ECOTOXICOLOGY AND ENVIRONMENTAL HEALTH

Assessment of the Physicochemical and Heavy Metals Concentration of Municipal Dumpsite in Nyanya District, Abuja, Nigeria

[1*]Uchendu, J. I., [2]Abu, G. O. and [2]Abah, A.

[1]Institute of Natural Resources and Environmental Management, University of Port Harcourt, Nigeria
[2]Department of Animal and Environmental Biology, University of Port Harcourt, Port Harcourt, Nigeria

*Correspondent: **Uchendu, J. I** (uchendujude@gmail.com)

Abstract

Due to poor landfill management and leachate contamination prevention, landfills or dumpsites remain among the most common human-induced contaminated sites in many developing countries, including Nigeria. The study examines the assessment of the physicochemical (pH, total cation-exchange capacity (TCEC), ion of Potassium (K+), Calcium (Ca+), Sodium (Na+) and Magnesium (Mg2+)) and heavy metals (lead (Pb), Cadmium (Cd), Copper (Cu), Zinc (Zn) and Manganese (Mn)) concentration of municipal dumpsite in Nyanya district, Abuja, Nigeria. The pH values of the soil samples indicate that they are acidic, trending as SP1 and SP5 (6.9) > SP2 (6.79) > SP3 (5.98) > SP4 (5.56) > SP6 (4.1). The Pb reported across the study area was above the WHO limit and trended as SP1 (2.63) > SP4 (2.6) > SP5 (0.753) > SP4 (0.752) > SP6 (0.65) > SP3 (0.628). The Cadmium (Cd) concentration ranged from 0.246 mg/L at SP6 to 0.292 mg/L at SP1 with a mean concentration of 0.27, and all concentrations exceeded the WHO allowable limit of 0.001. The Copper (Cu) concentration ranged from 0.044 mg/L at SP3 to 0.57 mg/L at SP2 with a mean concentration of 0.40, and all concentrations were within the WHO allowable limit of 1.5. The study outcome indicated soil pollution with Cd and Pb due to dumpsite activities. Therefore, there is a need for environmental management practices and effective waste management systems around the dump site.

Keywords: Heavy Metals, Soil Pollution, Environmental Pollution, Dumpsites, Abuja

Introduction

Recently, the amount of waste, particularly municipal solid waste (MSW), has been rapidly growing in many countries worldwide due to the increasing standard of living or because of industrial and business development (Stanczyk-Mazanek et al., 2019; Vaverkoa et al., 2020). One of the most widespread methods used for the final disposal of MSW is landfilling (Stanczyk-Mazanek et al., 2019). The global trend in landfilling applies to big industrial cities with thousands of tons of waste disposed in daily landfills and to rural areas where similar amounts of waste are landfilled each year (Vaverkoa et al., 2020).

In Nigeria, the most used method of waste disposal is through the landfill system due to its simplicity and low cost of maintenance (Gonzalez-Valencia et al., 2016); however, this method quickly causes the release of toxic substances into the environment (Afolabi et al., 2023). Landfills or dumpsites remain among the most common human-induced contaminated sites in many developing countries, including Nigeria; hence, toxic substances (such as carcinogenic heavy metals) are closer to the human environment than ever (Afolabi et al., 2023). This is generally due to poor landfill management and leachate contamination prevention, and some are cited as close to the living environment, which is of significant concern to public health (Ogbuechi et al., 2022).

The problem of environmental pollution stemming from indiscriminate waste disposal via open waste dumping has affected the human race over time. In developing countries like Nigeria, most cities dispose of their waste in open dumpsites at unsuitable locations without a proper waste management technique (Oluwatuyi et al., 2020). Consequently, these wastes build into pollutants with long-term adverse effects on the environment, with soil and groundwater being the major sources of contaminants (Oluwatuyi et al., 2019). Disposal of waste in landfills is integral to waste management strategies worldwide. Soils are usually considered the ultimate sink for heavy metals discharged into the environment (Odukoya, 2015). Therefore, the environmental problem of soil pollution by heavy metals has received increasing attention in the last few decades in developing and developed countries worldwide (Odukoya, 2015).

Reduced soil quality due to heavy metals contamination poses a risk to human health and the environment due to their toxicity, even at low concentrations, environmental persistence, and bioaccumulation capacity (Setala et al., 2017; Olagunju et al., 2020; Pecina et al., 2021). Heavy metals can be transferred into the human body through skin contact (derma absorption), consumption of contaminated food (ingestion), and breathing (inhalation) (Mavakala et al., 2022). Several studies have been conducted to estimate the magnitude of heavy metals in the environment and their potential risk to human health (Hassaan et al., 2016; Huang et al., 2020; Ohiagu et al., 2020; Alsafran et al., 2021; Afolabi et al., 2023). Management of environmental pollutants can be initiated through regular quantification of the environmental load of the contaminants (Olagunju et al., 2020). According to Tanee and Eshalomi (2015), the Concentration of heavy metals in the soil is a vital assessment to ascertain the risk level of the environmental medium and its status. Therefore, quantifying the heavy metals in the soil around and within the anthropogenically impacted area is essential and can help provide appropriate remedial measures (Afolagboye et al., 2020; Afolabi & Adesope, 2022). The study assesses the physicochemical and heavy metals concentration of municipal dumpsite in Nyanya district, Abuja, Nigeria.

Materials and Method

Study Area

Abuja is located in the middle of the country, falling within latitude 7^{o} 25‟ north and 9^{o} 20‟ north of the equator and longitude 5^{o} 45" and 7^{o} 39" (Figure 3.1). It has a land area of 8,000 km^2, which is two and a half times the size of Lagos. It is bounded on the north by Kaduna State, on the west by Niger State, on the East and South-East by Nasarawa State, and on the South-West by Kogi State, respectively. The FCT experiences three weather conditions annually: a warm, humid rainy season, which begins in April and ends in October, and a blistering dry season when temperatures can soar as high as 40. In between these two conditions, there is a brief interlude of harmattan, occasioned by the northeast trade wind, with the main feature of dust haze, intensified coldness and dryness. The high altitudes and the undulating terrain of the territory act as a moderating influence on its weather.

Data (Sample) Collection

Soil samples (6-composite samples) were collected at six designated points within the dumpsite area with a 20m distance between each point for soil sample collection. At each point, a radius of about 10 m was made around each point, and 5 random soil samples were collected around the radius into a collection pan at a depth of about 0-15 cm and mixed to form a composite sample for the designated point. The process was repeated for each point. The collected samples were instantly wrapped in foil papers (soil), appropriately labelled, and taken to the laboratory (Akwa Ibom State Ministry of Science and Technology Laboratory, Uyo) for analysis.

Data Analysis

The collected samples were analysed for relevant physicochemical and heavy metals parameters according to internationally accepted procedures and standard methods (American Public Health Association standard- APHA, 2012. The laboratory procedure used the pH meter (Orion Digital pH/ millivolt meter 611). The major ions were analysed colourimetrically based on the APHA4500- E method using a UV/Visible Spectrophotometer. Heavy metals were determined following the ASTMD 4691 method by Atomic Absorption Spectrophotometry (Perkin Elmer Analyst 400). The laboratory analysis procedure and quality control were similar to those described by (Afolabi et al., 2023). For quality assurance, all analyses were done in triplicates, and the mean was estimated for accuracy and precision. All instruments were decontaminated in HCl solution and properly washed while analyses were subjected to a high-quality reagent from Akwa Ibom State Ministry of Science and Technology Laboratory, Uyo.

Result and Discussion

The soil's physicochemical and heavy metals properties from a nearby dumpsite engaged by the communities around the study area were assessed, and the outcome was presented in Table 1. From the analysis, the pH value ranged from 4.1 at SP6 to 6.9 at SPI, with a mean value of 6.03, which was below the WHO standard of 8.5. The pH values of the soil samples indicate that they are acidic, trending as SP1 and SP5 (6.9) > SP2 (6.79) > SP3 (5.98) > SP4 (5.56) > SP6 (4.1). The reported pH indicated polluted soil, and the outcome was similar to those reported by Afolabi and Adesope (2022) for contaminated soil. The study corroborated with that of Udon and Chukwu (2014), where the pH of the soil studied became acidic (5.6) due to human activity impact. Chukwujindu (2011) reported a similar outcome of pH-acidity (5.41) in the study conducted on crude oil-impacted soil. The sandy attribute of the soil showed 50% sandy at SP5 to 65.3% at SP6 with a mean value of 58.18; the silt attribute of the soil showed 21.22% at SP1 and 38.94% at SP4 with a mean value of 28.53 while the clay attribute showed 11.38% at SP4 to 18.44% at SP5 with a mean value of 14.63. The Potassium ion (K^+) of the soil ranged from 0.25 cmol/kg^{-2} at SP4 to 0.7 cmol/kg^{-2} at SP3 with a mean value of 0.50, the Calcium ion (Ca^+) of the soil ranged from 1.32 cmol/kg^{-2} at SP2 to 2.25 cmol/kg^{-2} at SP4 with mean value of 1.86, the Sodium ion (Na^+) of the soil ranged from 0.06 cmol/kg^{-2} at SP2 to 0.75 cmol/kg^{-2} at SP3 with mean value of 0.21 while the Magnesium ion (Mg^{2+}) of the soil ranged from 0.18 cmol/kg^{-2} at SP5 to 0.29 cmol/kg^{-2} at SP6 with mean value of 0.23. The soil's total cation-exchange capacity (TCEC) ranged from 3.52 cmol/kg−2 at SP2 to 11.74 cmol/kg−2 at SP5, with a mean value of 5.42. Among the heavy metals, the lead (Pb) concentration ranged from 0.628 mg/L at SP3 to 2.63 mg/L at SP1 with a mean concentration of 1.34, and all concentrations exceeded the WHO allowable limit of 0.01. The Pb reported across the study area was above the WHO limit and trended as SP1 (2.63) > SP4 (2.6) > SP5 (0.753) > SP4 (0.752) > SP6 (0.65) > SP3 (0.628). The outcome was similar to those reported by Namla et al. (2022) for similar locations; however, the reported concentration in the present study was lower than those reported by Namla et al. (2022). A similar outcome was reported by Udoetok et al. (2011), where the Pb at the spilt site exceeded the allowable limit. The Pb can find its way into the human system through bioaccumulation in plants and animals, and Pb poisoning in humans damages the kidneys, liver, heart, brain, skeleton, and nervous system, which chronic exposure to low levels of Pb capable of limiting the intelligence capacity in children (Kinuthia, et al., 2022). The Cadmium (Cd) concentration ranged from 0.246 mg/L at SP6 to 0.292 mg/L at SP1 with a mean concentration of 0.27, and all concentrations exceeded the WHO allowable limit of 0.001. The Cd reported for the study was above the WHO limit and trended as SPI (0.292) > SP5 (0.291) > SP4 (0.27) > SP2 (0.25) > SP3 (0.248) > SP6 (0.246). The study conducted by Afolabi and Adesope (2022) reported a similar outcome, which reported a concentration lower than the present study. Accordingly, Cd can impede a plant's growth and development and is a vital contaminant due to its high toxicity level. The Copper (Cu) concentration ranged from 0.044 mg/L at SP3 to 0.57 mg/L at SP2 with a mean concentration of 0.40, and all concentrations were within the WHO allowable limit of 1.5. The reported Cu for the study was within the WHO limit across the sampled points and trended as SP2 (0.57) > SP5 (0.52) > SP6 (0.49) > SP4 (0.48) > SP1 (0.28) > SP3 (0.044). the outcome was similar to the outcome of the study conducted by Namla et al. (2022).

Table 1: Physicochemical and Heavy Metal analysis of the soil (Gosa Dumpsite)

Parameter	SP 1	SP 2	SP 3	SP 4	SP 5	SP 6	Mean	WHO
pH	6.9	6.79	5.98	5.56	6.9	4.1	6.04	8.5
Sand (%)	63.50	55.40	64.22	50.64	50.00	65.30	58.18	
Silt (%)	21.22	34.08	21.95	38.94	32.57	22.43	28.53	
Clay (%)	15.30	12.54	15.80	11.38	18.44	14.30	14.63	
K^+ (cmol/kg^{-2})	0.55	0.52	0.7	0.25	0.52	0.48	0.50	
Ca^{2+} (cmol/kg^{-2})	2.1	1.32	1.84	2.25	1.86	1.8	1.86	
Na^+ (cmol/kg^{-2})	0.08	0.06	0.75	0.14	0.06	0.18	0.21	
Mg^{2+} (cmol/kg^{-2})	0.26	0.21	0.23	0.21	0.18	0.29	0.23	
Total CEC (cmol/kg^{-2})	4.36	3.52	4.98	4.36	11.74	3.53	5.42	
Pb (mg/kg)	2.63	0.753	0.628	2.6	0.752	0.65	1.34	0.01
Cd (mg/kg)	0.292	0.25	0.248	0.27	0.291	0.246	0.27	0.001
Cu (mg/kg)	0.28	0.57	0.044	0.48	0.52	0.49	0.40	1.5
Zn (mg/kg)	ND	ND	ND	ND	ND	ND	-	
Mn(mg/L)	ND	ND	ND	ND	ND	ND	-	

Note: Sampling Point (SP), Not Detected (ND)

Conclusion

Environmental pollution due to anthropogenic activities remains a common issue in the 21st century. Soil pollution due to landfill or dumpsite activities remains among the leading routes to environmental pollution in recent times. Due to landfill activities, the study considered the physicochemical and heavy metal concentration of municipal dumpsite, and the outcome indicated soil pollution with Cd and Pb, which are capable of causing public health concerns. Future studies could consider the environmental assessment of the sounding groundwater and potential risk to human health. Overall, there is a need for environmental management practices and effective waste management systems around the dumpsite.

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