academicJournals

Vol. 8(1), pp. 41-47, January 2014
DOI: 10.5897/AJEST2013. 1621
ISSN 1996-0786 © 2014 Academic Journals
http://www.academicjournals.org/AJEST

African Journal of Environmental Science and Technology

Full Length Research Paper

Assessment of some heavy metals and physicochemical properties in surface soils of municipal open waste dumpsite in Yenagoa, Nigeria

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Accepted 9 December, 2013

The current study was designed for the assessment of lead, cadmium and chromium and some physicochemical properties of soils collected from an open dumpsite in Yenagoa, Nigeria. Surface soil samples at two depths (0-10 and 10-20 cm) were randomly collected at the dump field and control site, and were analyzed for physicochemical parameters and contamination by lead, chromium and cadmium using standard analytical methods. The results show that the main dumpsite had higher sand (>80.0%) and lower clay and silt contents than the control site. Soil mean pH varied between 4.89±0.05 in the control and 7.60±0.02 in the dump. Total nitrogen (N) content of the dump soils ranged from 0.06±0.07 to 0.24±0.09% and is slightly higher than that of the control soil. This is reflected in the high value of organic matter (4.71±0.85%) in dump soils. Available P was quite high ranging from 35.00±1.01 to 84.20±1.02 mg/kg. Cation exchange capacity (CEC) varied between 12.98±0.31 and 91.07±0.11 cmol kg^{-1}. ECEC levels were moderate to high ranging from 14.10±0.10 to 91.47±0.11 cmol/kg. All the soil samples had very high base saturation (>90.0%) and exchangeable Ca, Mg, K and Na, far above the critical levels set by FAO for agricultural soil. Average levels of Pb ranged from 14.75±0.05 to 16.14±0.04 mg/kg in the dump and 8.35±0.05 to 8.78±0.07 mg/kg in the control. Mean concentration of Cr in the dump soil varied between 0.05±0.01 and 0.06±0.01 mg/kg, and is slightly higher than the control (0.005±0.01 mg/kg), while Cd was found in trace amounts (<0.0001±0.01 mg/kg). These values are all far below the maximum tolerable levels set by FAO and WHO for agricultural soil. It is suggested that the dumpsite and the control area with their adequate soil nutrients and low levels of metals should eventually be converted to agricultural farmland. No remediation is needed at this time.

Keywords: Dump waste soil, heavy metal, soil fertility.

INTRODUCTION

Landfills have long been used as repositories for industries, municipal and commercial wastes. Nigeria, a developing country with non adequate waste disposal or recycling processes is at a risk of metal and organo-metallic contamination of its soil and surface water bodies, which poses health hazard and soil deterioration for agricultural purposes. Yenagoa Township, the capital city of Bayelsa State is located in a humid tropical, wetland area where high rainfall and temperatures favour rapid degradation of organic materials (Ayolagha, 2001).

In Bayelsa State, solid wastes are handled by the Bayelsa State Ministry of Environment. The Ministry has

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allocated an extent of land along Yenagoa-Tombia road for disposal of solid wastes collected from Yenagoa town and its environs. As Yenagoa is a non-industrialized city, the refuse generated within the city comprise largely of degradable materials from markets, offices, hospitals and households such as garbage, plastics, textiles, stationeries, sludge from sewage, dead animals, ashes, wood, food and farm waste products. However, metallic materials from damaged vehicle parts, electronics, computers, cans, etc, are also disposed in the same way as the other non-metallic materials, thereby constituting a source of metal contamination.

Open dumps are generally unsanitary and constitute malodorous places in which disease-carrying vermin such as rats and flies proliferate (Bellebaum, 2005). Methane and other gases are released into the surrounding air as microorganisms decompose the solid wastes and fires pollute the air with acrid smoke and other numerous volatiles. Liquids that ooze and seep through the solid waste heap ultimately reach the soil, surface water and ground water. Hazardous materials such as heavy metals, pesticides and hydrocarbons that are dissolved in this liquid often contaminate soil and water (Adelekan and Alawode, 2011). Anikwe and Nwobodo (2001) suggested that continuous disposal of municipal waste on soil may lead to increase in heavy metals in the soil and surface water that would be inimical to deep feeding plants. Heavy metals such as arsenic, cadmium, lead, chromium, nickel, cobalt and mercury are of concern primarily because of their ability to harm soil organisms, plants, animals and human beings (Adelekan and Abegunde, 2011). More emphatic are the untreated dumplings that rapidly increase soil toxicity making such large area dumpsites potentially hazardous for agricultural purposes. Yet these workers (Anikwe and Nwobodo, 2001; Adelekan and Alawode, 2011; Adelekan and Abegunde, 2011) also indicate that municipal waste dumpsites bear soils that are sufficiently rich in organic matter that would be acceptable for surface feeder plants. Consequently, Brady (1996) and Helmore and Ratta (1995) reported that open dump fields perform a dual purpose of safe disposal of wastes and simultaneously create improved physical and chemical properties of soils that constitute productive agricultural fields. Other studies have also revealed that dumpsites around two major cities in Nigeria could be effectively utilized for residential and agricultural purposes without risk of heavy metal toxicity (Urunmatsoma and Ikhouria, 2005; Asalawalam and Eke, 2006). Old dump fields therefore can be seen to provide farmers with fertile plots for cultivation of vegetables and other surface feeder crops.

Public concern about environmental pollution has focused attention on the disposal of urban and industrial waste hence this study intends to determine the contents of lead, chromium and cadmium and the fertility status of the soil of the dump field in Yenagoa area in view of interpreting the suitability of its soil for crop production.

MATERIALS AND METHODS

Study area

Yenagoa, the capital city of Bayelsa State, Nigeria lies between latitude 4° 50' to 5° 00' North and longitude 6° 11' to 6° 25' East. The town is located in a humid tropical wetland area with mean annual rainfall of about 2539 mm and an average mean temperature of 26.2°C. The dump field investigated is located opposite HPEB 119 Company along the Yenagoa-Tombia road lying between latitude 4° 58' 59.20"North and longitude 6° 19' 18.20"East (Ayolagha, 2001).

Waste soil sampling

Surface soil samples, after removing the overlying wastes, were collected randomly from the dump field at two depths; 0-10 and 10-20 cm using a Dutch soil auger and a spatula. Another set of soil samples were also collected at the same depths, from uncultivated land, at 100 m away from the dump site, to serve as control. The soils were air dried for three days, ground and sieved through a 2 mm sieve. These were stored in labelled polythene bags and were taken to the laboratory for analysis.

Analyses of some physico-chemical parameters of soil samples

Particle size distribution otherwise known as mechanical analysis was determined by hydrometer method (Bouyoucos, 1962) using sodium hexametaphosphate as dispersant. The texture class was also determined using the 'textured triangular diagram' (Loganathan, 1984).

Soil pH was measured in water suspension (1:2.5) using the glass electrode coupled pH meter. The potential acidity was measured in a 1:10 (w/v) ration of soil to solution of 1 M KCl.

The cation exchange capacity (CEC) was determined by extracting the cations with 1 M ammonium acetate buffered at pH 7. 30 ml of 1 M CH_3COONH_4 was added to 5 g of soil. The suspension was shaken for 2 h and then centrifuged (15 min, 6000 rpm). After centrifugation and filtration, the filtrate was transferred into a 100 ml flask and two other volumes of 30 ml ammonium acetate were added successively after 30 min of agitation and centrifugation. The final filtrates were completed to 100 ml with ammonium acetate solution.

Calcium (Ca) and magnesium (Mg) were determined by EDTA titration while potassium (K) and sodium (Na) were determined by flame photometry. Exchangeable acidity (EA) was determined by titration method (Juo, 1979). The effective cation exchange capacity (ECEC) was calculated as the total exchangeable bases plus exchangeable acidity.

Percentage base saturation (BS%) was calculated as the percentage of the sum of exchangeable bases divided by ECEC. Available phosphorous (Av. P) was extracted with Bray solution 11 and the phosphorous determined by the molybdenum method described by Udo and Ogunwale (1978). The percent organic matter (%OM) was calculated from the percent organic carbon (OC%) measured using Walker-Black (1934) wet oxidation method. Total nitrogen (TN) was determined using the modified Kjeldahl distillation methods (Juo, 1979).

Sample preparation and analyses of heavy metals

One gram of each of the sieved soil samples was digested using the nitric/perchloric acid digestion procedure, as described by Odu et al. (1986). The concentrations of heavy metals, Pb, Cr and Cd

Table 1. Physical properties/particle size distribution and metal concentrations of soil samples

Sample Code	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH H_2O	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
DS	0-10	87.40 ±0.03	6.12 ±0.02	6.48 ±0.03	Loamy sand	7.09 ±0.02	14.75±0.04	0.05 ±0.01	<0.0001±0.01
	10-20	91.42 ±0.02	3.14 ±0.02	5.46 ±0.02	Sandy	7.60 ±0.01	16.14±0.05	0.06 ±0.01	<0.0001±0.01
CS	0-10	39.41 ±0.01	16.13±0.01	46.47 ±0.04	Clay	5.01 ±0.03	8.78 ±0.07	0.005±0.01	<0.0001±0.01
	10-20	37.40 ±0.03	14.15±0.01	48.45 ±0.03		4.89 ±0.05	8.35 ±0.05	0.005±0.01	<0.0001±0.01

DS = Dumpsite; CS = control site. Data represent mean ± SD of two replicates.

Table 2. Chemical properties of soil samples.

Sample Code	Depth (cm)	pH KCl	pH H_2O	ΔpH	Av. P (mg/kg	OC	OM	TN	C/N	Exchangeable cation				CEC	EA	ECEC	BS (%)
						← % →				Ca	Mg	K	Na				
										← (cmol/kg) →							
DS	0-10	5.90 ±0.02	7.09 ±0.02	-2.81 ± 0.01	84.20 ±1.02	2.73 ±1.25	4.71 ±0.85	0.24 ±0.09	11.38 ±0.67	72.80 ±0.05	14.00 ±0.12	2.36 ±0.06	1.91 ±0.23	91.07 ±0.11	0.40 ±0.04	91.47 ±0.11	99.56 ±0.03
	10-20	5.86 ±0.01	7.60 ±0.01	-2.26 ± 0.01	68.22 ±0.89	0.60 ±1.07	1.03 ±0.64	0.06 ±0.07	10.00 ±0.57	45.60 ±0.10	12.40 ±0.07	1.13 ±0.10	1.95 ±0.08	61.08 ±0.09	0.96 ±0.06	62.04 ±0.10	98.45 ±0.05
CS	0-10	4.32 ±0.03	5.01 ±0.03	-1.21 ± 0.03	37.12 ±0.85	1.98 ±1.03	3.38 ±0.56	0.15 ±0.86	13.20 ±0.94	10.35 ±0.09	5.72 ±0.11	0.26 ±0.11	0.48 ±0.17	16.81 ±0.12	1.66 ±0.87	18.47 ±0.09	91.01 ±0.02
	10-20	4.26 ±0.02	4.89 ±0.05	-1.37 ±0.04	35.00 ±1.01	1.87 ±1.06	3.22 ±0.55	0.14 ±0.43	13.36 ±0.74	8.00 ±0.08	4.40 ±0.65	0.17 ±0.20	0.41 ±0.09	12.98 ±0.31	1.12 ±0.66	14.10 ±0.10	92.06 ±0.04

DS, Dumpsite; CS, control site; Av. P, available phosphorous; OC, organic carbon; OM, organic matter; TN, total nitrogen; C/N, carbon/nitrogen ratio; CEC, cation exchangeable capacity; EA, exchangeable acid; ECEC, effective cation exchangeable capacity; BS, base saturation. Data represent mean ± SD of two replicates.

were determined using atomic absorption spectrophotometer (UnicamSolaar32 model) following the standard procedures as given in APHA (1995). All analyses were done in duplicates.

RESULTS AND DISCUSSION

Characteristics of the soil samples

The results expressed as mean ± standard deviation of physico-chemical properties of the soils are presented in Tables 1 and 2.

Textural properties

Texture is related to certain physical properties of soil such as plasticity, permeability, ease of tillage, fertility, water holding capacity and overall soil productivity. For instance, for irrigation purposes, loamy and clay textures are classed as soils of high moisture holding capacity while loamy sands and sands have low moisture holding capacity (Brady, 1996).

In this study, the main dumpsite had higher sand and lower clay and silt contents than the control site. This was corroborated by Ideriah et al. (2006) who determined the soil quality around a solid waste dumpsite in Port-Harcourt, Nigeria, which is in the same humid tropical wetland area as Yenagoa.

According to Nyles and Ray (1999), soils with separate high sand and low clay content have high pollutant leaching potentials. Though the soils of the dumpsites predominantly contain high sand fractions (>80.0%) that allows high permeability of water and leacheates, the textural class (loamy sand) may be suitable for sanitary landfills (Loughry, 1973). The soils from the control sites consisted of moderately high clay fractions thus they exhibit plasticity and encourage surface water flooding and pollution. This clayey texture of the control soils also favours low permeability of water and leacheates (Ahn, 1993).

pH measurement

pH affects the mobility of heavy metals in soil. It has been found that soil pH is correlated with the availability of nutrients to the plant (Gray et al., 1998). Consequently, as pH decreases, the solubility of metallic elements in the soil increases and they become more readily available to plants (Oliver et al., 1998; Salam and Helmke, 1998).

Lower pH would favours availability, mobility and redistribution of the metals Pb and Cd in the various fractions due to increased solubility of the ions in acidic environment (Oviasogie and Ndiokwere, 2008). In the present study, soil pH (in H_2O) ranged from 4.89±0.05 in the control to 7.60±0.02 in the dump indicating a moderate acidic to a neutral reaction. The moderately acidic soil from the control site may tend to have an increased micronutrient solubility and mobility as well as increased heavy metal concentration in the soil (Odu et al., 1985). The value of KCl pH bears a strong correlation with aluminium saturation. Aluminium displaced by K^+ on the exchange complex consumes OH^- ions and increases $[H^+]$. The KCl pH values in the soils from the control are less than 5.2 which showed that exchangeable aluminium is present in the soils while the values in the dump soils were greater than 5.2 which are indicative of the presence of non-exchangeable aluminium. This could be attributed to hydrolysis, polymerization and precipitation (USDANRCS, 2004)

ΔpH is the numerical difference between the values of pH measured in KCl and H_2O, which results from the displacement of OH^- ions by Cl^- ions. It also highlights the displacement of the ions H^+ adsorbed on the exchange sites of the adsorbing complex from soil towards the soil solution (Yobouet et al., 2010). Since the ΔpH values for all the soil samples were negative, it means that the colloids have net negative charge which reflects the cation-exchange capacity as seen here which is very high (USDANRCS, 2004).

Organic carbon and soil organic matter

The presence of organic carbon increases the cation exchange capacity of the soil which retains nutrients assimilated by plants. Total organic carbon in the soils under investigation in this study was low to moderate ranging from 0.6±1.07 to 2.73±1.25% as indicated in Table 2. The moderately high amount of organic carbon of the refuse dump soils is suggestive of degradation or presence of degradable and compostable wastes (Munoz et al., 1994).

Soil organic matter (SOM) enhances the usefulness of soils for agricultural purposes. It supplies essential nutrients and has unexcelled capacity to hold water and absorb cations. It also functions as a source of food for soil microbes and thereby helps enhance and control their activities (Brady, 1996). The organic matter in the soil samples varied from 1.03±0.64 to 4.71±0.85%. The dump soils contain high amount of organic matter, about 4.71±0.85% which may be responsible for increase in the soil pH as compared to that of the control soil. This observation was supported by Oyedele et al. (2008) who reported that dump sites had significantly higher pH regime and soil organic matter as compared to the control soil. Ayolagha and Onwugbuta (2001) also demonstrated that high OM (>2.0%) in soils is conducive for heavy metal chelation formation.

The total nitrogen content

The total N content of dump soils ranged between 0.06±0.07 and 0.24±0.09% which is slightly higher than those of the control site which varied between 0.14±0.43 and 0.15±0.86%. The C/N calculated ranged from 10.00±0.57 in dump soil to 13.36±0.74 in control soil. Our result was supported by Brady (1996) who reported that C/N ratio in the topsoil is commonly between 10 and 12 in humid regions. Onwurah (2000) stated that C/N ratio is an index of biomass and they are responsible for the general restoration of microbial flora. Generally, if the ratio is below 20, this is often adequate to satisfy the N requirements of micro flora that decompose the residues (Eja et al., 2003). According to Ideriah et al. (2006), the low values of C/N ratios showed high decomposition and efficient mineralization process of the dump area. The waste dump C/N ratio is between 10.00±0.57 and 11.38±0.67 and it is lower than that of the control soil which is between 13.20±0.94 and 13.36±0.74. Therefore, the waste dump most likely contributed significantly to the very high levels of these soil properties.

Available phosphorous

The dumpsite had higher levels of P ranging from 68.22±0.89 to 84.20±1.02 mg/kg as compared to the control which varied between 35.00±1.01 and 37.12± 0.85 mg/kg; this could be attributed to the presence of high amount of organic matter and plants decomposition

(Ideriah et al., 2006). The high concentration of phosphorous contributes to good growth of plants as was observed. All the soil samples had available P values more than 10 mg/kg considered suitable for crop production (FAO, 1976).

Cation exchange capacity

The cation exchange capacity is the amount of exchangeable cation per unit weight of dry soil that plays an important role in soil fertility. It depends especially on the pH, clay and on the soil organic matter content. Results of this study revealed that soils from the dump had higher values of CEC ranging from 61.08±0.09 to 91.07±0.11 cmol kg^{-1} as compared to that of the control site which varied between 12.98±0.12 and 16.81±0.31 cmol kg^{-1}, although the clay content at the dumpsite was much smaller than that at the control site. So it is possible that a large part of exchangeable bases at the dumpsite must have been existing as a water-soluble form rather than an exchangeable form adsorbed at cation exchange sites. The increase in the TEB and organic matter in the dump field may result in plants taking up nutrients more easily (Aydinalp and Marinova, 2003).

ECEC levels were moderate to high varying from 14.10±0.10 to 91.47±0.11 cmol/kg. However, the ECEC status of dump soils was higher than those of the control and far above 20 cmol/kg regarded as being suitable for crop production (FAO, 1976). All the soil samples analyzed had very high base saturation (>90.0%) and were higher than 60%, the critical limit established for ecological zone (Holland et al., 1989). This also followed the pattern reported by Isirimah et al. (2003) for productive agricultural soil. The exchangeable acidity (EA) was generally low varying between 0.40±0.04 and 1.66±0.87 cmol/kg.

All the soil samples had high Ca values above 4.0 cmol/kg regarded as lower limit for fertile soils (FAO 1976). Exchangeable K varied from 1.13±0.10 to 2.31±0.06 cmol/kg in dump soils; these are higher than the levels in control soils and above 0.2 cmol/kg which is regarded as the critical limit of exchangeable K in soils (Unamba-Opara, 1985). The implication of these is that the soils are rich in nutrients and therefore an indication of good yield potential without any input of fertilizers.

Heavy metal concentrations

The evaluation of dumpsite soils for the concentration levels of toxic elements is essential for healthy crop production, thus this study has endeavoured to determine the levels of Pb, Cr and Cd in the various soil samples.

The distribution of mean concentration± standard deviation of the metals present in the soils is shown in Table 1. The result shows that the metal loads from the refuse dump soils were found to be slightly higher than the control area (100 m from the dumpsite) with the exception of Cd which was found in traces in all the soils. Our results are collaborated by Al-Turki and Helal (2004) and Ren et al. (2005) who reported that lead and cadmium are anthropogenic metals, and without external interference, are normally not abundant in upper layer soils.

Lead

The mean levels of Pb ranged from 14.75±0.04 to16.14±0.05 mg/kg in the soil samples from the dumpsite and 8.35±0.05 to 8.78±0.07 mg/kg in the control. These values were lower than EC (1986) upper limit of 300 mg/kg and the maximum tolerable levels proposed for agricultural soil, 90-400 mg/kg set by WHO (1993) and NEPCA (2010). This is in agreement with the results obtained from similar study by Umoh and Etim (2013) for soils from dumpsites within Ikot-Ekpene in Akwa-Ibom State, Nigeria.

Concentration of lead in the soils from both areas could be as a result of its sources from automobile exhaust fumes as well as dry cell batteries, sewage effluents, runoff of wastes and atmospheric depositions owing to the close proximity of the sites to high vehicular traffic along Yenagoa-Tombia road.

Chromium

The mean concentrations of Cr in the dump soil varied between 0.005±0.01 and 0.200±0.01 mg/kg, which was slightly higher, as compared to the control (0.005±0.01 mg/kg), but are still lower than the critical permissible level which is 50 mg/kg for soil recommended for agriculture by MAFF (1992) and EC (1986). Sources of Cr in the soils could be due to waste consisting of lead-chromium batteries, coloured polythene bags, discarded plastic materials and empty paint containers (Jung et al., 2006).

Cadmium

Cadmium levels in all the soil samples were found in trace amounts (0.0001 ± 0.01 mg/kg) and these values are far lower than the natural limits of 0.01-3.0 mg/kg in soil as given by MAFF (1992) and EC (1986).

The values of the metal concentrations obtained for both sites are all far below the maximum tolerable levels proposed for agricultural soil. This is in agreement with the findings of Asawalam and Eke (2006) and Njoku and Ayoka (2007) who investigated the trace metal concentrations and heavy metal pollutants from dump soils in Owerri, Nigeria.

Even though these heavy metal concentrations fell below the critical permissible concentration level, it seems that their persistence in the soils of the dump site may lead to increased uptake of these heavy metals by plants.

Conclusion

The concentration of the metals, Pb, Cr and Cd are all far below the maximum tolerable levels set by FAO and WHO for agricultural soil. The results of this study have clearly demonstrated that the low levels of heavy metals in the studied soil samples are consistent with the composition of the municipal wastes generated in Yenagoa and its environs. The results also show that the soil is not polluted by various pollutants and not harmful for recreational and agricultural purposes. It is therefore suggested that the dumpsite and the control area with their adequate soil nutrients and low levels of metals should eventually be converted to an agricultural farmland. No remediation is needed at this time.

ACKNOWLEDGEMENTS

The authors are grateful to Mr. Philip of National Root Crop Research Institute, Umuduike and the Staff of Anal Concept Limited, Port-Harcourt, for the analysis and running of the AAS for metal analysis. The assistance received from Mr. Domotimi Gerewei during collection and analysis of samples is acknowledged.

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