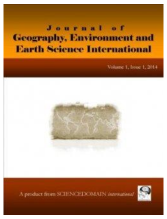

Journal of Geography, Environment and Earth Science International
3(2): 1-21, 2015; Article no.JGEESI.19197

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Evaluation of Heavy Element Levels in Leachate, Soil and Groundwater in the Lagos Landfill Areas of Nigeria

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Author's contribution

This work was essentially carried out by author IMI and supervised by CNA with ancillary contributions from many others. Author IMI read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2015/19197
Editor(s):
(1) Enrico Tavarnelli, Department of Physical, Earth and Environmental Sciences University of Siena, Italy.
(2) Anthony R. Lupo, Department of Soil, Environmental, and Atmospheric Science, University of Missouri, Columbia, USA.
Reviewers:
(1) Fábio Henrique Portella Corrêa de Oliveira, Biology Department, Paulista College of Health, Brazil.
(2) Anonymous, Moi University, Kenya.
Complete Peer review History: http://sciencedomain.org/review-history/10086

Original Research Article

Received 29th May 2015
Accepted 22nd June 2015
Published 8th July 2015

ABSTRACT

Landfills imbued with heavy elements are major threats to the environment. To assess anthropogenic enrichment, soil, leachate and groundwater samples were collected from active landfills in Lagos and analysed for some heavy elements. The geology of the sampled areas is essentially that of the Oligocene to Pleistocene Coastal Plain Sands except for those of Epe and Badagry which are Recent Deposits. The groundwater showed a range of values (in mg/l) of: Zn, 0-0.08; Fe, 0.009-1.104; Ni, 0.007-0.039; Cd, 0.013-0.062; Hg, 0.00008-0.00384; Pb, 0.004-0.63; Cr, 0.017-0.075; Mn, 0.01-0.043; As, 0-0.053. From the results, some of the boreholes in Olusosun, Soluos, and the hand-dug well water in Ewu-Epe are unfit for drinking. In soils, concentrations were highest at the top and lowest at base of sampling. Generally, the concentrations of most of the elements decreased with increased distance and/or depth from the landfill soils. These suggest that the landfills contribute significantly to the level of these elements in these environments and imply significant attenuation with depth possibly due to adsorption and/or precipitation. The elevated levels of cadmium and arsenic do not support their use as compost for food cultivation. Also, the presence of arsenic above prescribed limits in the Epe leachate is a major concern because the

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lithology is sandy, and has a reported depth of about 3 m to the unconfined aquifer that adjoins the Epe Lagoon.

Keywords: Soil; leachates; groundwater; attenuation; cadmium; arsenic; Lagos.

1. INTRODUCTION

Lagos with a current human population of about twenty one million and a population density of 6,030/km^2, has a daily generation per capita (GPC) estimated at 0.63 kg [1]. It yields about 13,230 tonnes/day of municipal solid waste (MSW) of which about 9,261 tonnes / day (about 70%) make it to the landfills. The waste is made up of (in % volume) 45, 15, 5, 10, 5, 8, 4, and 8 of vegetables, plastics, glass, paper, metals, fines, textiles and putrescibles respectively.

Nonetheless, the practice of landfill system as a method of waste disposal in many developing countries is usually far from recommended standard [2]. For instance, none of the Lagos landfill is properly engineered and fitted with requisite leachate collection facilities. Hence, these landfills are considered one of the major threats to groundwater. The scale of this threat depends on the concentration and toxicity of pollutants in leachates, municipal solid waste (MSW) type, and permeability of geologic strata, depth of water table and the direction of groundwater flow [3]. Most of the areas chosen as landfills in Lagos are particularly worrisome because massive portions of the overburden of the aquifer have been stripped off, thereby reducing the unsaturated zone from about 35 m to about 5 m or less in some places. The voids created have had about 3.2 million metric tonnes / year MSW dumped on its exposed surface in recent years. Aquifers are vulnerable to pollution if preventive measures are not taken to prevent pollutants reaching the water table. Even some modern sanitary landfills have also been reported to leak leachate and pollute groundwater [4].

Uncontrolled inputs of heavy elements are undesirable because, once accumulated in the soil or groundwater, these elements are generally very difficult to remove. Furthermore, according to the WHO Constitution, the enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being. Therefore, the impact of heavy metals on the environment should be a concern to government regulatory agencies and the public in order to prevent environmental despoliation [5].

Groundwater is one of the major sources of potable water supply in Lagos in general [6,7]. Since these heavy elements can become a threat to vegetation and animals, and ultimately affects the quality of human life through the food chain [8], it is important to continuously monitor the level of such pollutants in the environment. This forms part of the thrust of this study.

1.1 Aim and Objectives

This study attempts to assess some of the heavy elements in leachates, soil and groundwater in and around the Lagos landfill areas by comparisons with controls, and established standards. This is to establish if there is any inherent danger of the MSW disposal on these areas and to suggest remediation in the event of occurrence.

1.2 Location and Geology of the Study Areas

The study was undertaken in all the government operated landfills areas in Lagos, the transfer loading station (TLS) areas at Oshodi and Badagry (Figs. 1-3).

The geology of the Lagos megacity is made up of Coastal Plain Sands (CPS) and the Recent Sediments. The Recent Sediments are underlain by the CPS while the CPS overlay a thick clay layer, the Ilaro Formation (Fig. 2). The CPS consists of thick bodies of yellowish and white sands and gravels. The Formation is poorly sorted and has local shale interbeds, lenses of clays and sandy clay with lignite. Though the layers are somewhat lenticular, some are of rather limited lateral extension.

The CPS is equally referred to as the Benin Formation [9]. The name Coastal Plains Sands was introduced by Tattam [10] to indicate the extensive red earths and loose, ill-sorted sands underlying the Recent Deposits of the Niger Delta and overlying the Eocene Bende-Ameki group. The name is now well established in the stratigraphy of the Delta and it has been retained in the south western coastal sedimentary basin (although the abundance of clays in the Formation in this area do not make it entirely appropriate). It consist of soft, very poorly sorted, clayey sands, pebbly sands, sandy clays, pockets of shale, and rare, thin lignites. They are indistinguishable in the field from much of the Ilaro Formation and from the basal continental beds of the Abeokuta Formation, which are similar lithologically, and weather to the same, familiar red and brown sandy earths and clayey grits. The maximum recorded thickness of the formation is about 359 ft. [11].

2. METHODOLOGY

Reconnaissance geological surveys were first undertaken and recorded on reaching the field. Soil samples from within the control areas, four landfills, and the transfer loading station (TLS) at Oshodi were collected at depth ranging from 0-100 cm using a stainless steel hand auger. 0.5 kg each of soil samples were collected and stored in sample bags. Prior to analysis, the soils samples were dried at 105°C for 48 hours and then sieved (<2 mm) using stainless steel sieves to remove large debris, gravel sized materials and plant roots. The sieved samples were homogenized and ground with a pestle and a mortar and kept in desiccators prior to chemical digestion. Strong acid digestion method was applied to dissolve the samples and their inorganic contents in solution. The heavy metals were subjected atomic absorption spectroscopy (AAS). Microsoft Excel 2007 was employed for geomathematical evaluation. As it relates to this evaluation, the Pearson method was used for correlation. Linear regression and analysis of variance (ANOVA) were also conducted.

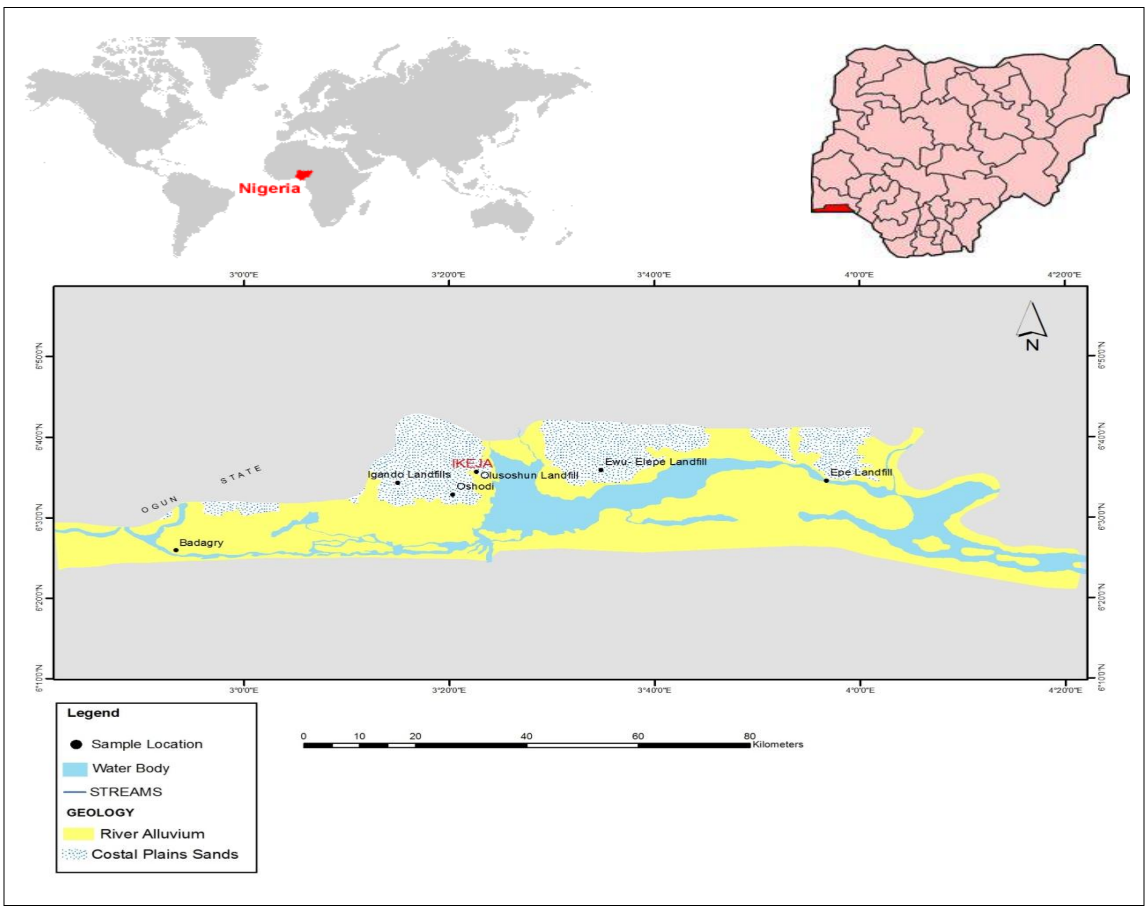


Fig. 1. Map of the geology of Lagos state showing the landfill locations and other areas (Inset: world map showing Nigeria and map of Nigeria showing Lagos State)

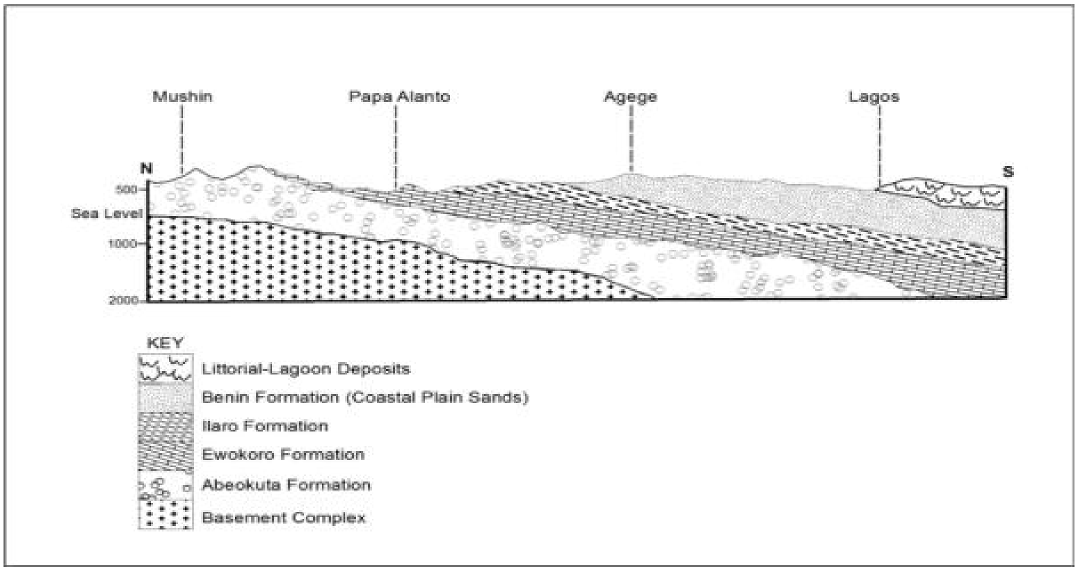


Fig. 2. N- S geological section showing the major geological formations in the Lagos area (after Jones and Hockey, 1964)

For leachates collection, sample containers (high density polyethylene-HDPE bottles), used to sample for heavy metal analysis, were washed with metal free detergent and rinsed with tap water. They were soaked in 1M HNO_3 for 24 hours and later rinsed with demineralised water and kept in air-tight container till sampling period. Samples were obtained as composite mixtures from different points at each site for proper representation. The sampling bottles were first rinsed with the leachate before sampling. The samples collected were preserved by the addition of concentrated HNO_3 (1 mg/l to leachate sample). This was to adjust the pH of the sample to less than 2, so as to arrest microbial activities and prevent loss of the metals by precipitation and adsorption. All samples collected were kept in ice chest to maintain them at a temperature below 4°C during transference from the field to the laboratory. They were also kept in refrigerator under the laboratory condition till analyses were completed on them. The time between sampling and analyses of samples was kept short and between recommended times by the standard method. To avoid contamination, the nitric acid used in preservation was ultra-pure grade (J. T. Baker, Ultrex). The methods of analyses adopted were as recommended by the standard method (American Public Health Association -APHA, [12].

The metal analysis were done by the digestion of 50ml of the sample using concentrated nitric acid to release the organic bound metals and those in particulate or those adsorbed on particulates. Analytical instruments included the Atomic Absorption Spectroscopy (AAS) and the DR 3800 spectrophotometer. Microsoft Excel (2007) software was used for statistical evaluation.

As it pertained to water sampling, one litre clean sample containers (high density polyethylene-HDPE bottles) were used for water collection. The tips of the taps from which samples were collected sterilized with ethanol to remove/ reduce the microbial load at the tips of the taps. These containers were filled to the brim to prevent trapping bubbles of oxygen. Samples were stored at room temperature (22°C). Analyses were undertaken at Schmidt Research Laboratories with assistance from LASEPA laboratories (Lagos).

3. RESULTS AND DISCUSSION

A comparison between the analyte concentrations in soils in Badagry and Olusosun landfill showed that concentrations decreased far more significantly with depth in Olusosun. Fe was also much higher at Olusosun given the lateritic soil. Ordinarily, if the concentrations of the parameters at Olusosun were naturally occurring, the top to bottom concentrations would have shown little variations.

Most of the measured indices correlated strongly and negatively with distance and depth. All the heavy elements in the Olusosun groundwater showed attenuation with distance except Mn and As. Mn increasing away from the landfill may indicate that its inherent natural concentrations were reduced by the effects of the landfill. It is possible that some of the sites of Mn, and As in the mineralogy of the natural soils were substituted by other chemical species from the landfill.

Correlation of the measured parameters in the Oshodi transfer loading station (TLS) groundwater at both depth, and distance was inconsistent. This suggests that the reference TLS is not the major contributor to the observed concentrations. Although it was expected that impervious concrete layer in the TLS and the dense thickness of the clayey/ lateritic lithology prevent leakage of leachate to the confined aquifer, given the proximity of the TLS to the highway and by consequence, high vehicular emission; better correlations were expected. However, a review of the geography of this study area shows that the samples were collected from an arcuate section away from the highway (Fig. 3). Part of the vehicular emissions may have been deposited on the soil adjacent the road. Also, some portions of the particulate matter may also have been wind-deposited over the 250 m diameter of this study in random manner. In addition, the interiors are also not free from other forms of anthropogenic activities which varied from industrial to construction, domestic, etc. Fe correlated poorly with distance and mildly with depth indicating that it is perhaps naturally inherent in the Oshodi groundwater because of the lateritic soil.

Assessment of groundwater in the Soluos 2 & 3 areas showed that all the heavy elements were negatively correlated with distance/depth. Most were also strongly correlated. This means that as distances/depth increased away from the landfill, the concentration of the measured parameters decreased. Using distance, Pb correlated the most with other measured heavy elements thereby producing the sequence: Pb > Cd >Ni >Hg > Cr >Mn > As > Fe. The excellent trend in the same negative direction indicates that the causation is similar. Conversely, Fe points more to nature given its reverse direction.

All the measured heavy elements in groundwater from the Ewu-Elepe landfill area displayed very strong and negative correlation with distance. Similarly, at depth, all the elements were strongly and negatively correlated in the Ewu-Elepe landfill soil (Fig. 5). The relationship was such that Ni > Cd > Cr > Fe > K > Pb >Hg > As >Zn > Mn.

The veracity of regression analyses in this study can be authenticated from a number of ways. For instance, (at mean groundwater depth of about 18 m), the estimated Cr was 0.05733 mg/l whereas the observed concentration was 0.062 mg/l (Table 1).

It also shows that whereas the soil is capable of adsorbing pollutants, not all of these are removed as the pollutant-bearing water infiltrates the pores in the soil to the aquifer. The results show that attenuation is exponentially higher for depth relative to distance. For instance, it takes a factor of 1:37 (depth : surface distance) to produce a unit change in potassium, zinc- 1:85 , iron- 1:64, nickel- 1:63, 1:,40,64,89,56,37, and 117 for Cd, Hg, Pb, Cr, Mn, & As respectively.

Table 1. Using the intercepts and slopes of the regression equations of the Olusosun landfill areas to estimate concentration/points of zero contamination: metals

	Fe	Ni	Cd	Hg	Pb	Cr
a	6.53579	0.15764	0.11193	0.01811	0.33771	**0.236071**
b	-0.33721	-0.00736	-0.00307	-0.00094	-0.01729	-0.00993
y=0, x=	-19	-21	-36	-19	-19	-23

Example: Estimation of concentration of Cr at a depth of 18 m:
Y= a + bx; Cr = 0.236071 + (-0.00993) × 18; Cr =0.23607 + 0.17874; Cr= 0.05733 mg/l
Example: estimation of depth (x) of nil pollutant concentration
Y= a + bx
(Where (y=0) = nil contaminant/ pollutant concentration
a = y intercept/ constant, b=slope, x= depth)

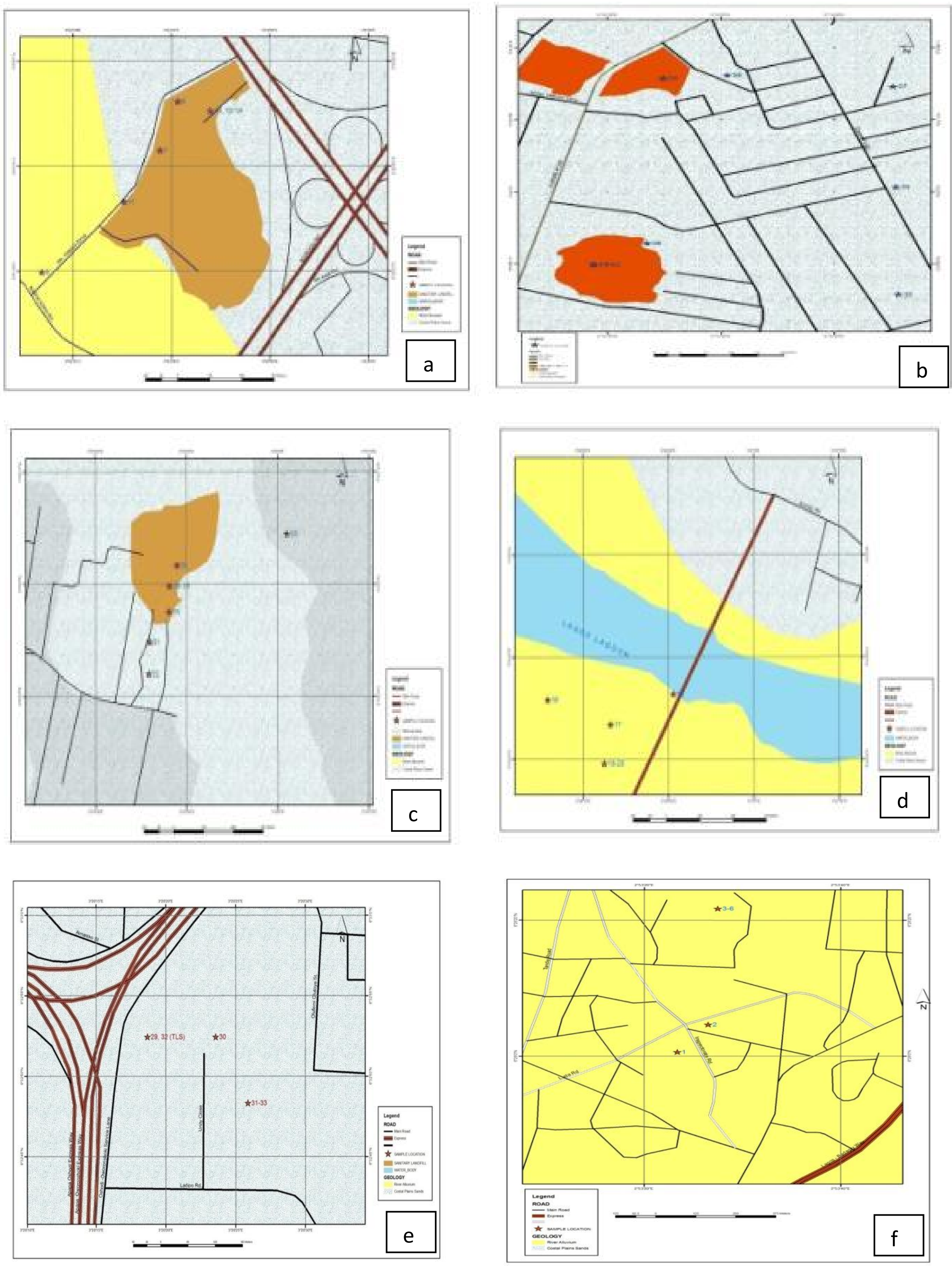


Fig. 3. Geological map of the various landfills and the sampled areas (a: Olusosun, b: Soluos 1-3 in Igando, c: Epe, d: Ewu-Elepe, e: TLS at Oshodi, f: Badagry (control)

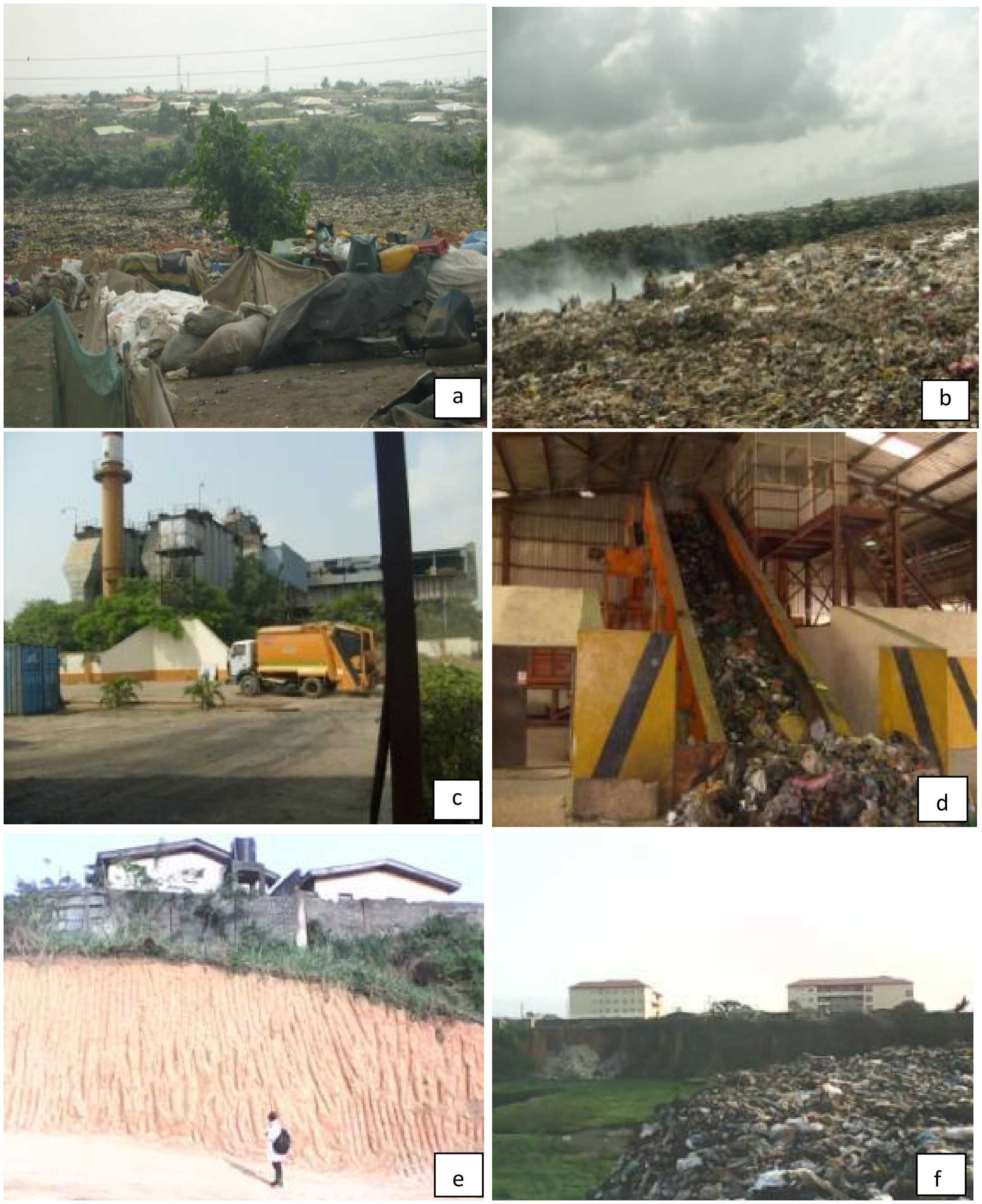


Fig. 4. Views from the landfills and transfer loading station (TLS) (a & b: portions of Ewu-Elepe, c: Parking lot at the TLS, -the overhanging structure is the moribund incinerator, d: Inside the TLS facility at Oshodi, e & f: extent of excavation in portions of Soluos 3)

More explicitly stated, as a rule of the thumb, it means for instance that in the Olusosun landfill area if it will take 1 m of soil thickness to completely adsorb Ni, a surface distance of 63 m will be required (assuming the leachate flows only on the surface gently like groundwater to permit adsorption). The concentration of cadmium taken up at a depth of 1 m of soil thickness will require a surface distance of 40 m (assuming the leachate flows only on the surface gently like groundwater flows to permit adsorption. Assuming a depth of 36 m is required for complete attenuation of Cd, required surface distance will be about 1.44 km. Corollary, a surface distance of about 2.7 km is needed for curb As pollution.

It is possible to predict theoretically, the position at which the effects of pollutants / contaminants cease to exist through the soil to the groundwater as a result of attenuative capacity. For instance, Cd showed that it required the most distance (802 m) away from the landfill for complete attenuation. Similarly, Cd showed it required the most depth (26 m). Mn increased with depth and may suggest natural imbuement.

The studied areas of Badagry (control) and Epe both have water table aquifer. The Badagry area has a reported natural soil cushion to the aquifer of between 4-9 m, Olusosun 16-38 m, Ewu-Elepe 4-28 m, Oshodi 7-37 m, and Soluos 5-30 m. With clayey / lateritic soils, the thicker values are quite excellent clearance to eliminate pollution.

The regression analysis for the Ewu-Elepe soil suggest that currently, anthropogenic constituents are almost completely eliminated between 1-2 m and only negligible fractions may be left after 3-4 m. At Soluos 2 and Soluos 3, the concentrations of the measured parameters in groundwater were also highest at proximities closest to the landfill. It was observed that the well water about 250 m from the landfill was most imbued with contaminants than those collected from boreholes. However, it is difficult to attribute all the anthropogenic inter-plays in this well to the landfill. Also the construction of the regression graphs without the inhomogeneity introduced by the well water gave better predictions indices. For instance, this can help to reconstruct the original maximum surface concentration of the waste water before attenuation. The intercept (per parameter) of the regression equation gives an estimation of this value. The intercept using distance also gives the original minimum surface concentration. The observed concentrations of modern leachates collected in this study approximate closely with this predictions.

Adsorption in the soils appears rapid. Yet, the results from the groundwater reveal that some of the leachates may have made it to the groundwater. The borehole sample drawn about 500 m from the landfill had the lowest concentration but shows that some of the leachates may have found its way over time to the groundwater in this area. Groundwater flow is very slow and allows for interactions with the soil-bearing aquifer walls. Further adsorption and precipitation of the pollutants within the groundwater act to reduce the concentration as the groundwater moves away from areas of imbuement. Therefore potability increases at greater depth and distance from the landfill.

Most of the landfills were improvised from burrow pits to which little or no engineering pre-treatments such as compaction (at close to optimum moisture content) were applied. They all lack proper leachate collection facilities. The excavations at these sites have adversely reduced the protection offered to groundwater.

Although presence of excavation was not observed in the Oshodi area, the evidence of contamination are possibly from vehicular emission given its dense traffic and probable septic leakages to the groundwater. The plausibility of industrial effluents and other domestic wastes making it underground in this densely populated area cannot be ruled out.

Portions of Soluos 3 had over 15 m of soil removed in the course of excavation for which there was no remediation (Fig. 4). This increases the susceptibility of groundwater to pollution. It was alleged by some local observers that groundwater sometimes reaches the surface at the peak of the rainy season to intermingle with the wastes.

It is estimated that about 70% of the heavy metals (such as lead, mercury and cadmium) found in landfills come from e-waste [13]. Arising from its rapid obsolescence, e-waste is one of the fastest waste streams. E-waste apart, one major concern about some medical wastes is its associated mercury content. Although even mercury in its elemental form is toxic, its most poisonous embodiment is methyl mercury, the result of a chemical modification by bacteria; the finding of such a process in landfills underscores the importance of ensuring that mercury does not enter the municipal-waste stream.

The high content of manganese in the Olusosun borehole in the landfill may also be closely associated with the corrosion of iron and steel products which was pervasive within the sphere of sample collection. It is likely that the Mn is from its use as an alloy in steel. The recorded high concentrations of lead (average concentrations of Pb in soil are between 15 and 25 mg/ kg [14], nickel, cadmium and chromium may be attributed to contribution from aerial deposition from vehicular emissions, batteries, petroleum products used in the landfill, lead-based paints, lead solders in cans, etc. Numerous studies have shown a clear impact of road traffic on levels of heavy metals in the environment [15,16].

The uncontrolled disposal of lead acid batteries and spent petroleum products probably increased the concentration of Pb, Cr, Cd, and Ni in the soil and landfill as collaborated by values obtained from the leachates.

In its natural setting, groundwater has many advantages over surface water in that there is filter for the water, removing obnoxious materials from the water as it moves through it. This may explain why the surface water at Epe Lagoon (about 1 km away from the landfill) is apparently more imbued with pollutants than the groundwater in many of the other subsisting landfill areas since soil acts as a filter.

Okagbue and Agbo have shown that it takes on the average about 2½ months for the effect of rainfall as a means of groundwater recharge to be noticed on the water table [17]. Other authors posited that on-going studies in Benin have corroborated this assessment because the travel time to the water table from precipitation is found to be at least 6 months [18]. The water table in

Fig. 5. Correlation of heavy elements (a: Olusosun Correlation with distance, b: Composite correlation with depth in the Ewu-Elepe landfill soil)

Benin is about 50 m from the surface whereas in Owerri, where Okagbue and Agbo carried out their studies, the depth to the water table is about 19 m. Corollary, this writer envisages that the groundwater recharge time for the Coastal Plains Sands formations in Oshodi, Olusosun, Ewu-Elepe and Soluos 2 & 3 (with an average depth of about 21 m and consisting of red clayey / lateritic soils and alternating layers of sand) may be less than 2 months. However, groundwater in the Epe and Badagry areas consisting predominantly of sands and silts and with a depth of about 2-10 m and mean depth of about 6 m, is expected to be recharged by precipitation within a month.

Metals added to soil will normally be retained at the soil surface. Movement of metals into other environmental compartments, i.e., ground water surface water, or the atmosphere, should be minimal as long as the retention capacity of the soil is not exceeded. The extent of movement of a metal in the soil system is intimately related to the solution and surface chemistry of the soil and to the specific properties of the metal and associated waste matrix.

Potential for attenuation processes to occur varies within the various subsurface zones, i.e. soil, unsaturated and saturated zone. Attenuation processes can be more effective in the soil rather than aquifers due to higher clay contents, organic

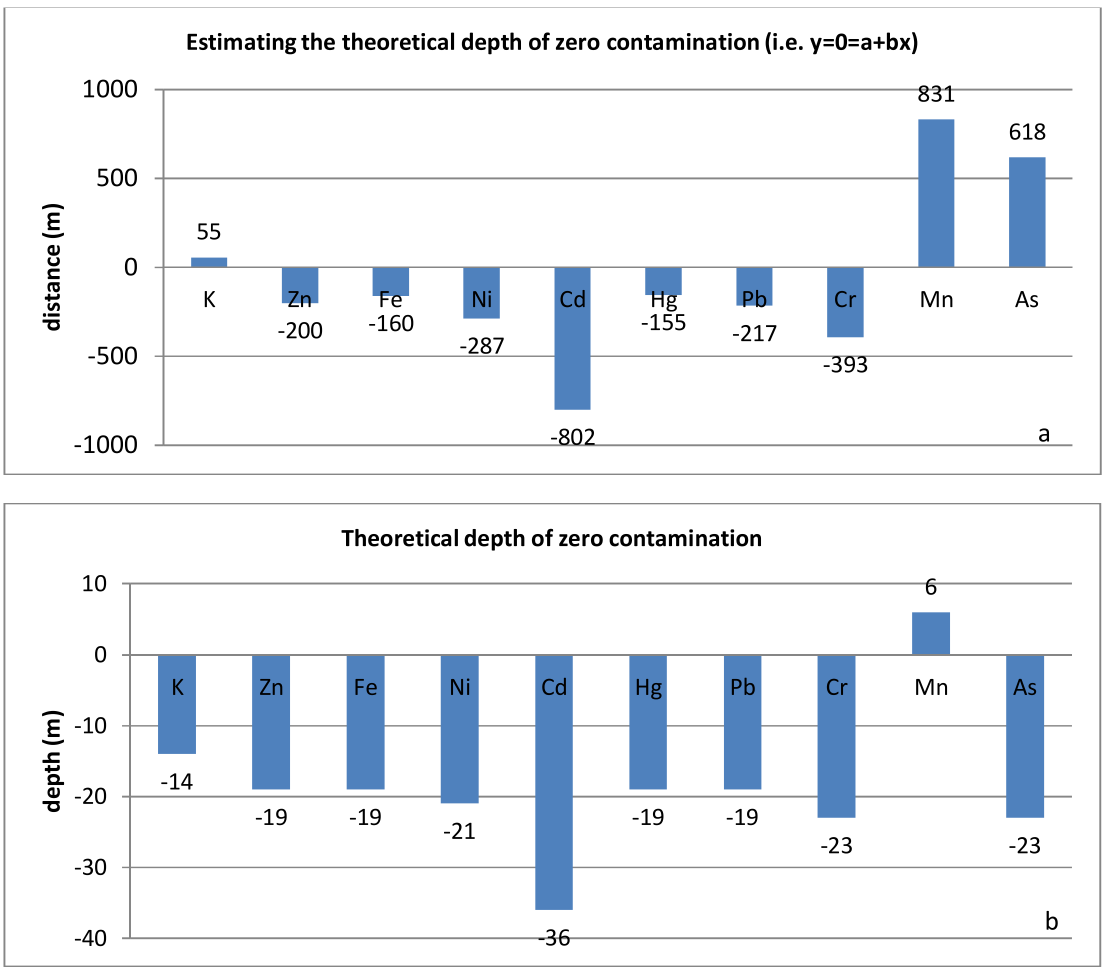


Fig. 6. Estimations from Regression analysis (a: theoretical distance of zero contamination to the groundwater in the Olusosun landfill area, b: theoretical depth of zero contamination to the groundwater in the Olusosun landfill area)

carbon, microbial populations and replenishable oxygen. This makes the soil a very important first line of defence against groundwater pollution, often termed 'protective layer'. The soil stratigraphy of the Igando landfills (Soluos 1-3) consists of lateritic clay that is capable of protecting underlying confined aquifer from leachate contamination [19].

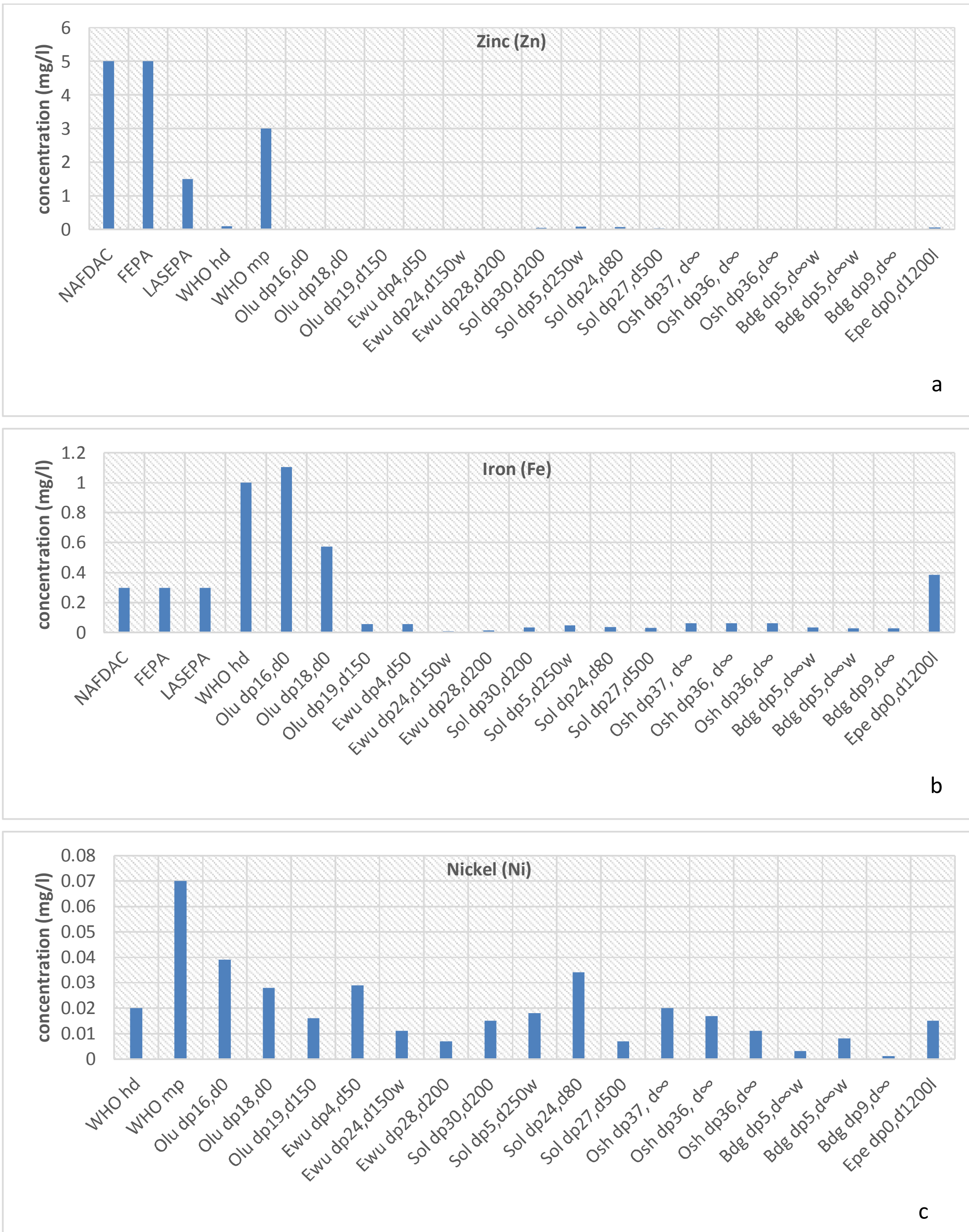


Fig. 7. Comparison of metal concentrations in groundwater/ surface water with standards (a: zinc, b: iron, c: nickel)

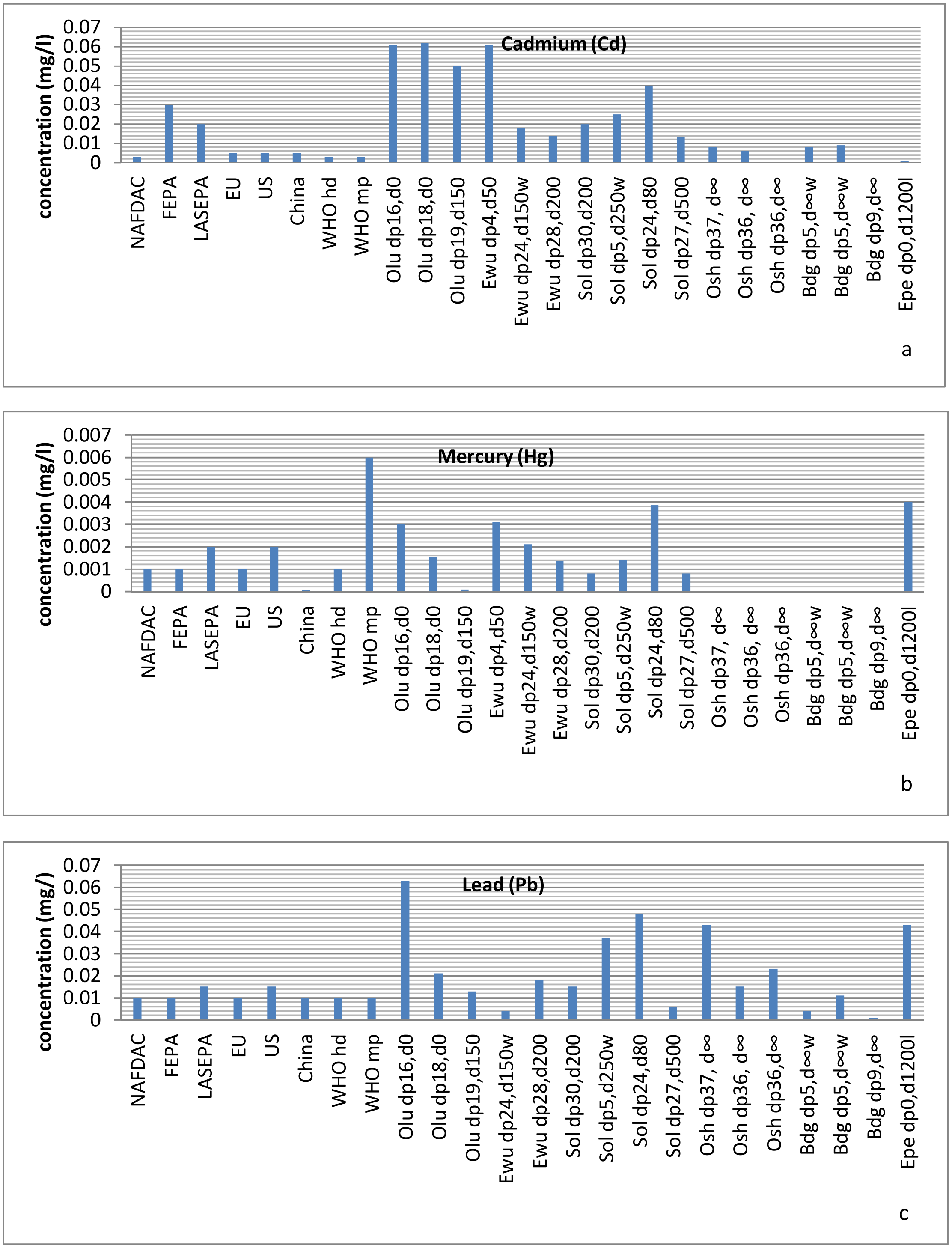


Fig. 8. Comparison of metal concentrations in groundwater/ surface water with standards (a: cadmium, b: mercury, c: lead)

The Olusosun landfill soil recorded Pb and Cr with the highest values of 95.3 mg/kg and 60.48 mg/kg. Although Mn was very high at between 0-20 cm (520 mg/kg) it dropped sharply to an average of 65 mg/kg in the intervening 80 cm. The concentrations between a depth of 40-100 cm (mean: 70 cm) seems a closer approximation to natural concentration than those of the top soil.

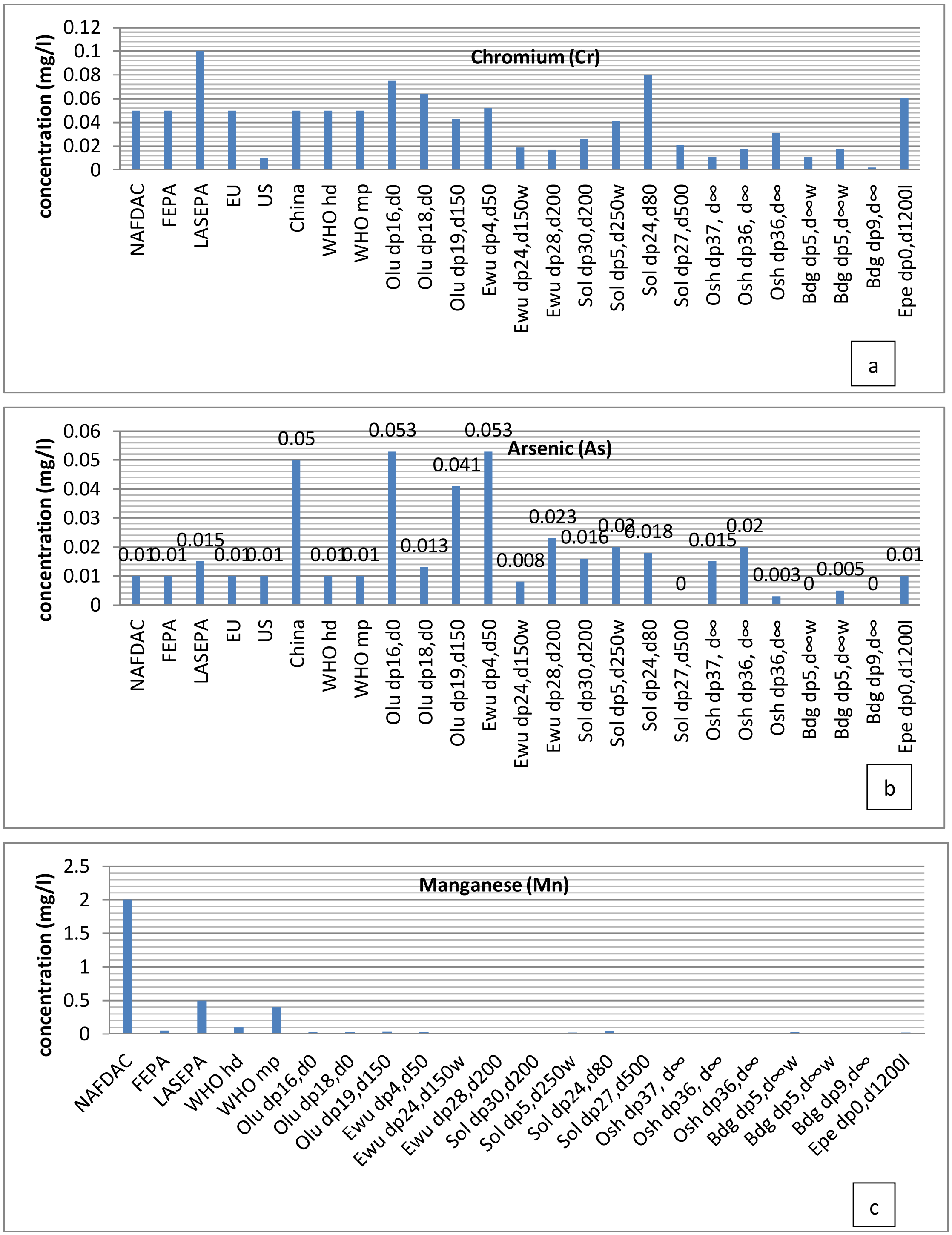


Fig. 9. Comparison of concentrations of elements in groundwater/ surface water with standards (a: chromium, b: arsenic, c: manganese)

Groundwater samples collected from two boreholes within the Olusosun landfill has Fe content that exceeded all the standards used in this study. Although there is no prescribed WHO maximum permissible limit for Fe, the Epe surface water exceeded NAFDAC and FEPA standards. The other landfills groundwater had Fe content that were below the set limits. Most of the groundwater had Ni contents that were within the approved standards. However, groundwater

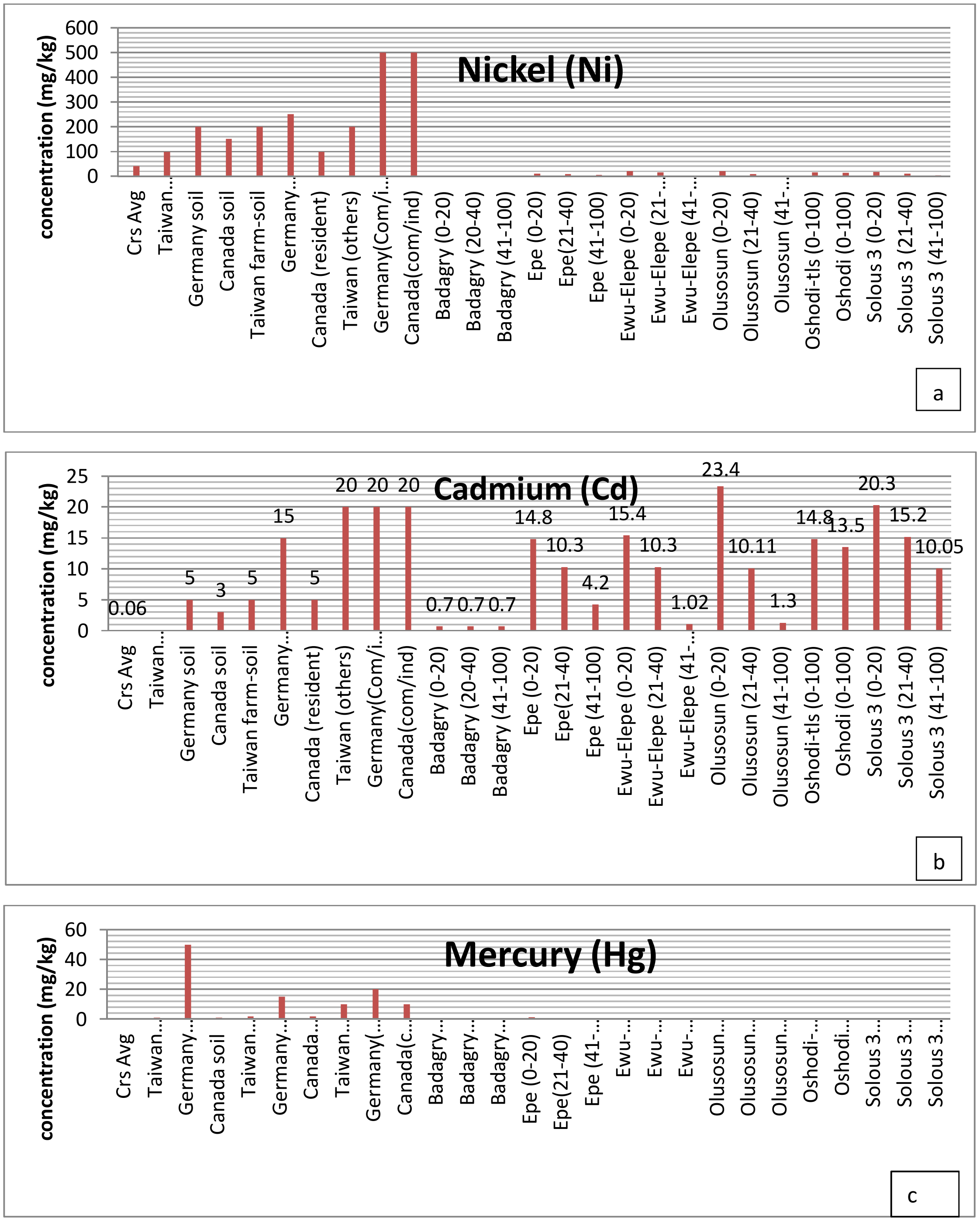


Fig. 10. Comparison of elemental concentrations in soils (at various composite mean depth) with standards and crustal average (a: nickel, b: cadmium, c: mercury)

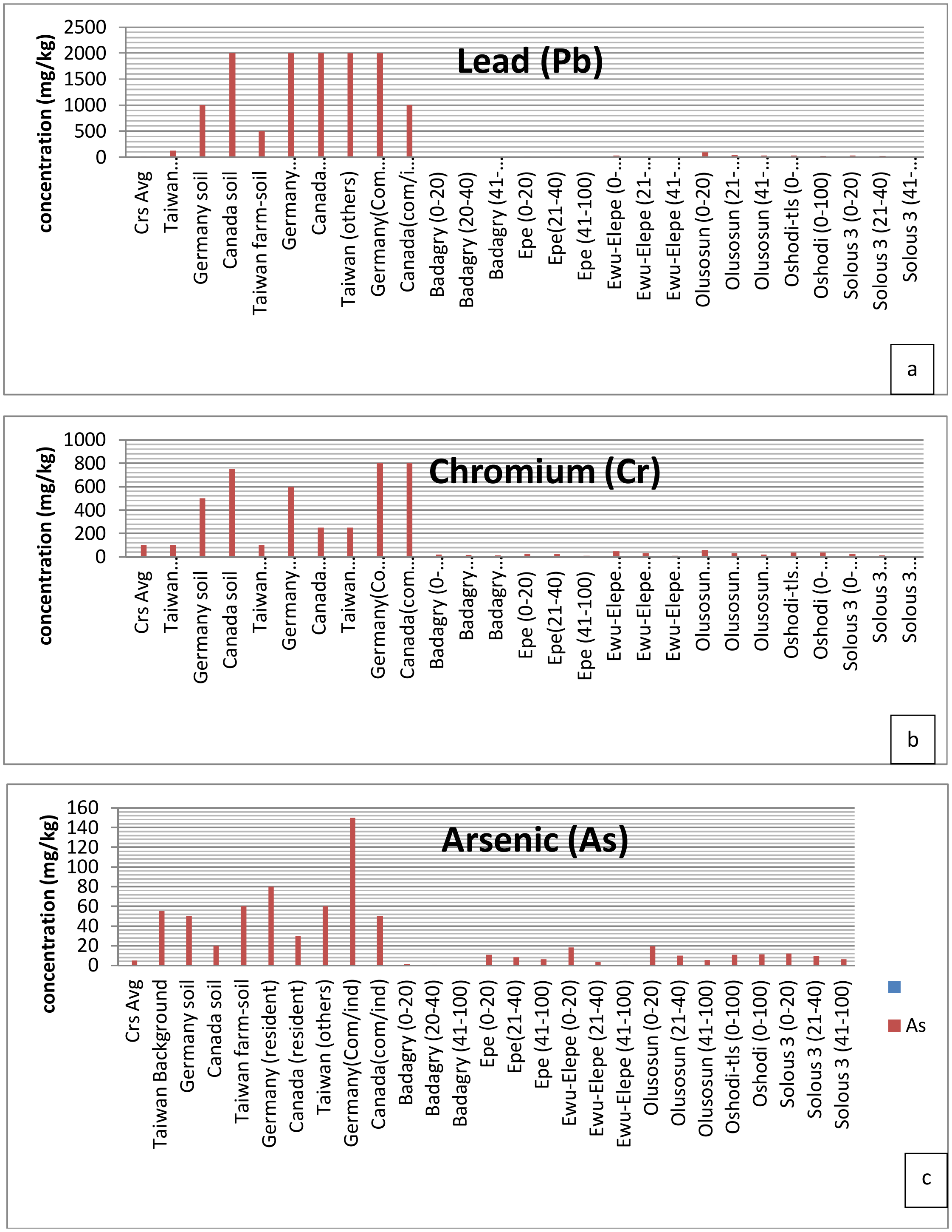
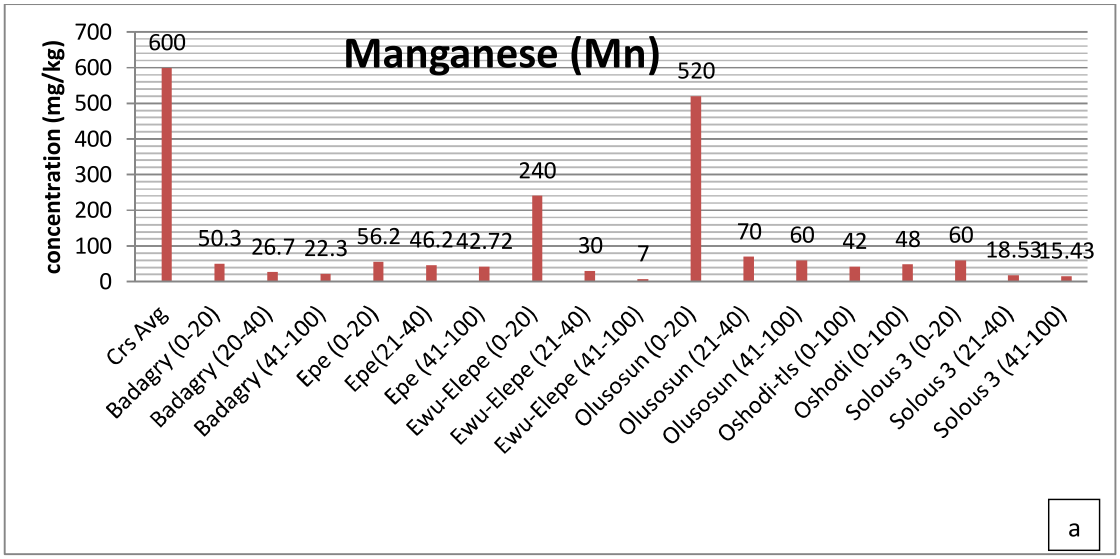


Fig. 11. Comparison of elemental concentrations in soils (at various composite mean depth) with standards and crustal average (a: lead, b: chromium, c: arsenic)

drawn at well with a depth of about 5 m and a distance of around 50 m from the Ewu-Elepe landfill, and that about 200 m from the landfill at Soluos exceeded the set limits.

Virtually all the groundwater exceeded most of the set standards for Cd (including the limit set by EU, China and US). FEPA and LASEPA limits were also exceeded by all the groundwater drawn from the Olusosun area in this study. The well at Ewu-Elepe and Soluos c exceeded the FEPA limit of 0.03 mg/l. The groundwater seems naturally enriched in Cd as reflected by the concentration from the control area but which nonetheless subscribed to those of FEPA and LASEPA. Nonetheless, anthropogenic imbuement is clearly reflected in most of the study areas.

Although the mercury (Hg) content of all the surface and groundwater were below WHO maximum permissible limit (MPL), some (such as Olusosun 1, Ewu-Elepe 1, Soluos c and Epe) were above the other approved limits. Lead-acid accumulator battery, dry cells, Chlorine manufacturing related effluent, electronic waste, medical waste, etc. increases the susceptibility of groundwater to mercury pollution. Metabolises of vinyl chloride plastics also releases Hg in the landfill. Other solid wastes from this process are deposited in the landfill. The greater depth to the aquifer provides better protection. E.g., Olusosun 2 & 3, Ewu-Elepe 2/3 which have deeper aquifers had lower doses of mercury. The observed mercury concentrations are mainly attributable to anthropogenic contributions as it was almost absent in the control area.



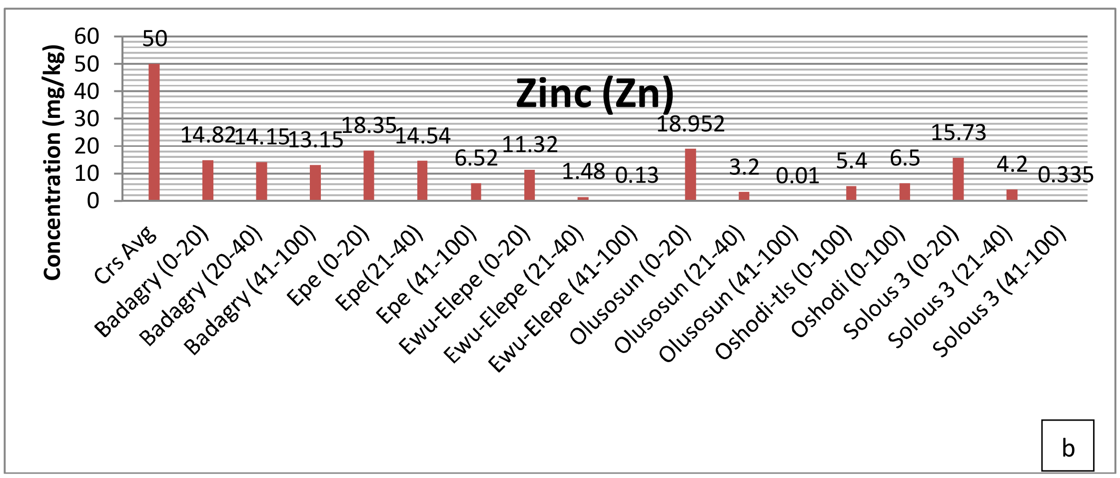


Fig. 12. Comparison of elemental concentrations in soils (at various composite mean depth) with crustal average (a: manganese, b: zinc)

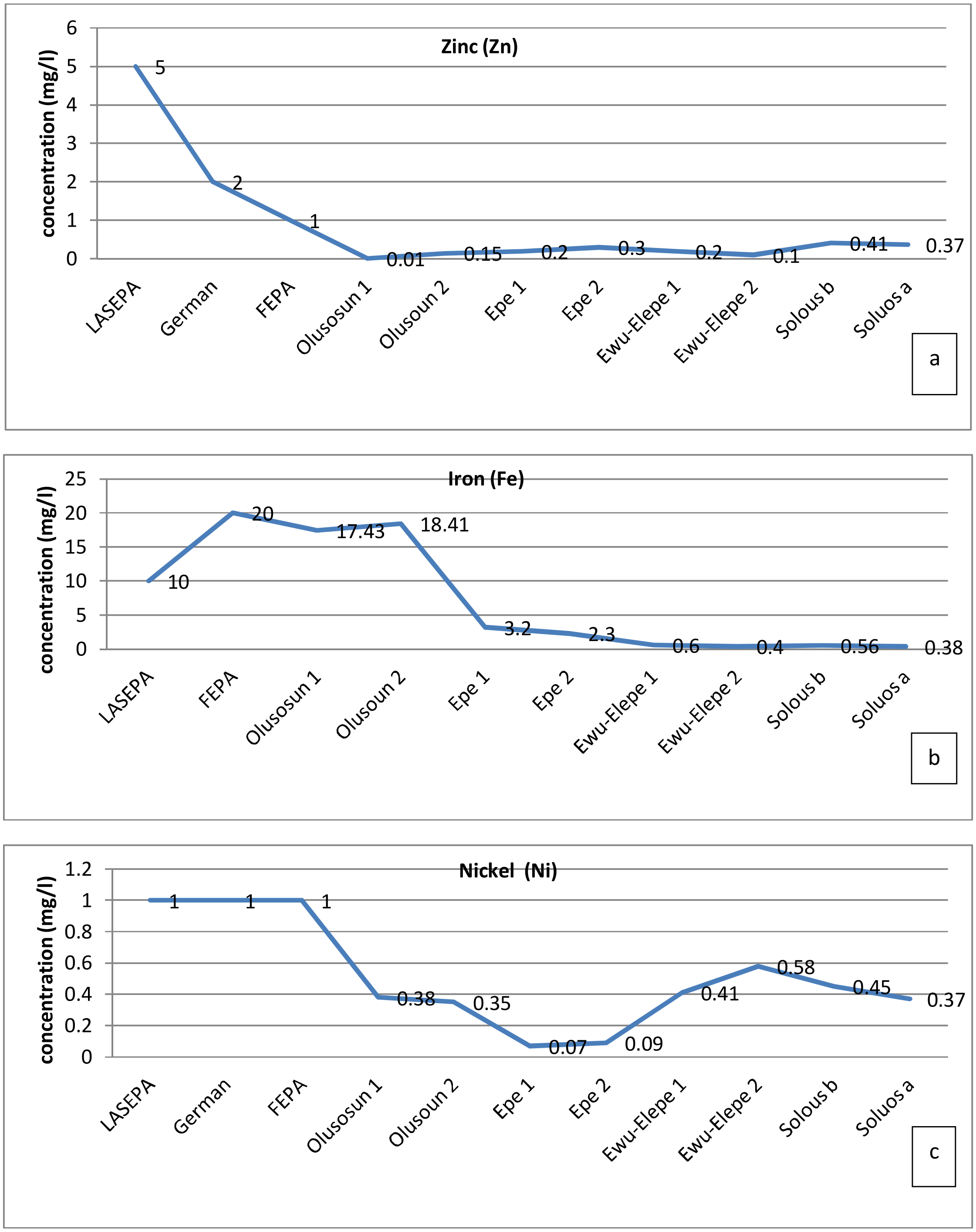


Fig. 13. Comparison of the elemental concentrations of the composite leachates with standards (a: zinc, b: iron, c: nickel)

Most of the samples over-shot the established limit for Pb except the groundwater drawn about 500 m from the Soluos landfill, and Badagry. Lead based paint waste forms part of the MSW. The Ewu-Elepe well-water was very well above acceptable limit. All the water samples had Cr

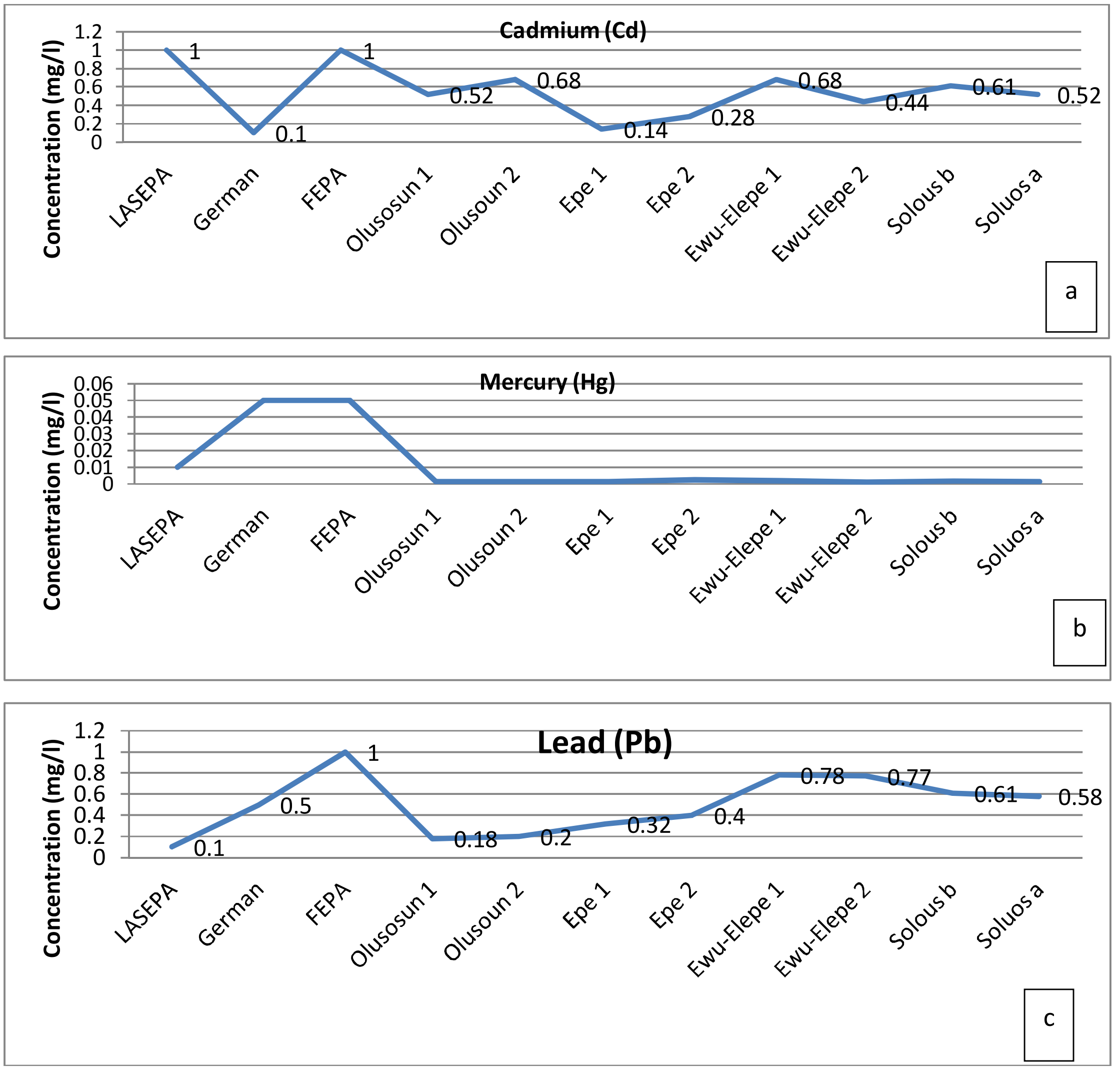


Fig. 14. Comparison of elemental concentrations of the composite leachates with standards (a: cadmium, b: mercury)

content that was below the standard set by LASEPA. Groundwater collected from the boreholes within the Olusosun landfill, Soluos c (which is suspected to be in the path of subterranean water flow), and the Lagoon water at Epe also exceeded the other limits. Only Olusosun 1, and Ewu-Elepe exceeded China's standard of 0.05 mg/l for As. As can also be released from pesticides and detergents. Badagry (1-3), Oshodi 3, Soluos d, Ewu-Elepe$_2$ were all below the other permissible limits of 0.1 mg/l established by FEPA, WHO$_1$, WHO$_2$, EU, and US.

Zn, Fe, Ni, Hg and Mn were all below the crustal average [20]. All the Ni contents in the soils were within all the standards established for use of soils in Taiwan, Germany and Canada. (Figs. 10-12). All the observed Cd concentrations exceeded the crustal average. Olusosun1 and Soluos-a exceeded the Cd limits set by these countries for soils designated for commercial/ industrial purposes. The Cd contributions are likely from the e-waste, batteries, and impurities in the zinc of galvanized pipes, metal fittings and solders. The uppermost layers of the Ewu- Elepe soil (0 - 20 cm) and Soluos b (20 - 40 cm) exceeded the German standard for soils for residential purposes. One significance of this analysis is that for the purpose of remediation, the removal of about a meter of top soil from Olusosun landfill and replacement with fresh attenuative soil will help to contain Cd pollution.

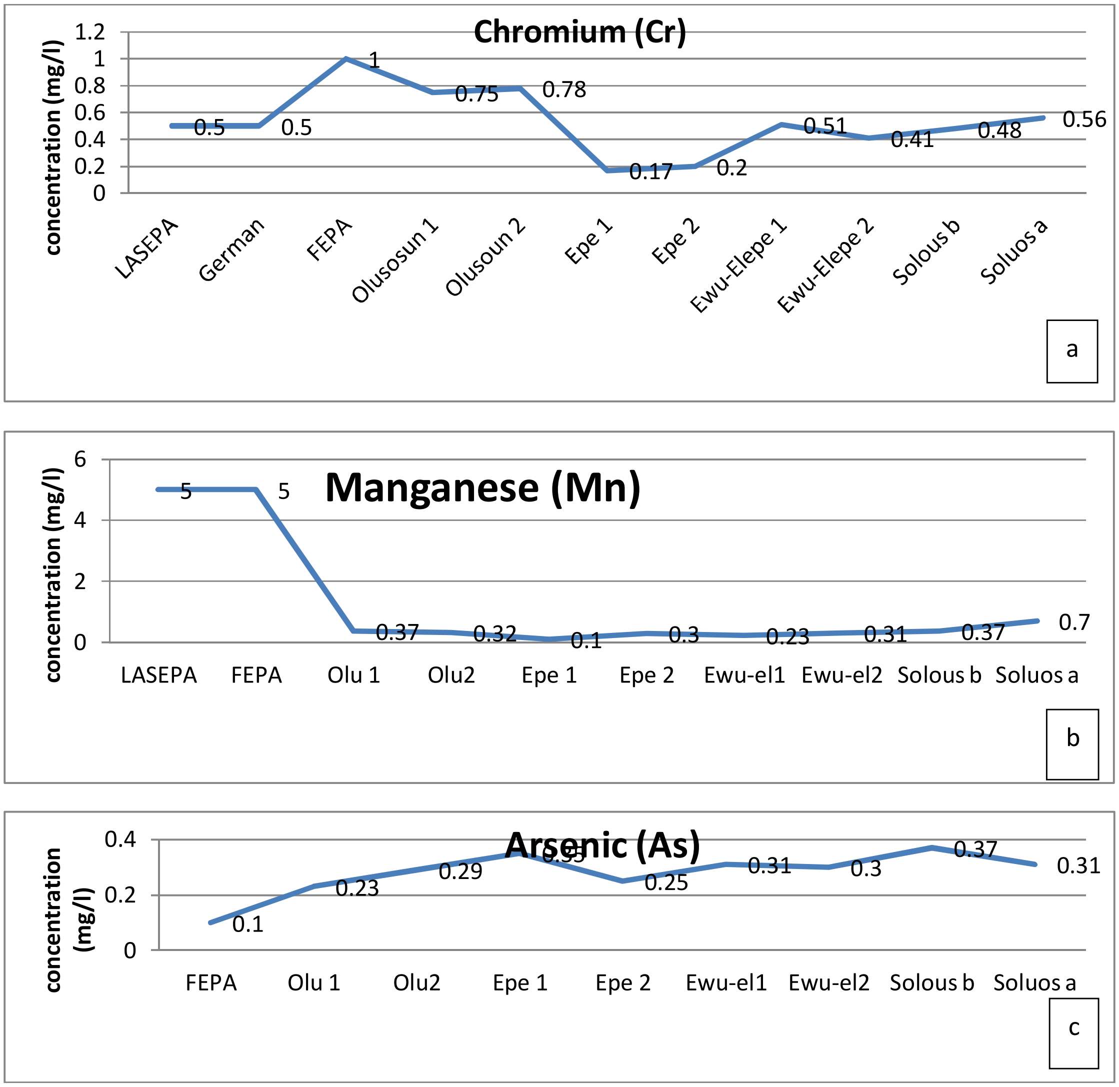


Fig. 15. Comparison of elemental concentrations of the composite leachates with standards (a: chromium, b: manganese, c: arsenic)

As a result of the lasting deleterious health effects of chemicals used by the Americans in the course of the Vietnam War, the contaminated soil and sediment is being excavated, and then heated to a high temperature to destroy the dioxins [21].

Pb in the top soil at Olusosun was above the crustal average, nonetheless all the analysed soils conformed to permissible standards. Comparison of the observed concentrations of the composite leachates with LASEPA and FEPA standards showed that their contents of Zn, Fe, Ni, Cd, Hg, Pb, Cr and As conformed. The metals also conformed to German standards (Figs. 13-14).

4. CONCLUSION

Groundwater from the boreholes at Olusosun landfill and the concrete well adjacent the Ewu-Elepe landfill are not potable. Groundwater abstracted from a borehole 80 m east of the Soluos 3 landfill exceeded most known standards for Ni, Cd, Pb and Cr in the Igando area where 3 different landfills are sited. Although it was inferred from this study that the transfer loading station (TLS) at Oshodi bears no known effect on the groundwater and soil, the enrichment of the measured parameters in this area is ascribed to vehicular emissions and other anthropogenic sources. These effects were however subordinate to the observed effects from landfill areas. Nonetheless, it is probable that the concentrations of the analytes in the landfills often combined the concomitant anthropogenic contributions with those from municipal solid waste (MSW) interactions. The observed heavy elements in Badagry (control area) are within the set standards and reflect near pristine conditions. Overall, the aforementioned sequence proves unequivocally that the MSW are the major contributors to the increased concentrations of most of the measured parameters in the landfills

Most of the composite leachates showed contamination with arsenic. The elevated levels of heavy elements above the WHO permissible limits in some of the groundwater samples is an indication that in the absence of a leachate collection system, the uncontrolled accumulation of leachates over time at the landfill base will represent a significant threat to the groundwater quality

Tested top soils (0-20 cm) within the Olusosun and Soluos 3 revealed cadmium enrichment beyond permissible limits. Given the high Cd and As content in some of the landfill soils, the use of recycled wastes as compost for food crops cultivation is not recommended due to the high risk impacts of these elements on human health.

Although local geological setting might have contributed to the enhancement of the natural attenuation of the analysed heavy elements to a certain degree, this has been significantly impaired by massive excavation. The result is the increased vulnerability of groundwater to pollution around the landfill locations. Future landfill sites should be sited far away from residential areas. It should also have a buffer zone of non-consumable cash trees to trap CO_2 and probably yield revenue.

Whereas practices by Lagos State Waste Management Agency (LAWMA) and the Lagos State Environmental Protection Agency (LASEPA) are steadily improving and being replicated locally and internationally, more still needs to be done. LAWMA should consider a more rigorous recycling agenda using modern landfill mining methods. Landfill mining offers promising potentials for both, energy recovery as well as raw material recovery. The bulk of heavy metal contamination in the landfills comes from e-waste. Therefore, proper enforcement of extant regulations on the import prohibition of these devices will provide better protection to groundwater and the soil. Each landfill should be fitted with methane capturing devices (as currently being considered in the Olusosun landfill) and leachate collection devices. Leachates collection is important because retention of leachates in soils weakens its attenuative capacity over time if not drained/ pumped off. Portions of Soluos 3 that currently experiences flooding due to seasonal rise in water table should be refilled with impermeable soils and stabilised to reduce groundwater contamination.

In order to mitigate further damages to the environment, the current Epe Integrated Landfill site should be considered for closure given the hazards it portends to the environment.

ACKNOWLEDGEMENT

The author is profoundly grateful to the Managing Director of LAWMA, Mr Ola Oresanya, and his able crew for the immense co-operation enjoyed all through the course of the geological site investigation and sampling. The support enjoyed from the staff of LASEPA and Schmidt especially; Engr. Adebisi O. G. Adesina (the G.M), Dr. (Mrs.) Adetola W. Onisarotu, Benjamin and others, is worthy of adulation. Corollary, the uncommon professional assistance availed by Dr. C. N. Akujieze remains invaluable.

COMPETING INTERESTS

The author has declared that no competing interest exist

REFERENCES

1. Ogwueleka TC. Municipal solid waste characteristics and management in Nigeria, Iran J. Environ. Health Sci. Eng. 2009;6:173-180.
2. Mull EJ. Approaches toward Sustainable Urban Solid Waste Management: Sahakaranagar layout. Int. Environ. Sci. Lund University, Lund, Sweden. 2005;37.
3. Al-Khadi S. Assessment of groundwater contamination vulnerability in the vicinity of

Abqaiq landfill-A GIS approach, dissertation. King Fahd University of Petroleum and Minerals, Saudi Arabia. 2006.
4. Lee GF, Jones-Lee A. Overview of Sacramento-San Joaquin River Delta water quality issues. Report of G. Fred Lee & Associates, El Macero, CA. 2004;148.
5. Feign A, Ravina I, Shalhevet J. Irrigation with treated sewage effluent. Springer, Berlin, Germany. 1991.
6. Longe EO, Malomo S, Olorunnwo MA. Hydrogeology of Lagos metropolis. J. Afr. Earth Sci. 1987;6(2):163-174.
7. Yusuf KA. Evaluation of groundwater quality characteristics in Lagos-City. Journal of Applied Sciences. 2007;7(13): 1780 -1784.
8. Harrison RM., (ed). Pollution: Causes, Effects and Control (2nd edn.). The Royal Society of Chemistry, London. 2001;579.
9. Short KC, Stauble AJ. Outline of geology of the Niger Delta. Bull. Am. Ass. Petro. Geol. 1969;54:761-779.
10. Tattam CM. A review of Nigerian stratigraphy. Geological Survey of Nigeria Report, Lagos. 1943;27-46.
11. Jones HA, Hockey RD. (). The geology of part of S. W. Nigeria, Geol. Surv. Nigeria, Bull. 1964;31:87.
12. American Public Health Association (APHA). Standard methods for the examination of water and wastewater. American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 19th edition, Washington, D.C; 1995.
13. Widmer R, Oswald-Krapf H, Sinha-Khetriwal D, Schnellmann M, Boni HW. Global Perspectives on E-waste. Environmental Impact Assessment Review 2005;25(5):436-458.
14. Miroslav R, Vladimir NB. (). Practical environmental analysis. UK: Royal Society of Chemistry. 1999;289:314 & 357.
15. Daniel P, Kovaes B, Prokisck J, Gyori Z. Heavy metal dispersion detected in soils and plants roads in Hungary. Chem. Speciation and Bioavailability, 1997;9(3): 83-93.
16. Ihenyen AE. Assessment of heavy metal pollution in roadside sediment in Benin City. Nigeria. Geologia.Tom Zeszut 3 (Poland). 1988;187-197.
17. Okagbue CO, Agbo JU. Evidence of downward displacement theory in natural groundwater recharge. Water Resources. 1989;1(2):143-146.
18. Akujieze CN, Oteze GE. A review of groundwater pollution in nigeria. Journ. NAH, Special Publication Series 2. 2012;23.
19. Longe EO, Balogun MR. Groundwater quality assessment near a municipal landfill, Lagos, Nigeria. Research Journal of Applied Sciences, Engineering and Technology. 2010;2(1):39-44.
20. Lindsay WL. Chemical equilibria in soils. John Wiley & Sons, New York, USA. 1979;449.
21. BBC News. US Starts Agent Orange Clean-Up in Vietnam; 2012. Available:http://www.bbc.co.uk/news/world-asia-pacific, (last accessed: 1st February, 2014).

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/10086