British Journal of Applied Science & Technology
4(33): 4623-4642, 2014
ISSN: 2231-0843

SCIENCEDOMAIN *international*
www.sciencedomain.org

Assessment of Some Physiochemical Impacts of Municipal Solid Waste (MSW) on Soils: A Case Study of Landfill Areas of Lagos, Nigeria

Imoukhuede M. Idehai[1*] and Christopher N. Akujieze[1]

[1]Department of Geology, Faculty of Physical Sciences, University of Benin, Benin City, Nigeria.

Authors' contributions

This work was carried out in collaboration between the authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2014/12964
Editor(s):
(1) Verlicchi Paola, Department of Engineering, University of Ferrara, Via Saragat 1, Ferrara, Italy.
Reviewers:
(1) Onwudiwe Nikejah, University of Nigeria, Nsukka, Nigeria.
(2) Leonie Asfora Sarubbo, Environmental Engineering Department, Catholic University of Pernambuco, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=670&id=5&aid=6177

Original Research Article

Received 26th July 2014
Accepted 25th August 2014
Published 23rd September 2014

ABSTRACT

Soil samples from all the active landfills in Lagos were analyzed for some physiochemical parameters in order to determine their suitability for use as compost. Of the assessed depth of 100 cm; from the surface to a depth of 20 cm, the concentrations of metals in the soil samples were in the order: Olusosun > Ewu-Elepe > Soluos 3 > Epe > Oshodi >Badagry. Concentrations of most of the analytes decreased with depth. Pb and Cr had the highest values of 95.3 mg/kg and 60.48 mg/kg respectively. Furthermore, the concentrations of the metals were higher than most of the anions. The cations were strongly and positively correlated with depth in most of the landfill soils such that Ni > Cd > Cr > Fe > K > Pb >Hg > As >Zn >K/ Mn. These imply significant attenuation with depth of the metallic imbuement possibly due to adsorption and/or precipitation. The alternative

**Corresponding author: E-mail: imoism@gmail.com;*

hypothesis was accepted for pH, EC, Fe, Pb, Cr at 99% confidence limit, and for Ni, Cd, As at 95% confidence limit. The elevated levels of cadmium and arsenic in the topsoils do not support their use as compost for food cultivation.

Keywords: Arsenic; cadmium; compost; correlated; food cultivation.

1. INTRODUCTION

Soil sustains man's existence as plants and animals subsist on it. When the soil is polluted, surface and groundwater are also at risk due to overflows and percolation. Therefore, understudying the impact of the municipal solid waste (MSW) on this megacity is of critical essence in order to prevent and/or mitigate deleterious consequences on the environment.

Lagos has a population of about twenty one million (21,000,000) people, a daily waste generation per capita (GPC) of 0.63 kg and a yearly deposit of over three million tonnes of unsorted municipal solid wastes (MSW) emplaced in improperly engineered landfills. Upon geo-bio-chemical reactions in the presence of excess water and bacteria, leachates are produced. These fluids maintain further interactions with the soil environment. This is because the ecosystem is an interconnected series of pathways whereby chemical, physical, and biological contaminants move between the four primary compartments of air, surface and ground waters, land, and biota [1].

Currently, some of these wastes are recycled as agricultural compost. However, the fact that large volume of e-waste and other wastes may contribute to heavy metal pollution; raises serious health concerns about this practice in this megacity.

Metal contamination of soils became a worldwide concern when it was observed that rice paddy fields irrigated with wastewaters from a zinc mine containing sphalerite (ore of zinc with accessory cadmium) caused excessive cadmium (Cd) intake and adverse health effects in farmers who had consumed rice grown in this polluted soils [2]. This first observation of the human disease called *itai-itai* has stimulated research on the potential adverse effect of Cd and other metals in soils and in agricultural systems.

This study aims at assessing the concentration of some physiochemical parameters of soils in the active landfills of the Lagos area in Nigeria. This is in order to ascertain the contributions of the municipal solid waste streams to their variations in concentrations, and to ascertain if these soils are suitable for agricultural cultivation of food crops.

1.1 Location of the Study Areas and Geological Settings

The study was undertaken in all the current Lagos State Waste Management Agency (LAWMA) operated landfills, Badagry (control area) and Oshodi in Lagos State of Nigeria. The geology of the landfill areas is essentially that of the Oligocene to Pleistocene Benin Formation (also known as Coastal Plain Sands - CPS) except for that of Epe landfill area which is of Recent Littoral and Lagoonal Deposits. The CPS underlies the Recent Sediments and overlies a thick clay layer, the Ilaro Formation (Figs. 1 and 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.

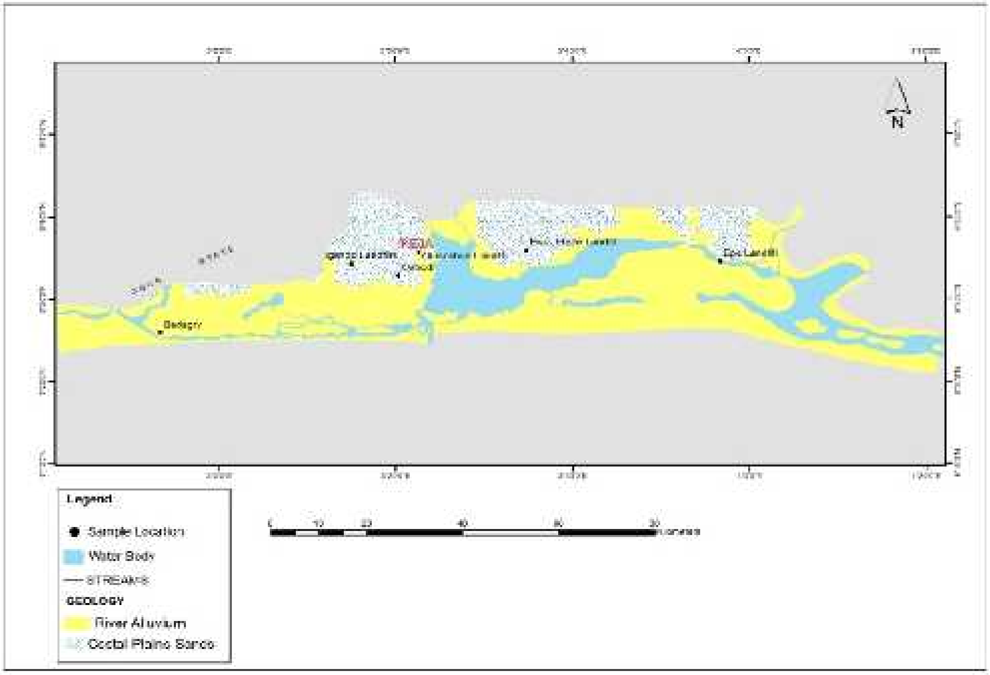

Fig. 1. Map of the geology of Lagos state showing the landfill locations

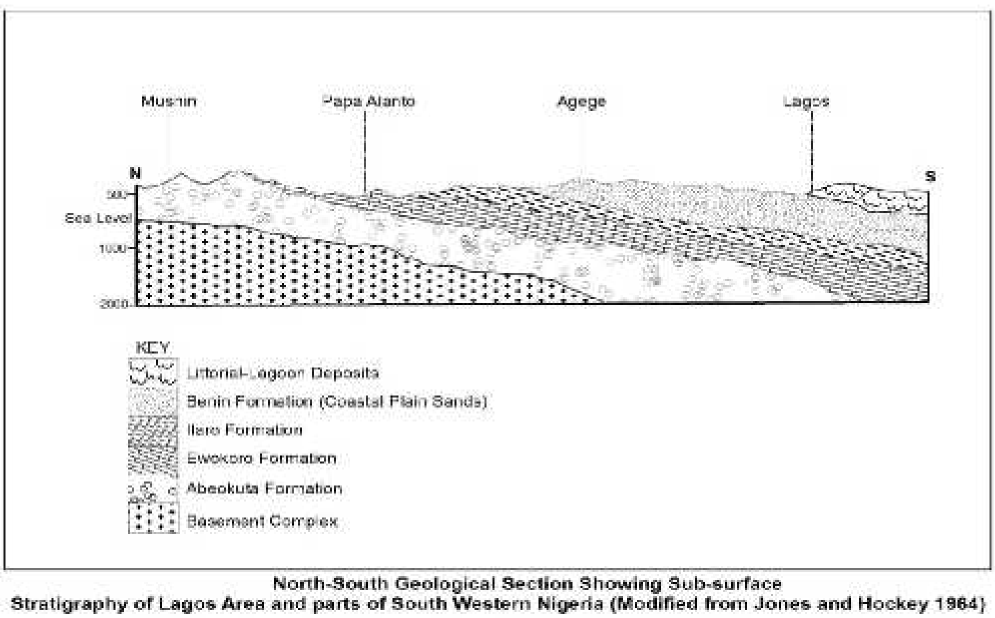

Fig. 2. N- S geological section showing the major geological formations in the Lagos area (after Jones and Hockey, 1964)

The name Coastal Plains Sands was introduced [3] 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 [4]. 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.

2. METHODOLOGY

Reconnaissance geological surveys were first undertaken and recorded on reaching the field. Seventeen (17) 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 105ºC 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 in-situ parameters were analyzed at the point of sample collection in the field. For instance, the parameter pH was determined using a pH meter. Temperature was determined by dipping the bulb of mercury-in-glass thermometer into the soil suspension and recording the readings. Electrical conductivity (EC) was measured using an EC meter. The anions and cations were subjected to DR 3800 spectrophotometry and atomic absorption spectroscopy (AAS) respectively. Microsoft Excel 2007 was employed for geomathematical evaluation.

3. GEOMATHEMATICAL EVALUATION OF RESULTS

At depth, all the metals were strongly and positively correlated in most of the landfill soils. This signifies similar origin. The relationship was such that Ni > Cd > Cr > Fe > K > Pb > Hg > As >Zn > Mn. The anions correlated excellently amongst themselves. EC & pH varied from poorly to strongly, and from negatively to positively correlated. This seeming anomaly suggests that nature apart, the inclusion of more parameters to those already measured may provide a better picturesque of the physiochemical interactions in the landfill soils (Figs. 3 and 4 and Table 1).

The interactions between the anions and the heavy elements were excellent. In terms of contributions from the landfills; nitrate > phosphate > chloride > sulphate. The correlation values, and the decreasing concentration of most of the analytes away from the landfill establish a case to implicate anthropogenic activities (by way of municipal solid waste [MSW] disposal) for contamination of the landfill soils.

Based on the estimates from regression in (Tables 2a and b), the predicted topsoil concentrations of Mn (55.89 mg/kg) and Fe (40.66 mg/kg) are among the highest within the heavy elements (depicted by the intercepts). This compares well with the observed concentrations of 56.2 mg/kg and 41.5 mg/kg for Mn and Fe at a mean depth of 0.1 m (i.e. 0-20 cm and with a range of 20 cm). The rate of change of concentration with depth of up to 1 m hovered between a factor of 1.6-30.8 for metals. Isolating the slope of mercury, the

Badagry soil gave a range of values for detected analyte metals as between 0.03 and 41. Whereas the composite soils in the Soluos 3, Olusosun and Ewu-Elepe gave a range of gradient of 7-64, 18-660 and 7-341 respectively. It is suspected that the mass of the solid waste interacted to block percolation in some areas and this allowed for leachate collection at Epe. All the measured parameters showed variations with depth. The mercury content in the Epe soil (though still low) was by far the highest in the study areas (followed by that of Ewu-Elepe). This is attributable principally to the infusion of medical waste into the waste in these landfills (Figs. 18 & 19).

Using the changes in concentration per depth and its very high gradient factor for most of the analyzed parameters, the Olusosun soil displayed the best adsorptive potentials. Corollary, the soils are rated as follows:

Most contaminated at the surface (w. r. t. heavy elements): Olusosun > Ewu-Elepe > Soluos 3 > Epe > Badagry

Most contaminated at the surface (w. r. t. other indices): Olusosun > Soluos 3 > Ewu-Elepe > Epe > Badagry

Best adsorptive potentials (w. r. t. heavy elements): Olusosun > Ewu-Elepe > Soluos 3 > Badagry > Epe

Best adsorptive potentials (w. r. t. other parameters): Olusosun > Soluos 3 > Ewu-Elepe > Badagry > Epe

Best overall adsorptive potentials: Olusosun > Soluos3 > Ewu-Elepe > Badagry > Epe
(Where w. r. t. = with respect to)

The regression analysis for the Ewu-Elepe soil suggest that currently, anthropogenic constituents are almost completely eliminated at a depth between 1-2 m and that only negligible fractions may be left after 3-4 m. This scenario is similar in most of the landfills with clayey lithology and points to rapid adsorption. Nonetheless, there remains major concerns since these portions are the humus regions for agricultural food cultivation.

Results obtained for the sampled areas in Oshodi seems spurious upon the application of regression analysis and indicates strongly that the Lagos Waste Management Agency's (LAWMA) transfer loading station (TLS) (built upon an impervious concrete pavement) does not contribute appreciably to the contamination of the soil in the area. The concentrations observed for most of the analytes in the Oshodi area were also lower than those obtained in the precinct of the landfill areas but were however higher than those obtained in the control area (Badagry). It is probable that particulate matters from vehicular emissions, domestic and industrial activities within the neighbourhood are contributory to these values. The combined effects of these contributions and those of the MSW in the landfills seem well established in observed concentrations at the Olusosun landfill.

Correlation and regression established that differences exist in soil amongst the control area (Badagry), Oshodi and the landfills. However, samples from the landfills responded almost similarly necessitating the application of the analysis of variance (ANOVA) to test if the results so obtained are due to imbuement of contaminants and/or pollutants by the MSW.

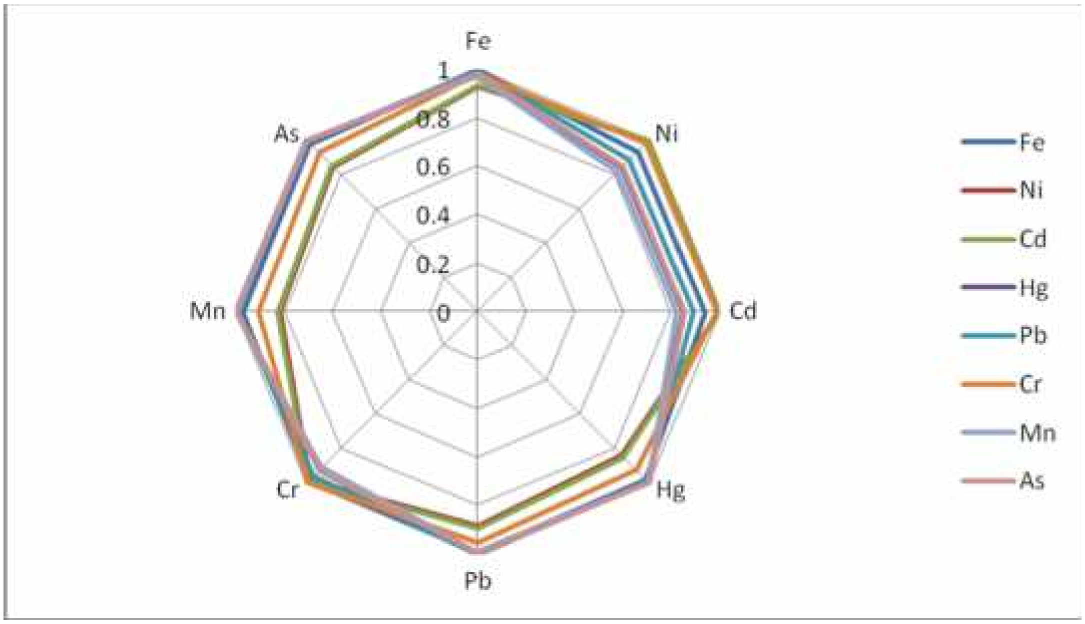

Fig. 3. Generalized composite correlation with depth of the heavy metals in the landfill soils

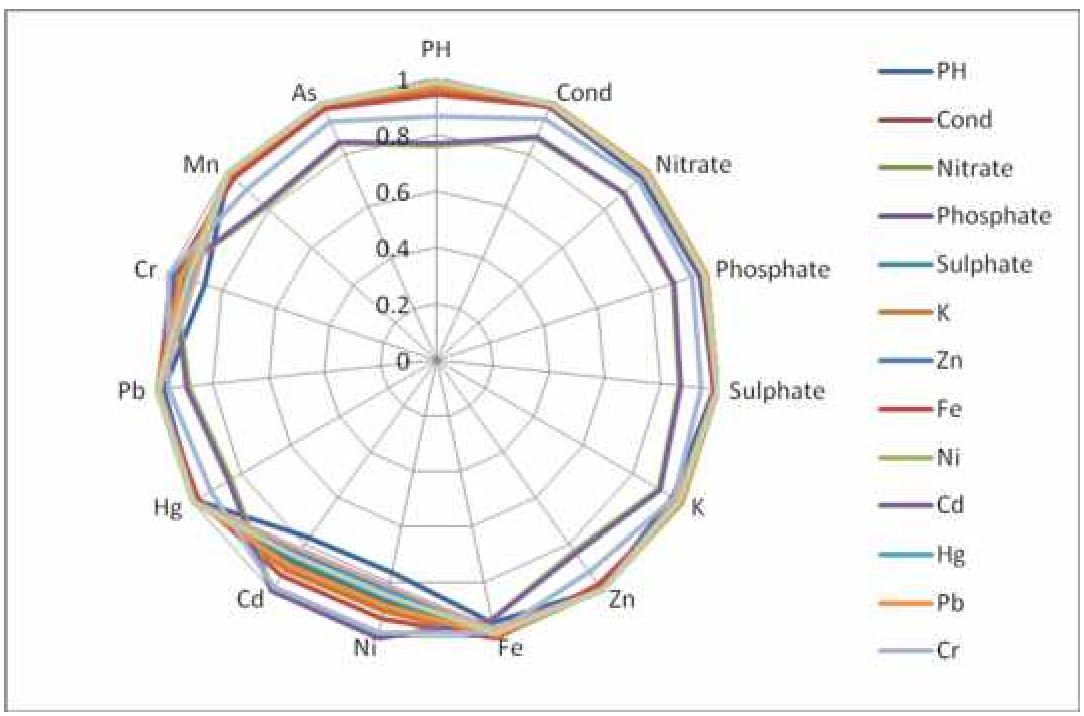

Fig. 4. Typical composite correlation with depth of the measured physiochemical parameters in the landfill soils

Table 1. Composite correlation with depth of the metals in the Ewu-Elepe landfill soil

	Fe	*Ni*	*Cd*	*Hg*	*Pb*	*Cr*	*Mn*	*As*
Fe	1	0.931743	0.936863	0.980942	0.99403	0.982359	0.970634	0.98137
Ni	0.931743	1	0.999897	0.843434	0.886564	0.983211	0.81703	0.844621
Cd	0.936863	0.999897	1	0.851064	0.893117	0.985731	0.825229	0.852224
Hg	0.980942	0.843434	0.851064	1	0.996285	0.927303	0.998877	0.999998
Pb	0.99403	0.886564	0.893117	0.996285	1	0.956091	0.991086	0.996474
Cr	0.982359	0.983211	0.985731	0.927303	0.956091	1	0.908525	0.92813
Mn	0.970634	0.81703	0.825229	0.998877	0.991086	0.908525	1	0.998769
As	0.98137	0.844621	0.852224	0.999998	0.996474	0.92813	0.998769	1

Table 2a. Regression analysis: comparison of the intercepts and gradients of the measured parameters in the study areas to a mean soil depth of 0.7 m

	pH	**EC**	**Nitrate (NO_3)**	**Phosphate (PO_4)**	**Sulphate (SO_4)**	**Potassium (K)**	**Zinc (Zn)**	**Iron (Fe)**
Badagry (a)	5.54	70.18	1.73	0.15	0.00	14.43	15.05	15.34
Badagry (b)	0.57	23.21	-0.18	0.042	0.00	-3.11	-2.74	-6.53
Soluos (a)	8.42	619.6	3.89	2.79	11.26	5.16	15.33	76.23
Soluos (b)	0.44	-553.6	-5.60	-4.05	-17.89	-7.30	-23.37	-63.94
Ewu-Elepe (a)	8.23	471.10	4.83	2.20	6.60	4.71	10.35	81.91
Ewu-Elepe (b)	-0.71	-239.3	-7.52	-3.40	10.50	-7.25	-16.47	-67.93
Epe (a)	7.44	1333.9	3.90	0.85	2.53	1.133	20.38	40.66
Epe (b)	0.36	410.71	-5.45	-1.38	-3.42	-1.58	-19.76	-19.77
Olusosun (a)	8.50	1645.7	5.61	3.32	15.40	11.66	17.72	117.90
Olusosun (b)	-0.46	342.90	-8.39	-5.00	-20.00	18.73	28.20	159.00

Table 2b. Regression analysis: comparison of the intercepts and gradients of the measured parameters in the study areas to a mean soil depth of 0.7 m

	Nickel (Ni)	Cadmium (Cd)	Mercury (Hg)	Lead (Pb)	Chromium (Cr)	Manganese (Mn)	Arsenic (As)
Badagry (a)	0.51	0.70	2.42^{-05}	0.06	18.60	48.34	1.56
Badagry (b)	-0.38	0.00	-1.8^{-05}	-0.04	-7.54	-41.57	-2.32
Soluos (a)	18.53	21.23	5.14^{-05}	28.61	28.24	55.07	12.86
Soluos (b)	-22.18	-16.48	-2.1^{-05}	-19.39	-34.16	-64.78	-9.38
Ewu-Elepe (a)	25.29	17.65	0.32	31.48	54.26	217.39	17.20
Ewu-Elepe (b)	-32.61	-23.86	-0.45	-43.88	-64.89	-341.07	-26.32
Epe (a)	10.17	16.12	0.89	13.91	31.30	55.89	11.13
Epe (b)	-6.88	-17.32	-1.42	-11.74	-30.80	-20.50	-7.16
Olusosun (a)	21.78	24.33	0.00010	91.62	59.35	458.93	19.84
Olusosun b	-29.54	-34.72	-0.0001	-101.94	-61.21	-660.71	-22.44

Note: Y= a+bx; But at the surface, x= 0. ∴ y= a. Also, at depth of nil pollution, y=0 hence x=-a/b; [a= intercept, b= slope, x= depth (in metre), y= concentration (in mg/kg)]

Consequently, the tested soils in the various landfills exhibited distinctive features to prove that they originated from different sources. Using depth, the alternative hypothesis was accepted (proving that at least one of the means of each of the measured parameter is different and that the results did not occur by chance) for pH, EC, Fe, Pb, Cr at 99% confidence limit (significant level, $\alpha = 0.01$). The alternative hypothesis was also accepted for Ni, Cd & As at 95% confidence limit ($\alpha = 0.05$). This infers that these parameters may have differed in the landfills by virtue of human influence since the geology of these areas (Ojota, Igando and Ewu-Elepe) is the same.

4. DISCUSSION

One cannot ignore the possible environmental hazards that can be created as a result of long term dumping of refuse in the soil. A residence time of about 1000 - 3000 years has been estimated for such heavy metals as Ni, Pb and Cd in temperate zones [5]. This means that these metals remain distributed for a very long time in the soil in large amounts. Heavy metals have a great ecological significance due to their toxicity and accumulative behaviour [6].

The Olusosun landfill soil recorded electrical conductivity with a mode of 1600 µS/cm. The pH ranged between 8.2 - 8.5 and decreased with depth. The concentrations of the metals were higher than most of the anions. Pb and Cr posted 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. All the anions measured conformed with the set standards. Sulphate was the most significant anion in terms of concentration (mode: 13 mg/kg). The concentrations between a depth of 40-100 cm (mean: 70 cm) seems a closer approximation to natural concentration than those of the top soils. Comparisons of the concentrations of some of the physiochemical parameters at different depths in the Olusosun landfill soil are shown in (Figs. 5 & 6). Similarly, a comparison of the concentration of some of the measured parameters at a depth of 0-20 cm across soils in the study areas is given in (Fig. 7).

The observed concentrations of nitrate, sulphate, phosphate and pH in all the tested soils conformed to FEPA and LASEPA standards [7]. Zn, Fe, Ni, Hg and Mn were all below the crustal average [8]. The Ni contents in the soils were within all the standards established for use of soils in Taiwan, Germany and Canada [9] (Figs. 08-17). All the observed Cd concentrations exceeded the crustal average. Olusosun 1 and Soluos-a exceeded the Cd limits set by the aforementioned countries for soils designated for commercial/industrial purposes. The Cd contributions are likely from the e-wastes, dry cell batteries and paint cans, impurities in the zinc of galvanized pipes, metal fittings and solders form of plastics as pigments or stabilizing agents. More recent data indicate that the increasing use of cadmium in batteries means that perhaps 75% of the cadmium in MSW today is in the form of batteries. 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. A significance of these analyses is that for the purpose of remediation, the removal of about a meter of top soil from Olusosun will help to contain Cd pollution. This seems plausible. For instance, because of the lasting deleterious health effects of chemicals used by the Americans in the course of the Vietnam War, the polluted soil and sediment are being excavated. Consequently, they are heated to a high temperature to destroy the dioxins [10].

Pb in the top soil at Olusosun was above the crustal average, which infers that the local geology has relatively lower concentration of this metal as all the analyzed soils conformed to permissible standards.

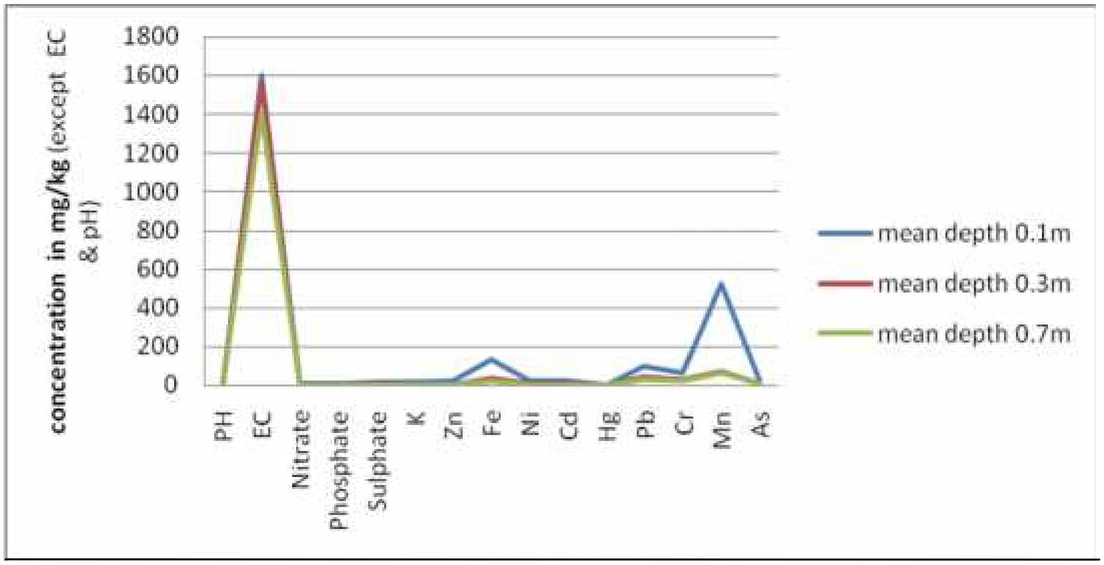

Fig. 5. Comparison of the concentrations of the analytes at different depths in the Olusosun landfill soil

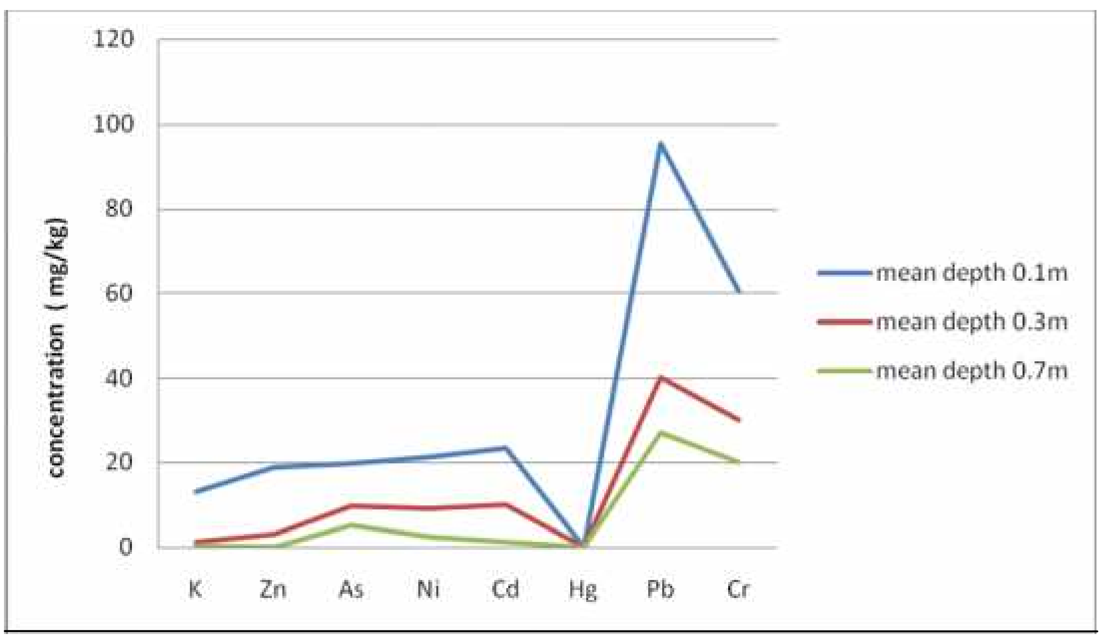

Fig. 6. Comparison of the concentrations of metals at different depths in the Olusosun landfill soil

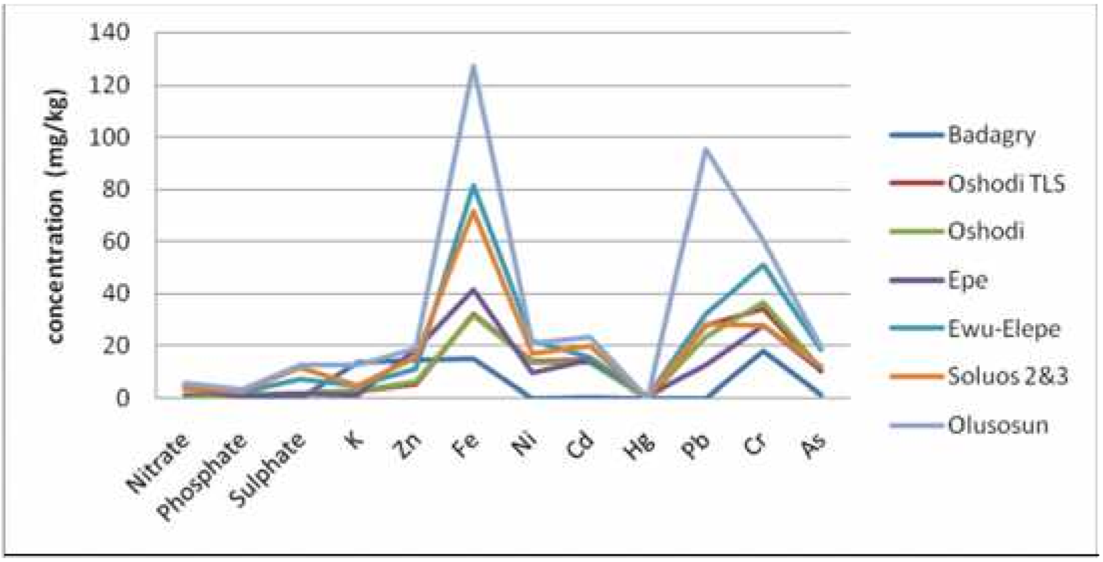

Fig. 7. Comparison of the concentration of the analytes at a depth of 0-20 cm across soils in the study areas

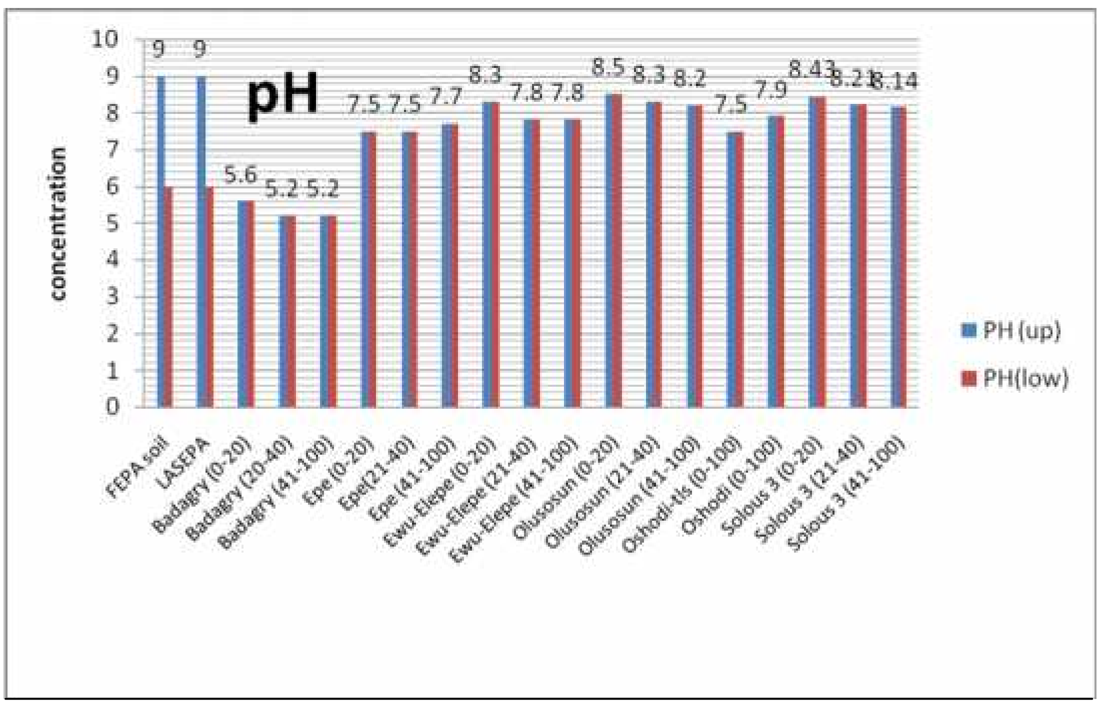

Fig. 8. Comparison of pH concentrations in soils with standard

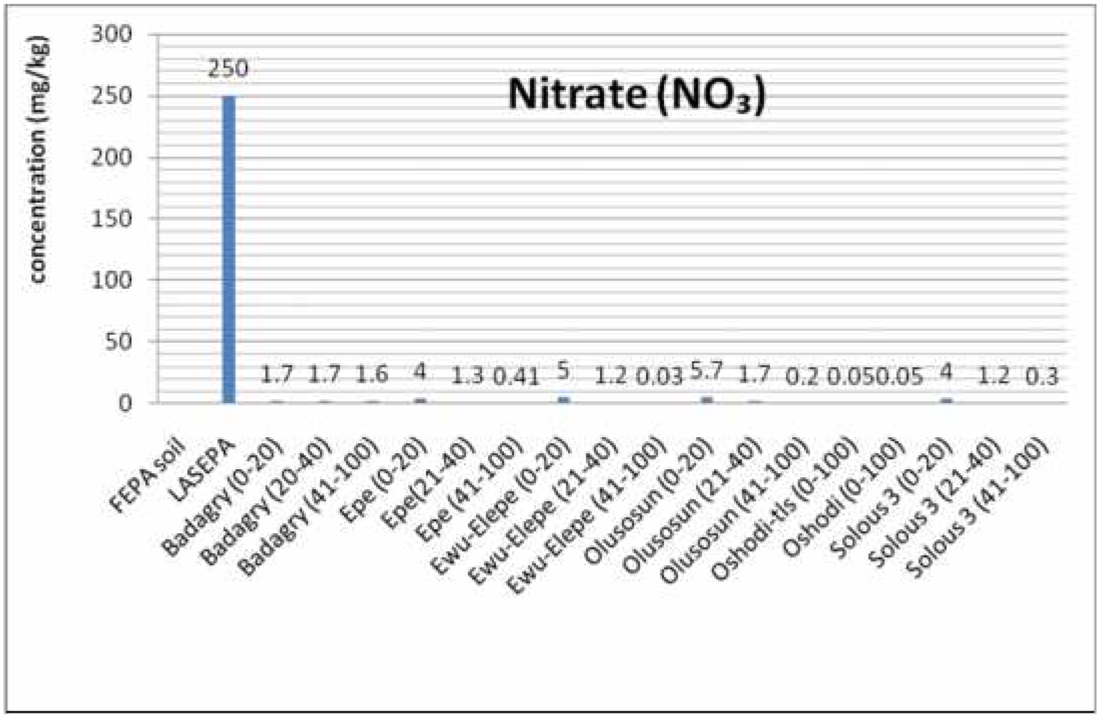

Fig. 9. Comparison of nitrate concentrations in soils with standards

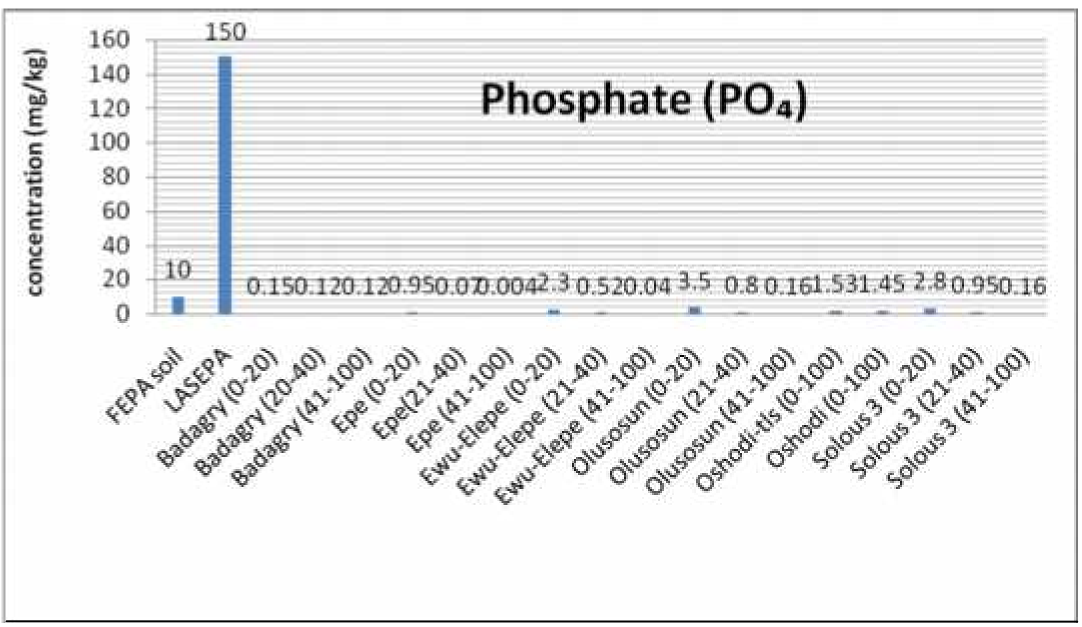

Fig. 10. Comparison of phosphate concentrations in soils with standards

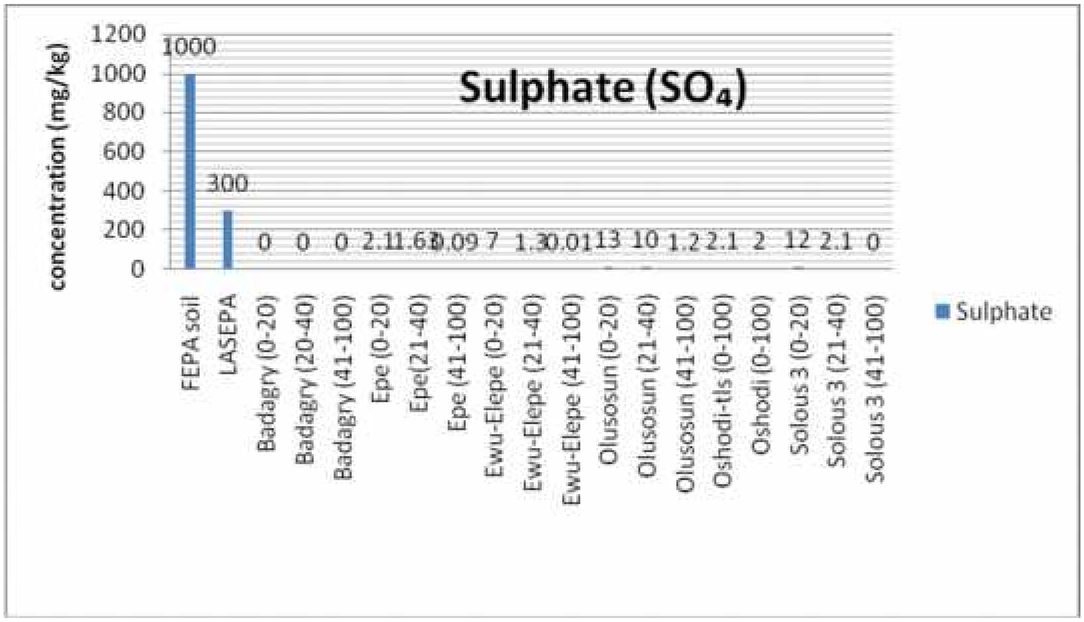

Fig. 11. Comparison of sulphate concentrations in soils with standards

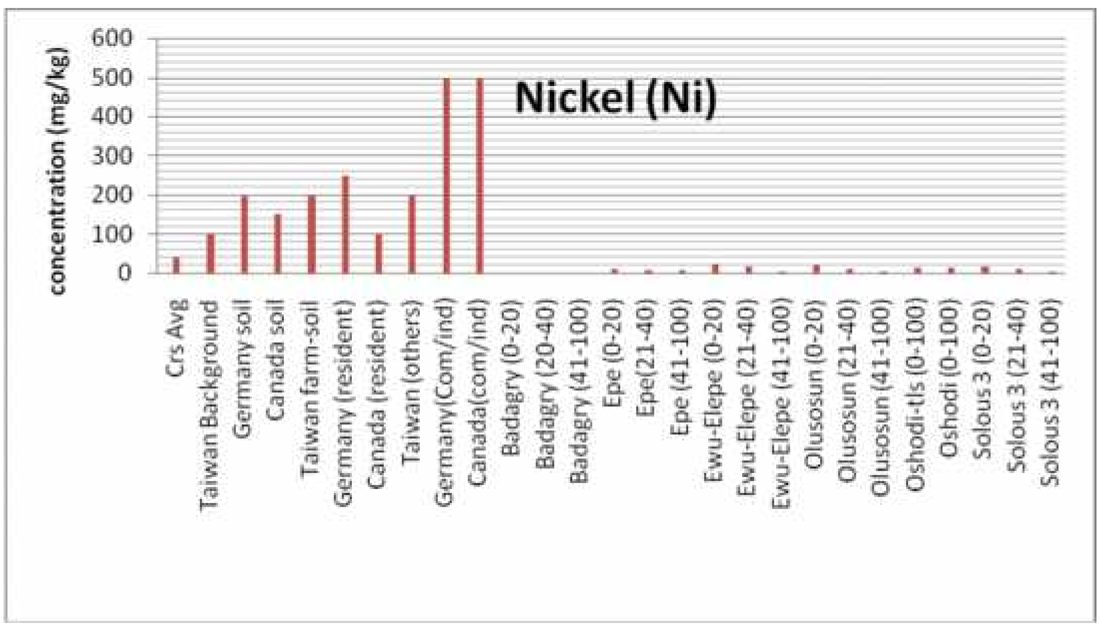

Fig. 12. Comparison of nickel concentrations in soils with standards

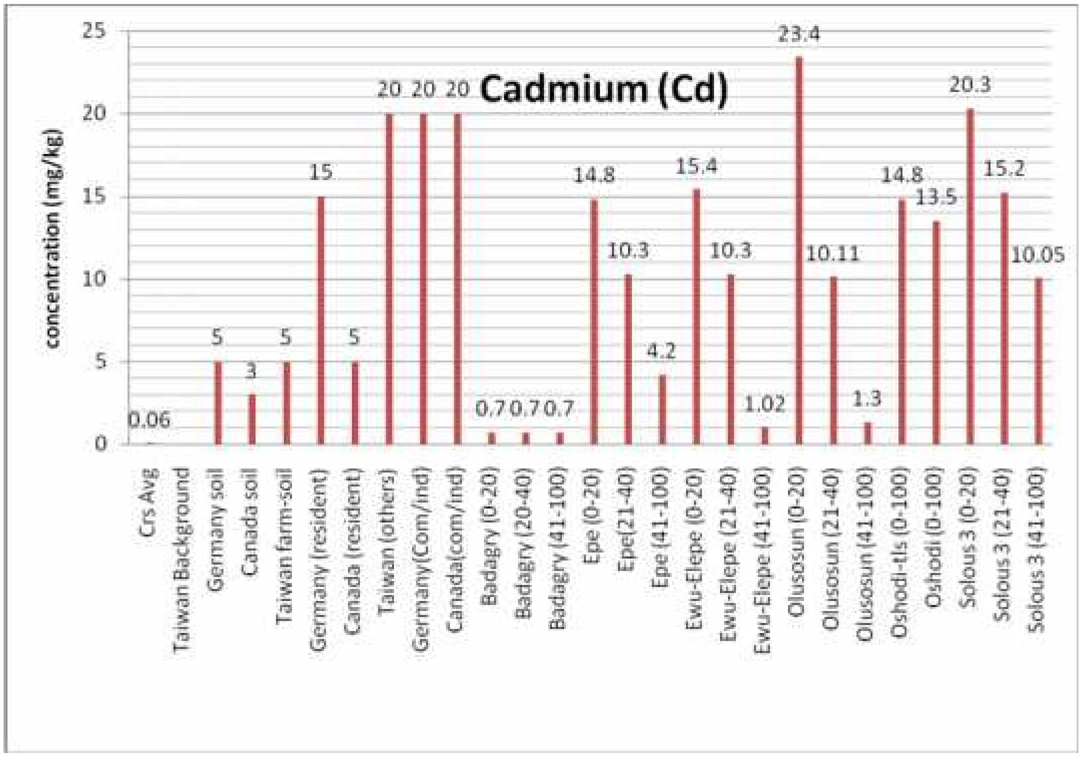

Fig. 13. Comparison of cadmium concentrations in soils with standards

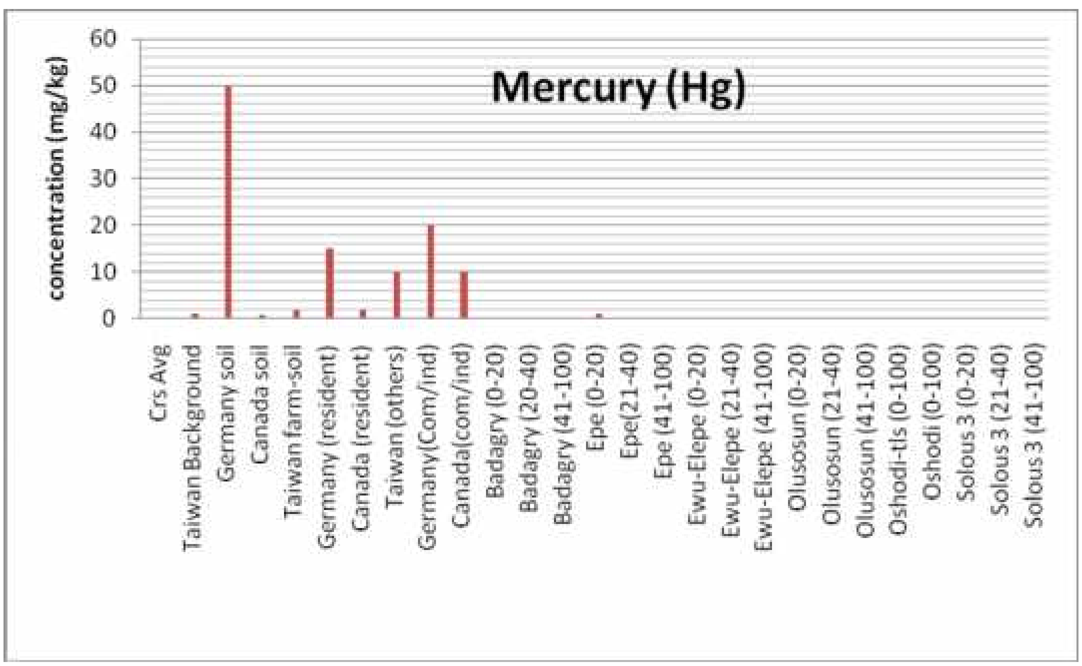

Fig. 14. Comparison of mercury concentrations in soils with standards

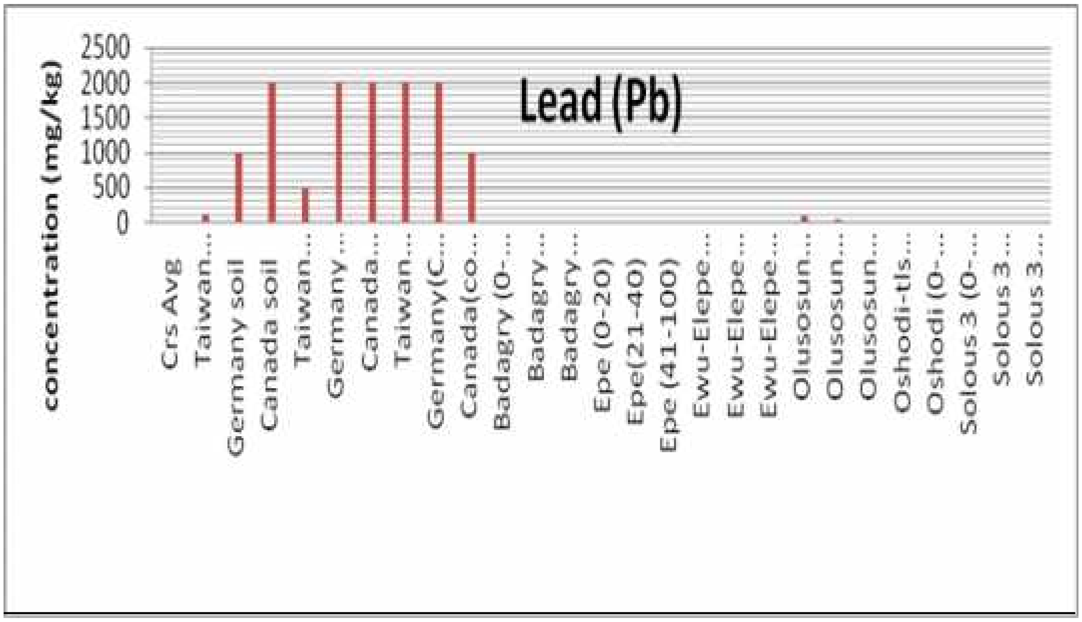

Fig. 15. Comparison of lead concentrations in soils with standards

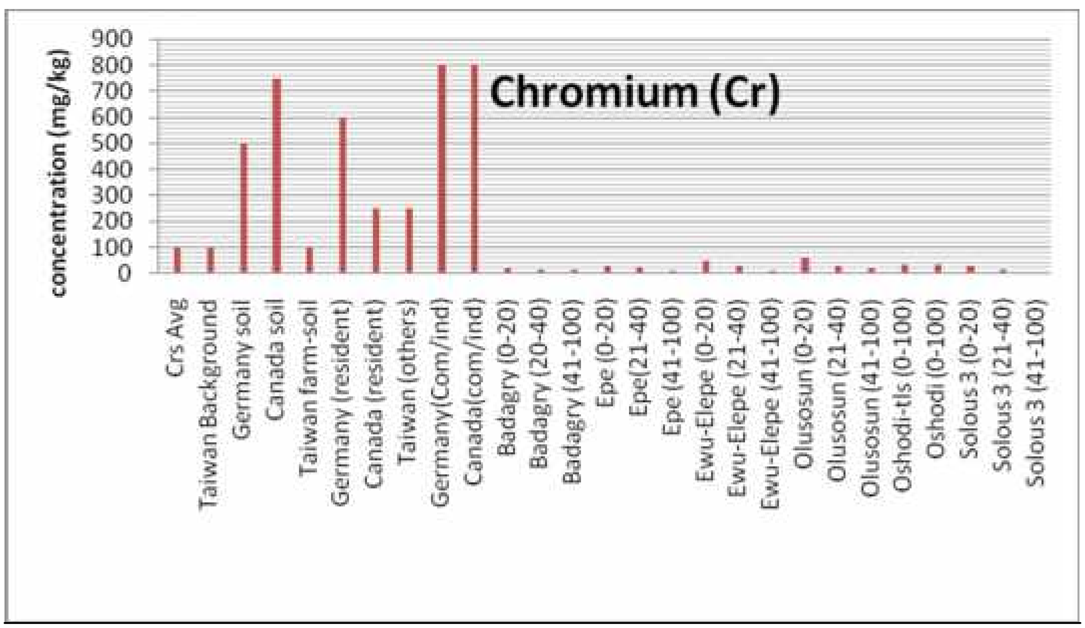

Fig. 16. Comparison of chromium concentrations in soils with standards

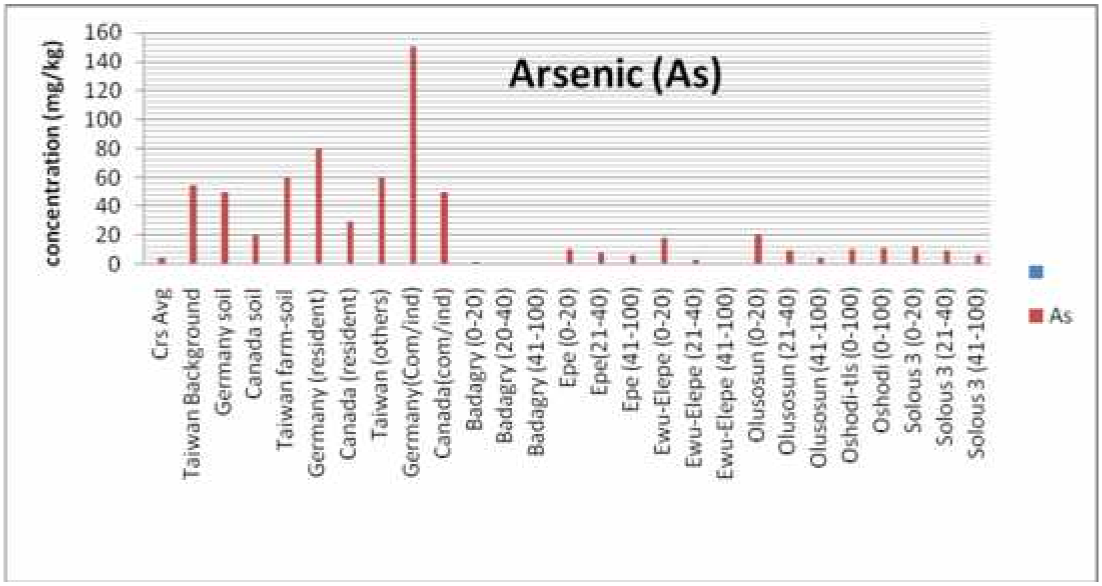

Fig. 17. Comparison of arsenic concentrations in soils with standards

Fig. 18. Fresh loads of medical waste being dumped at the Ewu-Elepe landfill

Fig. 19. Poorly incinerated medical waste at the Epe landfill

Generally, the potency of these effects seems attenuated in the clayey/ lateritic soils with depth and distance away from the landfills. This re-enforces the fact that the principal effects emanates from the landfills as concentrations essentially decreased away from the region of direct MSW loads.

Although the local geology favours reasonable iron content in most of the soils, increased concentrations may also have been induced by the Fe scraps dumped in the landfill [11]. The Zn concentrations can be correlated with contributions from fluorescent tubes, batteries, and a variety of food wastes as well as the burning tyres at the site. Chromium may be in the form of non-ferrous metal scrap but perhaps some of the load in waste was in leather. Nickel is often found to be mostly associated with scrap metal, and with glass and fine particles. Much of the mercury in waste is believed to exist primarily within disposed products including batteries, fluorescent bulbs, thermostats and other switches, and measuring and control devices such as thermometers. Certain medical wastes (Figs. 18 and 19) are known contributors of mercury in a landfill environment. A 2002 estimate found that dental amalgam waste from dental offices is a major mercury-containing input to MSW, contributing a significant amount of the total mercury in solid waste.

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 as it can volatilize to pollute air quality and percolate into groundwater. The toxic effects of inorganic mercury compounds in humans include damage to the kidney.

Apart from contributions of the waste streams in the landfills, the observed elevated levels of cadmium may also have been contributions from local air pollution [12]. From the results, the relatively high concentrations of cadmium may have been occasioned by substitution for Hg, Zn and some other trace elements by reason of the MSW infusion into the landfills. In Taiwan, it was observed that when rice was planted in a soil with 1-2 mg/kg Cd (0.1 N HCl extractable), the Cd concentration in the grain can be over 2 mg/kg [13]. This means that the current practice of using landfill-generated compost for agricultural consumables by LAWMA in the Lagos Area and elsewhere may portend dire health consequences. Cadmium has a high renal toxicity, which is not only due to its mode of action but also to its irreversible accumulation in the kidney and has a biological half-life of 10-35 years. Although the mobility of arsenic in top soils is low, leaching over long time-scales may increase arsenic concentrations in groundwater under arable lands as in the Ewu-Elepe landfill area. Therefore, the discomfiting concentrations of arsenic and cadmium in most of the landfill soils do not support their use for food crops. Groundwater may also be at risk in areas where the mass of soil clearance is insufficient and / or where the soil lacks attenuative capacities to contain the downward migration of these pollutants.

Manganese may be naturally occurring in many of the observed soils, but the sharp drop in concentration from 520 mg/kg at a depth of between 0-20 cm to an average of 65 mg/kg in the intervening 80 cm points strongly to anthropogenic inter-plays. Manganese is known to cause neurological effects.

Since these heavy metals can become a threat to vegetation and animals, and ultimately affect the quality of human life [14] through the food chain, it is important to continuously monitor the level of such pollutants in the environment. Hence, part of the thrust of the present study was initiated in an attempt to find out the concentrations of the various physiochemical parameters in landfill soil environment in order to aid mitigation.

All soils naturally contain trace levels of metals. The presence of metals in soil is, therefore, not indicative of contamination. The concentration of metals in uncontaminated soil is primarily related to the geology of the parent material from which the soil was formed. Depending on the local geology, the concentration of metals in a soil may exceed the crustal average. Use of common ranges or average concentration of trace metals in soils as an indicator of whether a soil is contaminated is not appropriate since the native concentration of metals in a specific soil may fall out of the listed ranges. Only by direct analysis of uncontaminated soils can background levels of metals be determined [15]. In this study, the soils were collected from a 1 m stretch profile beginning with the top soil. The use of control soils, coupled with analyses from various strata provided veritable clues about contamination/pollution.

Generally, the concentrations of most of the measured parameters decreased with increasing depth from the area of the MSW mass in the landfills. This suggests that the landfills contribute significantly to the level of these indices in the environment. Trace metals were marginally recorded in the control area (Badagry). The concentrations of the analytes increased in the Oshodi soil probably due to vehicular emissions coupled with other anthropogenic activities. Nonetheless, the landfills were the areas with the highest concentrations of the investigated parameters. They all showed remarkable attenuative potentials given the clayey /lateritic lithology except the Epe landfill soil, which is essentially sandy. From the surface to a depth of 20 cm, the concentrations of metals in the soil were in the order: Olusosun > Ewu-Elepe > Soluos 3 > Epe > Oshodi > Badagry. In order of overall decreasing concentrations, the soils can be grouped thus: Olusosun (landfill area) > Soluos 3 (landfill area) > Ewu-Elepe (landfill area) > Epe (landfill area) > Oshodi (TLS area with concrete pavement) > Badagry (control area).

5. CONCLUSION

Results of the physiochemical analyses of the landfill soils reveal pollution occasioned by the infusion of municipal solid wastes. The comparatively lower concentrations in the control area (Badagry) - with near pristine conditions, and the transfer loading station areas at Oshodi - with considerable vehicular traffic, accentuates this assertion. The clayey soils in the landfills are highly adsorptive and can theoretically attenuate the effects of most pollutants at soil mass thicknesses of about four (4) metres. Furthermore, the decreasing concentrations of most of the measured physiochemical parameters with depths across all the tested soils point more to anthropogenic inter-plays.

With exclusion of humus, the landfill soils can be used for construction purposes. However, without remediation, the elevated concentrations of cadmium and arsenic make them unfit for use as agricultural compost. It will add immense human and environmental health value to debar further introduction of heavy metal components into these landfills.

COMPETING INTERESTS

Authors declare that there are no competing interests.

REFERENCES

1. Mackay D. Multimedia environmental models: The fugacity approach. Lewis Publishers, Boca Raton, FL, USA; 1991.
2. Kobayashi K. Metabolism of pentachlorophenol in fishes In: Pentachlorophenol & Environmental Toxicology (K. R. Rao Ed.), Plenum Press, New York. 1978;89-106.
3. Tattam CM. A review of Nigerian stratigraphy. Geological Survey of Nigeria Report, Lagos. 1943;27-46.
4. Jones HA, Hockey RD. The geology of part of S. W. Nigeria. Geol Surv Nigeria, Bull. 1964;31:87.
5. Bowen MR, Howland P, Last FT, Leakey RRB, Longman KA. *Triplochiton scleroxylon:* Its conservation and future improvement. FAO Forest Genetic Resources Information. 1977;6:38-47.
6. Purves D. Trace element contamination of the environment. Amsterdam: Elsevier. New York. 1985;243.
7. Federal Environmental Protection Agency (FEPA). Water quality, federal water standards, guidelines and standard for environmental pollution control in Nigeria, National Environmental Standards – Part 2 and 3, Government Press, Lagos 1991;238.
8. Lindsay WL. Chemical equilibria in soils. John Wiley & Sons, New York, USA. 1979;449.
9. Regulatory Standards of Heavy Metal Pollutants in Soil and Groundwater in Taiwan Dar-Yuan Lee and Chia-Hsing Lee Department of Agricultural Chemistry, National Taiwan University).

10. BBC News (2012): US starts Agent Orange clean-up in Vietnam Available: http://www.bbc.co.uk/news/world-asia-pacific (18th Feb 2014)
11. Idehai IM. Municipal solid waste disposal in Lagos: Effects on the environment, and partial estimation of the landfill gas and recyclable potentials. M.Sc Thesis, University of Benin, Nigeria; 2013.
12. LAWMA. Integrated Waste Management Shifting the Paradigm. Paper presented at the 47th Annual International Conference of the Nigerian Mining & Geosciences Society (NMGS). LAWMA. 2011;110. Available: www.lawma.gov.ng.
13. Lee DY, Lee C. Regulatory standard of heavy metal pollutant in soil and groundwater in Taiwan. 2011;10-17.
14. Harrison RM, (ed) Pollution: Causes, effects and control (2nd edn.). The Royal Society of Chemistry, London. 2001;579.
15. McLean JE, Bledsoe BE. Ground water issue: Behavior of metals in soils. United States EPA/540/S-92/018. 1992;25.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=670&id=5&aid=6177