 and Soluos 3 pose serious risks to the nearby water resources.

Phosphates concentrations in the raw leachates ranged from 1.0 to 42 mg/L. Abule-Egba landfill leachates had the highest value of phosphate. The concentrations of phosphates in run-off leachates from Olusoshun and Abule-Egba were 3.4 and 0.76 mg/L respectively. The concentrations of phosphates in raw leachates from Soluos 2 and Abule-Egba (closed landfills) exceeded the FEPA discharge limit for effluents. The presence of phosphates in water increases eutrophication and therefore promotes the growth of algae. With the exception of raw leachates in Abule-Egba and Soluos 2 landfill sites, the values of phosphates in this study were low compared to previously reported results (Aziz et al. 2010; Tchobanoglous et al. 1993). However, phosphate concentrations were at similar levels to the values found recently for dumpsites in Port Harcourt, Nigeria (Agbozu and Nwosisi, 2015). The high concentrations of phosphates in Abule-Egba and Solous 2 raw leachates may be attributed to the composition of their wastes stream composed relatively large amount of detergent garbage and residues of inorganic fertilizers.

COD is a measure of gross organic pollution in water. The concentration of COD in the raw leachates exhibited a range of values between 247 and 3962 mg/L. Olusoshun contained the highest level of COD. The values of COD in the run-off leachates from Olusoshun and Abule-Egba were 1532 and 205 mg/L. COD values in all the leachates in this study exceeded the LASEPA regulatory limit. The COD values were generally higher than the values obtained for leachates collected at dumpsites in Port Harcourt, Nigeria (Agbozu and Nwosisi, 2015).

3.2 Trace and Major Elements in Leachates

Leachates usually have high organics concentration, complexation of metals with those organics is therefore, very likely. Generally, the concentrations of trace and major elements were low (Table 2). All the leachate samples contained comparable levels of Cd (BDL to 0.009 mg/L). Similar results were obtained for Cd by Agbozu and Nwosisi et al. 2015. Cd contents in the leachates were lower than both the LASEPA and FEPA regulatory limits. However Cd contents in Abule-Egba raw and run-off leachates exceeded the WHO regulatory limit for drinking water. Concentrations of Pb ranged from 0.003 to 1.680 mg/L. High concentrations of Pb were observed in Abule-Egba and Olusoshun raw leachates. The levels of Pb in both landfills exceeded the LASEPA, FEPA and WHO regulatory limits. The levels of Pb in leachates from all other landfills were below the regulatory limit. The high level of Pb in Abule-Egba and Olusoshun could be attributed to dumping of Pb-related wastes such as used batteries and photographic processing materials in the landfills. This presence of high concentrations of Pb in raw leachates from both landfills is a matter of concern as Pb is known to be one of the highly toxic environmental pollutants. Recently, a high level of Pb contents was also observed in waste soils from Abule-Egba landfill (Ajibola 2016).

Table 2: Trace and Major Elements in Leachates of Active and closed Landfills in Lagos

Trace/Major Element	RLS2	RLS3	RLA	RLO	ROO	ROA	LASEPA	FEPA	WHO
Cadmium	BDL	BDL	0.009	0.008	0.001	0.003	2.0	<1	0.003
Lead	0.014	0.003	1.037	1.680	0.004	0.019	0.1	<1	0.01
Nickel	0.016	BDL	0.023	0.039	0.019	BDL	3.0	<1	0.07
Zinc	0.089	0.012	0.623	0.128	0.035	0.049	5.0	<1	3
Copper	0.010	0.006	1.407	0.025	0.009	0.025	3.0	<1	2.0
Manganese	0.344	0.121	0.567	0.088	0.037	0.056	5.0	5.0	0.1
Calcium	8.305	4.31	9.575	2.765	1.625	2.033	200	200	-
Sodium	1.251	0.569	0.807	0.761	0.417	0.414	-	-	-
Potassium	2.416	0.971	1.402	1.680	0.826	0.604	200	-	-

Note: LASEPA- Lagos State Environmental Protection Agency
FEPA-Federal Environmental Protection Agency
WHO- World Health Organization

Ni contents in the leachates ranged from BDL to 0.039mg/L. Olusoshun landfill leachate contained the highest level of Ni. Ni contents in leachates from all the landfills in this study were generally below the regulatory limits. Concentrations of Zn in the raw leachates ranged from 0.012 to 0.623 mg/L. The level of Zn in Abule-Egba leachate was a bit high compared to other landfill sites. The concentrations of Zn in all the leachates were below the regulatory limits. High concentration of Zn in Abule-Egba leachates could be related to dumping of used batteries and fluorescent lamps into the landfill. Copper contents of the leachates ranged from 0.006 to 1.407 mg/L. Highest concentration of Cu was also observed in Abule-Egba raw leachate and exceeded the FEPA limit. Concentrations of Cu were generally lower than the values measured in leachates from a dumpsite in Effurun, Nigeria (Ohwoghere-Asuma and Aweto, 2013).

Manganese contents ranged from 0.088 to 0.567 mg/L. Similar levels of Mn were determined in sanitary landfills in Alexandria, Egypt (Abd El-Salam and Abu-Zuid, 2015). Highest concentration of Mn was found in Abule-Egba raw leachates. Mn concentrations in Abule-Egba and Soluos 2 (closed landfills) leachates exceeded the WHO limit for drinking water. However, Mn levels in all the landfills' leachates were below the LASEPA and FEPA regulatory limits.

The concentration of Calcium in the raw leachates ranged from 2.765 to 9.575 mg/L. Abule-Egba landfill contained the highest value. The high level of Ca could be linked to the corresponding high content of total hardness. Sodium ranged from 0.569 to 1.251 mg/L. Soluos 2 landfill contained the highest level of sodium. The levels of sodium contents in closed landfills (Abule-Egba and Soluos 2) were higher than the active landfills (Soluos 3 and Olusoshun). Potassium concentration ranged from 0.971 to 2.416 mg/L. In comparison to the LASEPA standard, potassium contents were generally low.

3.3 Quality Assessment of Groundwater around the landfill sites

The results of quality characteristics of groundwater near the landfill sites in this study are presented in Table 3 and Fig 2. The pH of groundwater samples from the landfill sites were generally within the national standards for drinking water (NSDWQ) and the WHO limits. With the exception of Abule-Egba total dissolved solids in all the groundwater samples from other landfill sites exceeded the NSDWQ and WHO regulatory limits. Highest level of TDS was observed in Soluos 3 groundwater. TDS levels in the groundwater reveal the saline behaviour of water (Kanmani and Gandhimathi, 2013a). Total hardness in Soluos 3 groundwater was higher than NSDWQ and WHO limits for drinking water. Thus, groundwater samples in and around Soluos 3 landfill would be expected to be corrosive for plumbing fixtures, tend to form scale-coatings in water heaters, require the use of larger amounts of soap for washing and shorten the durability of clothes. Alkalinity of the groundwater samples was generally low in comparison with the WHO standard. The Chloride contents in the groundwater samples ranged from 10 to 263 mg/L. High values of chloride were present in the groundwater around the active landfill sites (Soluos 3 and Olusoshun). Chloride content in Olusoshun exceeded the NSDWQ and WHO regulatory limits. This high content of chloride in Soluos 3 groundwater is a matter of concern as chloride is a conservative contaminant and poses serious threat to groundwater (Ohwoghere-Asuma and Aweto, 2013). The groundwater from all the landfill sites contained similar level of phosphate (0.71 – 0.76 mg/L). The phosphate levels were generally low.

Table 3: Physicochemical Quality Characteristics of Groundwater around active and closed landfills in Lagos

Parameter	GWS2	GWS3	GWA	GWO	LASEPA	NSDWQ	WHO
pH	7.9±1.2	6.8±1.4	8.1±1.6	7.3±1.0	5.5-9	6.5-8.5	6.5-8.5
TDS (mg/L)	2500±418	3500±372	800±174	1333±186	2100	1000	1000
TSS (mg/L)	500±102	500±84	200±59	667±127	100	-	-
Hardness (mg/L)	25±4	190±52	125±34	43±6	-	150	100
Alkalinity (mg/L)	34±8	6±2	35±12	32±10	-	-	200
Chloride (mg/L)	75±8	249±45	10±2	263±64	250	250	250
Phosphate (mg/L)	0.73±0.1	0.71±0.1	0.72±0.2	0.76±0.1	-	-	-
COD (mg/L)	-	233±25	-	110±15	200	-	-

Note: LASEPA: Lagos State Environmental Protection Agency
NSDWQ-Nigerian Standards For Drinking Water Quality
WHO- World Health Organization

Chemical Oxygen Demand (COD) values in all the groundwater samples, with the exception of Soluos 3 groundwater, were below the LASEPA limit. The high level of COD in Soluos 3 groundwater calls for concern as it is an indication that the groundwater sample was polluted with organics.

Trace metals concentrations in all the groundwater samples were generally low (Fig. 3). Worthy of note was the concentration of Cd in the groundwater of Olusoshun which exceeded the national guidelines for drinking water and the WHO regulatory limit. This high concentration of Cd in Olusoshun groundwater is a matter of concern as Cd may affect the kidneys, liver, bones and teeth (Hogan 2010).

Soluos 3 groundwater had the highest concentration of Pb though the Pb contents in the groundwater near all the landfill sites were below the NSDWQ and WHO limits. The highest level of Zn was observed in Olusoshun groundwater. Similarly, the highest level of Cu was found in Olusoshun groundwater though at a level lower than the NSDWQ and WHO limits. Ni contents in all the groundwater samples were generally low and were below the NSDWQ and WHO limits.

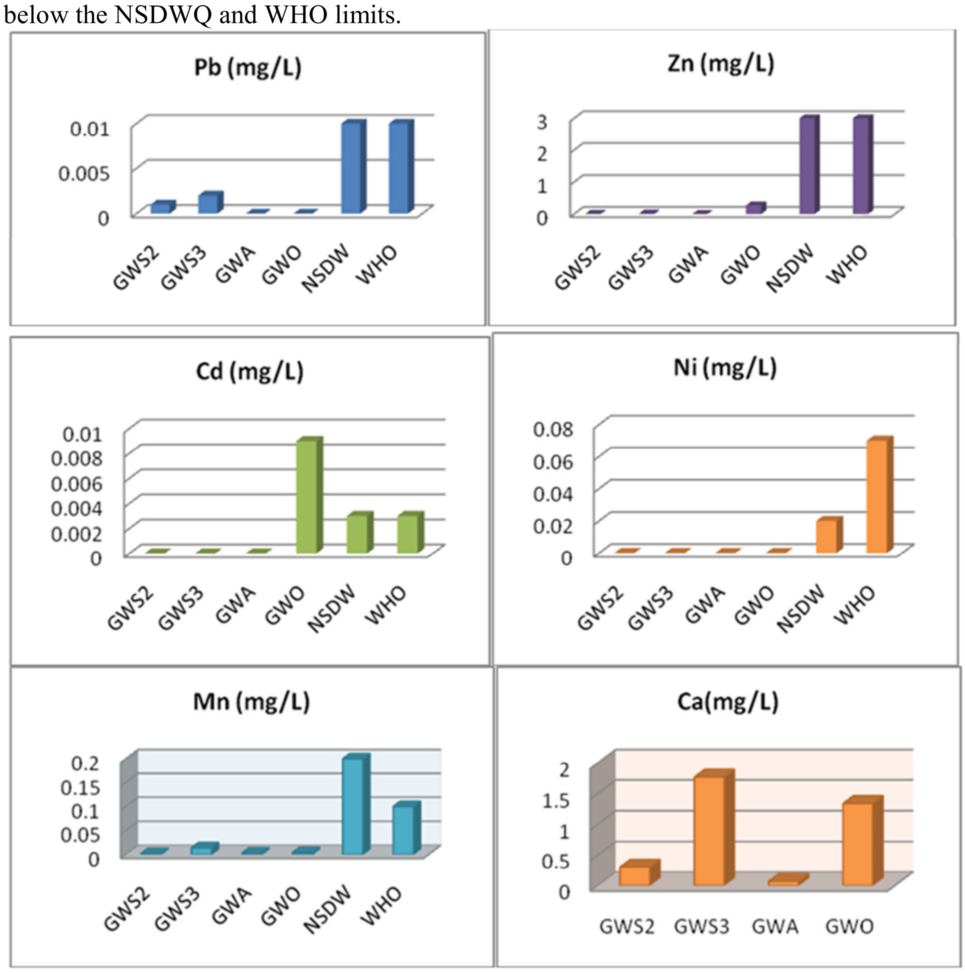

Fig 2: Trace and Major Elements Concentations in groundwater around Landfills in Lagos.

Conclusion

The quality characteristics of leachates from four landfills (two closed and two active landfills) have been evaluated. Groundwater quality near the landfill sites was also assessed. The physico-chemical analysis of the leachates revealed that total hardness in the leachates from all the landfills exceeded the LASEPA and FEPA regulatory limits. COD values in the leachates from all the landfills exceeded the LASEPA regulatory limit which is an indication of high gross organic pollution of the leachates. Generally, the concentrations of trace and major elements in the leachates were low. High concentrations of Pb were determined in the raw leachates from Abule-Egba and Olusoshun landfills. This presence of high concentrations of Pb in raw leachates from both landfills is a matter of concern because Pb is one of the highly toxic environmental pollutants. Total hardness level in groundwater near Soluos 3 landfill (190 mg/L) exceeded the NSDWQ and WHO limits. Groundwater near Soluos 3 landfill would therefore be expected to be corrosive for plumbing fixtures, tend to form scale-coatings in water heaters, requires the use of larger amounts of soap for washing and shorten the durability of clothes. High contents of chlorides were present in the groundwater around the active landfill sites (Soluos 3 and Olusoshun). Trace metals concentrations in the groundwater samples were generally low. High concentration of Cd was found in Olusoshun groundwater and this is a matter of concern as Cd is known to affect the kidneys, liver, bones and teeth. Finally, the leachate quality characteristics of the closed and active landfills in this study and the associated groundwater quality characteristics did not follow specific patterns but might have been largely influenced by the composition and type of solid wastes disposed at each of the landfill sites.

Acknowledgement

The author acknowledges the management of the Lagos Waste Management Authority (LAWMA) for the approval to collect samples at the landfills in this study. The efforts of Azeezat Ayinla, Ismail Hamzat and Aanuoluwapo Adegoke are also acknowledged.

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