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Physicochemical Characteristics and Evaluation of Waste Landfill in Rumuagholu, Rivers State, Nigeria

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Abstract

This study was conducted to evaluate the physico-chemical characteristics and pollution aspect of wastes in Rumuagholu landfill and their health effects in two stations at Rumuagholu, Rivers State, Nigeria. Parameters including temperature, pH, electrical conductivity, salinity, nitrogen, potassium and phosphorus were examined following standard methods. Additionally, heavy metals (Cd, Ni, Zn, Cu, Pb, Cr, Mg, Al and Fe) were analyzed using atomic absorption spectroscopy (AAS). The findings indicated elevated levels of salinity and nitrogen surpassing permissible limits, and a slightly acidic pH in both stations. The statistical analysis shows the values were not significantly different ($P<0.05$). Heavy metal analysis identified Cd, Pb, and Cr exceeding permissible limits in both stations, suggesting a significant presence in the landfill. Continuous monitoring and potential upgrades to an engineered process are crucial to decrease the pollution problems in the future.

Keywords: Landfill site, heavy metals, Pollution, waste, Rumuagholu

INTRODUCTION

Urban areas are known for high levels of industrial activities which generate more pollutants and therefore are subject to the menace of resultant indiscriminate disposal of both domestic and industrial wastes. A typical example of such urban center is Port Harcourt city located in the heart of the oil-rich Niger Delta of Nigeria.

Physicochemical analysis involves the measurement of various physical properties of systems, most often phase transition temperatures and other thermal properties (thermal conductivity, heat capacity, thermal expansion), electrical properties (conductivity, dielectric permittivity). Also measured is density, viscosity, as well as the dependence of the rate of the transformations occurring in a system on the system's composition (Atkins and Paula, 2006).

Heavy metals are elements having atomic weights between 63.546 and 200.590 (Kennish, 1992), and a specific gravity greater than 4.0 (Connell *et al*., 1984). They exist in soil in colloidal, particulate and dissolved phases with their occurrence in water bodies being either of natural or anthropogenic origin (Adepoju-Bello *et al.*, 2009). They include aluminum, arsenic, beryllium, bismuth, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, strontium, thallium, tin, titanium, zinc, etc. (Garg, 2009).

A heavy metal is a member of a loosely-defined subset of elements that exhibit metallic properties (Duffus, 2002). Heavy metals are released into the environment by both natural and anthropogenic sources. The main natural sources of metals in soils are chemical weathering of minerals; the anthropogenic sources are associated mainly with industrial, agricultural, mining, land disposal of wastes, waste incineration, mechanic workshop and fuel filling station (Fernandez *et al*., 2012).

Heavy metals contamination of topsoil has been a major concern regarding their toxicity, persistence and non-degradability in the environment. Toxicity of these compounds has been reported extensively (Momodu and Anyakora, 2010; Anyakora *et al.*, 2011). They accumulate overtime in soils, which act as a sink from which these toxicants are released to the groundwater and plants and end up through the food chain thereby causing various toxicological effects. Effects of elevated concentrations of heavy metals to soil functions, soil microbial composition and microbial growth have long been reported under both field and laboratory condition (Tyler *et al*., 1989).

Some heavy metals are dangerous to health and environment (e.g. mercury, cadmium, lead, Chromium). Some may cause corrosion (e.g. zinc, lead). Some of these elements are actually necessary for humans in minute amount (cobalt, copper, chromium, manganese and nickel) while others are carcinogenic or toxic, affecting, among others, the central nervous system (manganese, mercury, lead, arsenic), the kidneys or liver (mercury, lead, cadmium, copper) or skin, bones, or teeth (nickel, cadmium, copper, chromium) (Zevenhoven and Kilpinen, 2001). Health effect of elevated levels of Zinc (Zn) are severe vomiting, diarrhoea, bloody urine, liver, kidney failure and anaemia (Fosmire, 1990), while excessive Lead (Pb) poison causes inhibition of haemoglobin synthesis, dysfunction in the kidneys, reproductive systems and cardiovascular system (Ferner, 2001). Other effects of Lead (Pb) poison are damage to gastro-intestinal system, mental retardation in children, abnormalities in fertility and pregnancy (Dara, 2000). Excess Cadmium (Cd) have been reported to bring about renal dysfunction, anaemia, hypertension, bone marrow disorder, cancer, kidney damage, bronchitis, liver and brain disorder (Dara, 2000), while, high concentration of Manganese (Mn) could result in kidney failure, liver and pancreases malfunctioning (Underwood, 1977). Human activities in urban areas largely contribute to the contamination of urban soils and this is a major health concern. Iwegbue *et al*. (2006) reported elevated concentration of Cd, Cr, Cu, Pb, Ni, and Zn in an automobile mechanic workshop soil while Dauda and Odoh (2012) in their study revealed the high degree of contamination of Pb, Cd and Zn in soil from fuel filling stations in Benue state, Nigeria.

In addition, Ubwa *et al*. (2013) reported high levels of Cd, Zn, Ni, Cr and Pb from soil around the Gboko Abattoir in Benue state, Nigeria. Unlike organic pollutants, heavy metals do not decay and thus pose a different kind of challenge for remediation (Baby *et al.*, 2010). One of the largest problems associated with the persistence of heavy metals is the potential for bioaccumulation and bio-magnification causing heavier exposure for some organisms than is present in the environment alone (Beetseh and Abrahams, 2013). The extent of human impact is now so pervasive and profound, that there is need to investigate the levels of heavy metals in soils from different anthropogenic sites.

Landfill practice is the disposal of solid wastes by infilling depressions on land. The depressions into which solid wastes are often dumped include valleys (abandoned) sites of quarries, excavations, or sometimes a selected portion within the residential and commercial areas in many urban settlements where the capacity to collect, process, dispose of, or re-use solid waste in a cost-efficient, safe manner is often limited. The practice of landfill system as a method of waste disposal in many developing countries is usually far from standard recommendations (Mull, 2005; Adewole, 2009; Eludoyin and Oyeku, 2010). A standardized landfill system involves carefully selected location, and is usually constructed and maintained by means of engineering techniques, ensuring minimized pollution of air, water and soil and risks to man and animals. It involves placing waste in lined pit or a mound (sanitary landfills) with appropriate means of leachate and landfill gas control (Alloyway and Ayres, 1997; Eludoyin and Oyeku, 2010). Land filling of municipal solid waste is a common waste management practice and one of the cheapest methods for organized waste management in many parts of the world (El-Fadel *et al*., 1997; Jhama and Singh, 2009; Longe and Balogun, 2010). Increasing urbanization results in increased generation of waste materials and landfills become the most convenient way of disposal. Most of these landfills are mere 'holes in the ground' do not qualify as sanitary means of solid waste disposal. According to Papadopoulou *et al*. (2007), as the natural environment can no longer digest the produced wastes, the development of solid waste management has contributed to their automated collection, treatment and disposal. One of the most common waste disposal methods is landfilling, a controlled method of disposing solid wastes on land with the dual purpose of eliminating public health and environmental hazards and minimizing nuisances without contaminating surface or subsurface water resource.

This study was carried out to determine the physico-chemical characteristics and evaluation of waste landfill at Rumuagholu, Rivers State, Nigeria.

MATERIALS AND METHODS

Study Area: This study was carried out in Obio/Akpor Local Government Area of Rivers State, Nigeria. Two stations were sampled and were adjacent to each other. Station 1 has a coordinate of 4°53'12"N, 6°58'40"E and station 2 was located 200m away with coordinate of 4°53'36"N, 6°59'0"E.

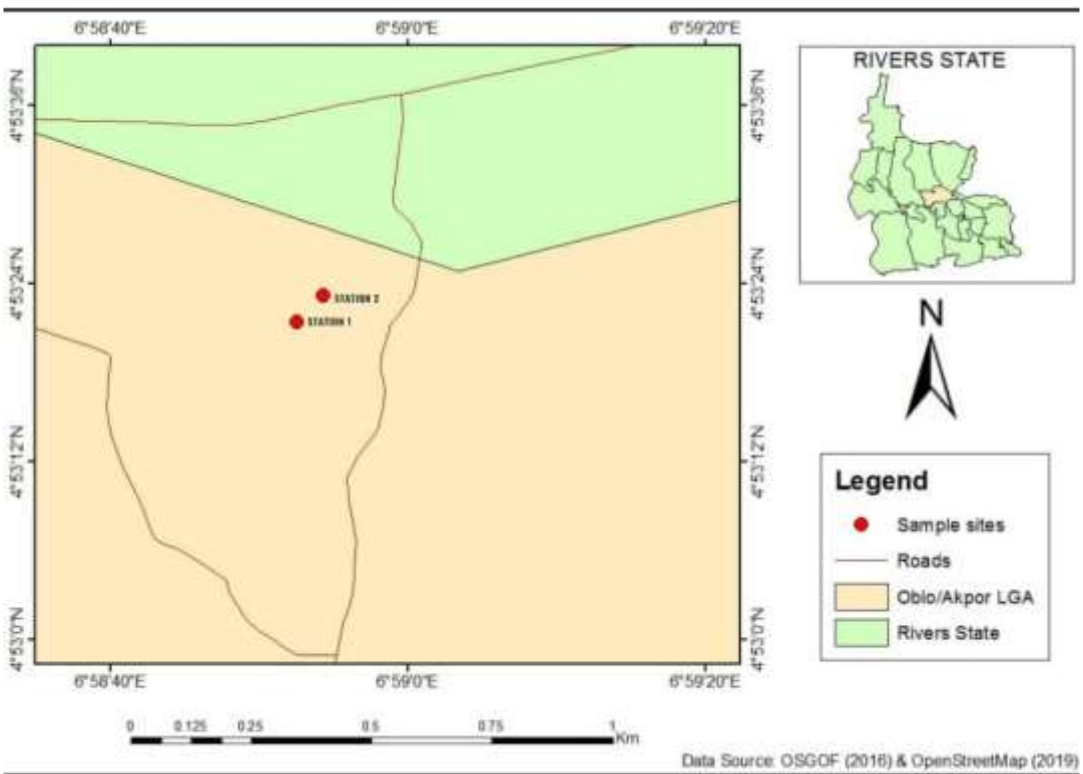

Fig. 1: Map showing sample stations at Rumuagholu landfill

Sample collection: Sampling was collected from December, 2020 to February, 2021. A systematic sampling technique was employed for field sampling. Soil samples were collected from a depth of 0 to 15cm from the surface using a soil auger as described by Allen *et al.* (1974). From each station, three soil samples were taken using soil auger and were pulled together to form a composite of each individual sample. They were placed in clean dried polyethene bags, labelled and transported to the Soil Science laboratory, Department of Crop/Soil Science, Rivers

State University for analysis (Abdullhami *et al*., 2018).

Determination of Physico-chemical characteristics of soil: The soil colour was determined using Munsell oil colour chart. The pH was determined using calibrated pH meter (Horiba pH meter D-51). The temperature was measured using earth thermometer (CS230 temperature profiler) and Electrical conductivity (EC) was measured using EC metre. Soil texture was measured using hydrometric method and salinity measured using hand-held salinity metre.

Determination of heavy metals in soil: The digestion procedure used for determining heavy metals was as recommended by Association of Official Analytical Chemists (AOAC) described by Omojola (1993). All metals were determined with a Thermo Scientific ICE 3000 series atomic absorption spectrophotometer.

Data analysis: The data collected were statistically analyzed using descriptive statistics (mean, standard deviation and ranges) and inferential (ANOVA) statistics. $P<0.05$ was considered to indicate statistical significance.

RESULTS AND DISCUSSION

The pH value of the landfill was observed in the range of 4.50 – 5.03 which indicated that the landfill soil was acidic and below permissible limit (WHO, 2007) (Table 1). This pH range is consistent with the results of Benton (2002) who observed a strongly acidic landfill. The pH range observed in this study is also lower than the results of Osakwe (2014). The acidity of the soil investigated could be due to the presence of non-biodegradable wastes such as batteries, fertilizers and pesticide containers. The relatively low value of electrical conductivity (248.00 – 263.33μS/cm) (Table 1) was below permissible limit (WHO, 2007) and indicates the minute presence of dissolved inorganic materials in the samples.

The value of temperature (26.27 – 25.70ºC) was below permissible limit (WHO, 2007) and shows an increase in the microbial activity and increase in the decomposition of organic matter in the soil. The value of salinity (743.33 – 758.33‰) was above permissible limit (WHO, 2007) and indicates a relatively high salt level in the soil which can hinder water absorption, inducing physiological drought in the vegetation. All of these are capable of altering the environmental ambience of the soil characteristics of the study area. The presence of nitrogen (0.08mg/kg) in the soil samples indicates that fertilizer and pesticide containers are dumped at the landfill (Downie, 1999) and was above permissible limit (WHO, 2007). The concentration of phosphorous (0.01 mg/kg) in the soil shows that fertilizer containers were dumped at the landfill. The value of potassium (0.00 – 0.02mg/kg) in the soil shows that fertilizer and pesticide containers were dumped at the landfill (Downie, 1999).

The results of this study revealed varying concentrations of heavy metals though low in concentration. This could be attributed to the ubiquitous nature of heavy metals in the environment coupled with the influence of the anthropogenic activities such as waste incineration in the study areas investigated. This persistence in the occurrence of heavy metals could be due to the fact that heavy metals are non-biodegradable in nature, thermal stability and potential to accumulate to toxic levels, even at low concentrations which is consistent with the studies of Adepoju-Bello *et al.* (2009). The presence of Fe (0.01 mg/kg) (Table 2) in the soil sample indicates that tins and cans are dumped in the landfill (Martin, 2004) and the levels were below permissible limit (WHO, 2007). The concentration of Zn (0.09mg/kg in station 1 and 0.08mg/kg in station 2) in this study shows that the landfill receives wastes from batteries (Olivetti *et al.*, 2011) the levels were below permissible limit (WHO, 2007). The presence of Pb in the soil samples are in the range of 0.07mg/kg – 0.08mg/kg and were above permissible limit (WHO, 2007). The possible source of Pb may be batteries disposed at the landfill which indicates toxicity to all forms of life at this level. The high level of Cd in the soil samples (0.03mg/kg) may have been as a result of tyres and Nickel-Cadmium batteries as well as plastics disposed at the landfill (Shakya *et al*. 2006) and the levels were above permissible limit (WHO, 2007). The concentration of Cr (0.02mg/kg) shows that the possible source may be metal steel disposed at the landfill and the concentrations were above permissible limit (WHO, 2007). The presence of Ni in the soil sample may have been as a result of spent batteries, wire, electrical parts in the landfill (Al-Thyabat *et al.*, 2013) and the levels were below permissible limit (WHO, 2007). The concentration of Cu (0.01mg/kg) in the soil shows that the landfill receives wastes from tins, cans and copper cookware and the concentrations were below permissible limit (WHO, 2007). This is consistent with the results of Dauda and Odoh (2012) who observed a dumpsite with high concentrations of Cr, Cd and Zn.

Table 1: Mean Physico-chemical Parameters of waste at Rumuagholu landfill, Port Harcourt

Physico-chemical Parameters	Station 1	Station 2	WHO (2007)
Temperature (^{O}C)	26.27±0.64[a]	25.70±0.61[a]	25 – 30
pH	4.50±0.26[a]	5.03±0.50[a]	6.5 - 8.5
Electrical Conductivity (µS/cm)	248.00±16.09[a]	263.33±2.11[a]	1000
Salinity (‰)	743.33±25.17[a]	758.33±7.64[a]	300-700

Means with similar super letters in the same row shows no significant difference
Source: World Health Organization (2007)

Table 2: Mean Concentration of Heavy Metals of Waste at Rumuagholu landfill, Port Harcourt

Metals (mg/kg)	Station 1	Station 2	WHO (2007)
Lead (Pb)	0.07±0.01 [a]	0.08±0.01 [a]	0.015
Chromium (Cr)	0.02±0.01 [a]	0.02±0.00 [a]	0.1
Magnesium (Mg)	0.00±0.00	0.00±0.00 [a]	150
Aluminum (Al)	0.00±0.00 [ab]	0.00±0.00[ab]	0.1
Iron (Fe)	0.01±0.00 [ab]	0.01±0.00 [ab]	0.03
Cadmium (Cd)	0.03±0.01 [a]	0.03±0.01[a]	0.003
Nitrogen (N)	0.08±0.01 [a]	0.08±0.01[a]	0.05
Potassium (K)	0.00±0.00	0.02±0.01[a]	
Zinc (Zn)	0.09±0.01 [ab]	0.08±0.02[ab]	1.5
Copper (Cu)	0.01±0.00 [ab]	0.01±0.00[ab]	0.5
Nickel (Ni)	0.01±0.00 [a]	0.02±0.00 [a]	
Phosphorus (P)	0.01±0.00 [a]	0.01±0.00 [a]	

Means with similar super letters in the same row shows no significant difference while mean with non-similar super letters in the same row shows significant difference ($P<0.05$)
Source: World Health Organization (2007)

CONCLUSION

This study has shown that the concentration of selected metals in the landfill were below permissible limit (Zn, Cu, Mg, Al, Fe) except for N, Pb, Cr and Cd which revealed values above permissible limit (WHO, 2007) in both stations. Statistically, the values were not significantly different (P<0.05).

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