JASEM ISSN 1119-8362

Full-text Available Online at www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage. *December*, 2009
Vol. 13(4) 65 - 70

Some physico-chemical and Heavy metal levels in soils of waste dumpsites in Port Harcourt Municipality and Environs

[1]DAVID N. OGBONNA*; [2]BENJAMIN L. KII; [2]PATRICK O. YOUDEOWEI

[1]Department of Applied and Environmental Biology; [2] Department of Environmental Management, Institute of Geosciences and Space Technology; Rivers State University of Science and Technology, PMB 5080, Port Harcourt, Nigeria. 08033094635. E-mail address: dnogbonna@yahoo.com

ABSTRACT: Various physico-chemical techniques were used to investigate the characteristics and heavy metal concentration of soils in some selected waste dumpsites in Port Harcourt. This is because the soils act as vehicles for the permeability of leachates into various levels of aquifers in the environment. The results show that the soils are moderately acidic with a mean pH value of 5.5 for the 1m subsoil and 5.8 for 30cm soil depth in the various dumpsites, while the total organic carbon (TOC) levels show that it was low with 3.41% and 2.90% for depths 30cm and 1m respectively. The cation exchange capacity (CEC) of the soils showed a range of 21.36 – 28.79 meq/100g for a depth of 30cm and 20.94 – 26.44meq/100g for a depth of 1m soil level across the waste dumpsites. The textural class of the soils was observed to be a mixture of sand, clay and loam in all the sites. Low sand fractions (>40%) was observed for almost all sites except for Elekahia and Eleme roads that had 64.7% and 56.4% respectively. The results of the heavy metal concentration in all the locations of the waste dumpsites were above permissible limits. In this study, the soil did not meet up the moisture requirement for a waste land filling and could therefore be prone to porosity, surface flooding and underground water pollution. It is therefore suggested that the use of impermeable geomembrane is necessary for all dumpsites to minimize seepage of leachates from causing pollution of both surface and groundwater resources taking into account the possibility that the containment system may be threatened by any disaster. @ JASEM

The problem and major environmental concerns associated with the dispersal or disposal of industrial and urban wastes generated by human activities is the contamination of the soil. Controlled and uncontrolled disposal of wastes, accidental and process spillage, mining and smelting of metalliferous ores, sewage sludge application to agricultural soils are responsible for the migration of contaminants into non-contaminated sites as dust or leachates and contribute towards contamination of our ecosystem (Ghosh and Singh, 2005). A wide range of inorganic and organic compounds cause contamination especially when they are exposed to rain, its decomposition produces noxious odour, thereby, constituting a health hazard (Weiss, 1974; Ogbonna *et al*., 2006a). Major components of these compounds include heavy metals, combustible and putriscible substances, hazardous wastes, explosives and petroleum products (Adriano, 1986; Alloway, 1990). Soil microorganisms can degrade organic contaminants, while metals need immobilization or physical removal because metals at higher concentrations are toxic and can cause oxidative stress by formation of free radicals (Henry, 2000) and thus may render the land unsuitable for plant growth and destroy the biodiversity. Soils provide a suitable natural environment for biodegradation of wastes and therefore serve as a sink for the adsorption and absorption of ions and as a medium for the restoration of vegetation and normal land use (Ekundayo, 2003). Because of the shallowness of water table and nature of soil types in Port Harcourt municipality, this study was undertaken to assess the suitability of the soils as receptacles for waste dumpsites and heavy metal concentrations generated in such environments.

MATERIALS AND METHODS

Collection and treatment of soil samples

The soils of five (5) locations namely Rumuolumini Road, Eastern by pass, Elekahia, Eleme and East West Roads used for waste dumpsites in the municipality was chosen for the study. Samples were collected every two weeks for analysis for a period of six months with well labelled sterile containers. At each sampling station, the surface debris was removed and subsurface soil dug to a depth of about 30cm and 1m with a hand auger, then 2g of soil samples from each depth was taken into the sterile containers and labelled. A total of 24 samples, 2 from each soil depth and site were collected on each visit. The temperature of each sample was determined immediately after collection at each station using a thermometer, after which the samples were transported to the laboratory for analysis.

Determination of Soil Characteristics

Six (6) profile pits were dug in each location with length x width x depth measurements of 2m x 1m x 2m respectively (Ekundayo, 2003). Each profile pit was described morphologically in-situ, after which soil samples are collected with a core sampler (for bulk density determination) and secondly with a scooping knife (for proximate soil analysis) from each discrete soil horizon. The soil samples were bagged separately according to the method of Hodgson (1983). The samples were air dried, crushed and sieved for various physico-chemical parameters.

* Corresponding author: David N. Ogbonna

Particle size analysis was done using the hydrometer method (Juo, 1979). Bulk density was determined by the core method as modified by Evans *et al* (1982). The pyenometer method described by Black (1965) was used to determine particle density. Total porosity was calculated from particle density and bulk density. Moisture content was determined by gravimetric method in which samples were dried to constant weight. The double ring infiltrometer method as reported by Ahuja *et al* (1976) was used to determine infiltration rate. Stickness, plasticity and consistency were determined by feeling the samples with the fingers.

Determination of Heavy metals

One gramme of the soil sample was digested with a mixture of hydrofluoric, nitric, perchloric and sulphuric ($HF + HClO_4 + H_2SO_4$) acids. The clear digest was diluted into 50ml mask with deionized water. The sample solution was analysed for Pb, Cd, Cu, Zn and Fe using air acetylene flame atomic absorption spectrophometer (AAS) (Perkin Elmer A3100). The atomic absorption spectrophotometer was fitted with D_2 background correction devices and analysis of the reagent blanks were also carried out.

RESULTS AND DISCUSSION

Soil Characteristics

The soils were observed to be moderately acidic with a mean pH value of 5.5 for the subsoil (1m) and 5.8 for 30cm soil depth at the various locations of the waste dumpsites, while the levels of total organic carbon (TOC) in the locations showed that it was slightly lower with 3.41% and 2.90% for depths 30cm and 1m respectively (Table 1). The cation exchange capacity (CEC) of the soils examined showed a range of 21.36 – 28.79meq/100g for a depth of 30cm while 20.94 – 26.44meq/100g was observed for depth of 1m subsoil levels across the stations.

Table 1: Physico-chemical characteristics of the soils of waste dumpsites at various depths in Port Harcourt Municipality and Environs.

S/NO	PARAMETERS	EBP		EWR		ELK		RLM		ELE		C	
		30cm	1m	30cm	1m	30cm	1m	30cm	1m	30cm	1m	30cm	1m
1.	pH	5.8	5.8	5.8	5.5	6.4	6.5	6.0	6.0	6.0	5.5	5.8	6.0
2.	N(%)	2.20	2.84	0.72	0.12	2.94	0.09	0.24	0.18	0.06	0.07	0.06	0.04
3.	TOC(%)	3.41	2.90	0.68	0.14	2.56	0.08	1.06	0.76	0.68	0.08	0.06	0.05
4.	TOM(%)	5.93	5.05	1.18	0.24	4.45	0.14	1.84	1.32	1.18	0.14	0.10	0.09
5.	Ca(meqCa)	14.21	12.98	18.46	16.54	15.42	14.36	19.31	19.84	16.21	17.81	20.16	19.21
6.	Mg(meqNa)	5.58	6.18	7.21	4.80	3.81	4.32	7.26	6.32	5.32	6.41	8.14	7.36
7.	Na(meqNa)	1.06	0.94	1.21	1.42	1.06	1.02	1.14	1.08	1.06	1.14	1.21	1.32
8.	K(meqK)	1.42	1.26	1.60	1.71	1.08	1.24	1.08	1.14	1.31	1.08	1.16	1.08
9.	EA(Cmol/g)	0.86	0.81	0.06	0.84	0.92	0.98	0.90	0.81	0.82	0.71	0.84	0.82
10.	CEC(meq)	22.27	21.36	28.59	24.47	21.37	20.94	28.71	28.38	23.89	26.44	30.67	28.97

NOTE:
C = Control
RLM = Rumuolumini Road
EBP = Easter Bypass
ELK = Elekahia
ELE = Eleme Road
EWR = East West Road

However, the pH, TOC, CEC and particle size distribution are among several components of soil that affect the availability, retention and mobility of metals with increasing pH (Itanna, 1998; Bhattacharya *et al*., 2002). The pH levels that are acidic tend to have an increased micronutrient solubility and mobility as well as increased heavy metal concentration in the soil (Odu *et al*., 1985) ,thus rendering the soil unsuitable for waste landfilling. The soil did not also meet up the moisture requirement for waste landfilling and could therefore be prone to ponding, surface flooding and underground water pollution.

The absence of total organic carbon in the various sites could be probably due to the utilization of the elements by microorganisms as sources of nutrients for mineralization process which could account for its depletion in the soil.

The cation exchange capacity is the amount of exchangeable cation per unit weight of dry soil that plays important role in soil fertility. Nigerian soils with cation content of 2meq/100g soils are considered for calcium and magnesium while 0.2meq/100g soils and above are adequate for potassium ion (Odu *et al*., 1985). The CEC is directly related to the capacity of adsorbing heavy metals since the adsorption behaviour depends on combination of the soil properties and the specific characteristics of the element (Barry *et al*., 1995). Therefore, in this study, TOC values did not show any corresponding values in CEC in terms of building sites for humic acids and contribution to retention of cations in the soils as reported by Abollino *et al* (2002).

The textural class of the soils was observed to be a mixture of sand, clay and loam in all the sites investigated. Low sand fractions (less than 40%) was observed for almost all the sites except for Elekahia and Eleme Roads dumpsites that had 64.7% and 56.4% respectively (Table 2). Waste

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dumpsites with low sand fractions (<40%) are not suitable for waste landfilling (Ekundayo, 2003; Ogbonna, 2004; Ogbonna *et al*., 2006b) since they are rapidly permeable and could allow large quantities of leachates from the wastes to invade the deposited refuse and finally to the groundwater resources. Similarly, the East West Road and Eleme Road waste dumpsites with 64.8% and 65.8% respectively did not also meet the textural requirement for refuse disposal in Port Harcourt, because they have mean clay fractions greater than 31%. High clay fractions/concentrations greater than 31% encourage surface water flooding and pollution.

Table 2: Characteristics of soils of the waste dumpsites in Port Harcourt Municipality and environs

S/N	PARAMETERS	EBP		EWR		ELK		RLM		ELE		C	
		30cm	1m	30cm	1m	30cm	1m	30cm	1m	30cm	1m	30cm	1m
1.	Moisture (%)	2.0	4.6	1.8	1.7	3.3	2.0	1.3	1.1	1.1	0.9	1.2	1.5
2.	Clay (%)	12.1	10.5	64.8	65.8	16.7	5.10	9.30	16.7	23.1	65.8	56.5	28.6
3.	Silt (%)	72.5	78.4	13.8	13.7	72.5	30.2	58.2	46.5	20.5	13.4	13.1	48.4
4.	Sand (%)	15.4	11.1	21.4	20.5	10.8	64.0	32.5	36.8	52.4	20.8	30.4	23.0
5.	Textural Class (%)	L/S	L/S	C/S	C/S	L/C	S/L	L/S	L/S	S/C	C/S	C/S	L/C
6.	Bulk Density(g/cm^3)	2.7	2.5	3.12	2.9	2.8	2.8	2.1	2.0	2.5	2.4	2.0	1.9
7.	Clay Density(g/cm^3)	0.33	0.26	2.02	1.91	0.29	0.14	0.19	0.33	0.56	1.58	1.13	0.54
8.	Silt Density(g/L)	1.96	1.96	0.43	0.36	2.03	0.85	1.22	0.93	0.51	0.32	0.26	0.92
9.	Sand Density (g/L)	0.42	0.28	0.67	0.59	0.30	1.81	0.68	0.74	7.41	0.49	0.61	0.44
10.	Infiltration Rate	High	High	Low	Low	High	Very High	High	High	High	Low	Low	High
11.	Plasticity/ Stickiness	NP/ NS	NP/ NS	P/S	P/S	NP/ NS	NP/ NS	NP/ NS	NP/ NS	NP/ NS	P/S	P/S	NP/ NS
12.	Pore Size (%)	34.9	38.6	26.4	25.4	34.8	42.3	35.6	36.8	26.8	24.5	38.4	37.6

NOTE:
NP =Not Plastic
NS = Not Sticky
L = Loamy
S = Sand
C = Clay
RLM = Rumuolumini
EBP = Easter Bypass
ELK = Elekahia
ELE = Eleme Road
EWR = East West Road
C = Control

The bulk density of the soils ranged between 2.0gcm^3 in the Rumuoluemini road dumpsites to 3.12gcm^3 at the East West road. High bulk density (>1.5gcm^3) reduces water infiltration and plant root penetration resulting in increased surface water pollution (Ekundayo and Fagbami, 1996; Ekundayo, 2003). The infiltration rates were observed to be very high in other sites except for East West Road that was low. High infiltration rate in soils where refuse are disposed predisposes inhabitants to health risks because of underground water pollution, therefore these sites are not suitable for use as waste landfill sites. Infiltration rates less than 0.9cm/min and greater than 4.0cm/min are recommended as unsuitable for sanitary landfilling of wastes (Bonarius, 1975). Surface water that infiltrates the soil cover increases the rate of waste decomposition and eventually causes leachate to leave and create pollution problems (Ekundayo and Fodeke, 2000).

In the Niger Delta where seismic activity is prevalent, there is need to design structurally waste dumpsites with the selection of design dimensions and material properties such that the containment system can withstand probable natural and man-made hazards. The characteristics should take into account; dimensions of flow system ie, discharge divide to recharge divide, thickness of unsaturated zone, thickness of geologic layers in saturated zones and total thickness of saturated part of the flow system ie maximum depth of groundwater circulation, total porosity, field capacity and pore size distribution index of materials in the unsaturated zones. This is because there could be one or more components of the waste dumpsites that could fail given the occurrence of the hazardous event. Other factors of concern in utilizing wastes containment system is proximity to sensitive environments such as depth of water table below liner, distance to nearest natural groundwater discharge point and distance to groundwater recharge divide(Geraghty and Miller,1983; ICF, 1985).

Heavy Metal Concentration

Heavy metals are elements having some atomic weight between 63.54 and 200.59, and a specific gravity greater than 4 (Kennish, 1992). Although trace amount of some heavy metals are required by living organisms, any excess amount of these metals can be detrimental to the organisms (Berti and Jacobs, 1996). Metals also have a high affinity

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for humic acids, organic clays, and oxides coated with organic matter (Elliot *et al.*, 1986; Connel and Miller, 1984). The solubility of the metals in soils and groundwater is predominantly controlled by pH (Baker and Walker, 1990; McNeil and Waring, 1992; Henry, 2000), amount of metal and cation exchange capacity (Martinez and Motto, 2000), organic carbon content (Elliot *et al*., 1986) and the oxidation state of mineral components as well as the redox potential of the system (Connell and Miller, 1984).

The results of the heavy metal concentration in this study are presented in (Table 3). The soils can be considered highly polluted, since the concentration of the metals in all the stations/waste dumpsites were above permissible limits. The results show that the soils are acidic which favours the precipitation and mobilization of heavy metals (Bhattacharya *et al.,* 2002).The results are similar to reports by other workers (Helmissari *et al*., 1995; Ma and Rao, 1997; Bamgbose *et al*., 1999; Rockszyk and Szerszen, 1988; Kabala and Singh, 2001). The seepage of these heavy metals through the soils of the waste dump in Port Harcourt can infiltrate directly through unsaturated zones to cause severe pollution problems. Their presence in groundwater can cause a long term health risk to humans through the food chain (Erah *et al*., 2002; Ogbonna *et al*., 2006b). Although metals are essential, at higher concentrations they become toxic and present different problems to soil microorganisms, because they cause oxidative stress by formation of free radicals. They can also replace essential metals in pigments or enzymes, thus disrupting their function (Henry, 2000) and may render the land unsuitable for plant growth and destroy the biodiversity.

Table 3: Concentration of metals (mg/l) for soils in selected dumpsites around Port Harcourt municipality and Environs

Metals ($MgKg^{-1}$)	Permissible Limits Mgl^{-1}	EBP		EWR		ELK		RLM		ELE	
		30cm	1m	30cm	1m	30cm	1m	30cm	1m	30cm	1m
Pb	0.01	19.64	28.42	6.54	3.81	46.18	4.43	12.41	6.81	16.18	9.25
Cd	0.003	15.46	12.32	4.32	2.16	21.31	2.18	1.28	6.21	21.25	10.14
Cu	2.0	68.14	56.25	21.56	18.31	16.41	1.38	46.18	10.35	76.18	24.36
Zn	3.0	128.16	125.21	48.21	21.32	76.96	10.32	84.21	11.20	45.38	21.18
Fe	0.005	280.16	250.36	56.42	42.18	84.13	20.11	180.1	150.2	210.4	220.3

Permissible limits (WHO, 1998)

NOTE:
C = Control
RLM = Rumuolumeni Road
EBP = Easter Bypass
ELK = Elekahia
ELE = Eleme Road
EWR = East West Road

Therefore, the only remediation technologies are by destruction or transformation of the contaminant or by immobilization to reduce the bioavailability and separation of the contaminant from the bulk soil using the in-situ technique (Ghosh and Singh, 2005). This method is cost effective and can reduce impact on the ecosystem. This technique involves importing clean soil and mixing with the contaminated soil, thereby immobilizing the inorganic contaminants in the soil. This can be achieved by complexing the contaminants, or through increasing the soil pH by liming (Alloway and Jackson, 1991). Increased pH decreases the solubility of heavy metals in soils. Other physico-chemical techniques for soil remediation can render the land useless for plant growth as they remove all biological activities, including useful microbes such as nitrogen fixing bacteria, mycorrhiza, fungi as well as fauna in the process of decontamination (Burns *et al*., 1996).

* Corresponding author: David N. Ogbonna

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* Corresponding author: David N. Ogbonna