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Assessment of Heavy Metal Concentrations in soil at Solid Waste dump at Aluu Road: Measures for Health Impact and Environmental Sustainability

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Abstract: *Heavy metal concentrations in soil collected at evacuated solid waste dump at Aluu were analyzed. The results of the analysis show that some of the soils are contaminated with toxic heavy metals and they were compared with food and agricultural organization (FAO) in connection with World Health organization Standard (WHO), FAO / WHO standard for heavy metals concentrations in the soil. The result of the analyses shows that chromium(Cr), nickel(Ni), Zinc(Zn), iron(Fe), Arsenic(As) are below the threshold values recommended by FAO/WHO standards while in three samples, cadmium(Cd) concentrations is higher than the recommended value in soil, cadmium have a range of 0.5-4.65mg/kg. Copper(Cu) is more than the permissible value in five samples. Copper ranges between 5-154mg/kg. A soil sample has excess lead(Pb) concentrations of 119.50mg/kg. Manganese(Mn) is higher than recommended value in all the samples. The implication is that the excess heavy metal in the soil can incorporate into crops and affect humans through food chain and this can result to health issues. Heavy metal pollutants can accumulate in surrounding environments thereby degrading and threatening the soil quality. The emission of greenhouse gases from the anaerobic decomposition of organic waste can contributes to air pollution and climate change. People living in close proximity to these dumpsites and waste scavengers can be directly or indirectly have some health risk due to prolonged exposure to toxic fumes and particulate matter.*

Keywords: *Solid waste dump, Heavy Metal, Health impact, Environmental Sustainability*

I. Introduction

Solid waste dump/refuse sites are areas for the disposal of household, industrial, agricultural, and sometimes hazardous waste. One of the major concerns associated with solid waste dumps is the presence and accumulation of heavy metals; these heavy metals originate from various sources such as batteries, electronics, paints, metal scraps, fertilizers, pesticides, medical waste, and some household products (Heather et al, 2012; Mohammad et al, 2021; Sebastian et al., 2014, Sahil and Lolita, 2022;). Heavy metals can leach into the soil and groundwater over time. The liquid that drains or 'leaches' from a landfill often contains dissolved heavy metals, making it a serious pollutant if not properly treated (Dorthe and Thomas, 1999; Muhammad et al. 2025, Onwualu-John and Uzoegbu, 2022) . These metals infiltrate the soil, they disrupt soil chemistry and reduce its fertility (Atoosa et al., 2024; Philomene and Komariah, 2021; Alengebawy et al., 2021). Plants growing on contaminated soil may absorb these metals, leading to bioaccumulation. Heavy Metals do not only affect plant health but also introduce toxins into the crops, endangering animals and humans that consume the crops. Heavy metals can seep through soil layers and pollute underground aquifers. The consumption of heavy metal-contaminated water and food can lead to severe health issues. Waste pickers (Scavengers), children and women, are expose to hazardous conditions in open dumpsites, they are expose to infectious materials, and toxic substances especially when they are not with protective device. There is also risk of injuries, infectious diseases, respiratory diseases, cancer, kidney damage, neurological disorders, immune deficiency, and deformation in children and eventually, death (Mahdi et al., 2021; Monisha et al., 2014; Xiang et al. 2016;

Solid waste dump contributes to climate change, the anaerobic decomposition of organic materials in waste dumps produces methane (CH_4), a greenhouse gas with a global warming potential (Mousania et al., 2014). The burning of waste materials releases black carbon (soot) in the environment which accelerates the warming of the atmosphere. The cumulative effect of these emissions contributes to rising global temperatures, thereby altering the weather patterns, and climatic condition which also affects the food security. This research aims to assess the heavy metals concentrations in a solid waste dump at Aluu.

II. Geologic setting

The study area (Some aspects of Aluu) is within the Niger Delta Basin Nigeria. The basin has three geologic Formations which are the Benin, Agbada and Akata Formations.

Benin Formation

The Benin Formation is a prominent geological unit found in the southern part of Nigeria, particularly within the Niger Delta Basin. It is the uppermost of the three main lithostratigraphic units in the Delta Basin; it overlies the Agbada and Akata Formations. The Benin Formation is of the Miocene to Recent period and is composed of coarse-grained sandstones, gravel, and some clay beds.

Benin Formation is highly porous and permeable (Akujieze and Oteze, 2006). The permeable and porous nature of the Formation makes it an important aquifer for groundwater. The sands are mostly continental in origin and deposited in a fluvial to deltaic environment (Osokpor and Maju-Oyovwikowhe, 2021). The thickness of the Benin Formation is about 2,000 meters in some areas, in some parts of the Niger Delta, the Benin Formation serves as the main source of groundwater through boreholes and wells.

Agbada Formation

The Agbada Formation represents the middle unit of the delta's tripartite lithostratigraphy. It overlies by Benin Formation and underlie by Akata Formation. The Agbada Formation is of Eocene to Pliocene age and is the stratigraphic unit for hydrocarbon (oil and gas) production in Nigeria (Tuttle et al 1999).

It is composed of sequence of sandstones, siltstones, and shales, it shows deposition in a transitional environment which range from delta-front to fluvio-marine settings. The sands are typically well-sorted and serve as reservoir rocks (Memuduaghan et al., 2021). The interbedded shales of the Formation function as source and seal rocks. The thickness of the Agbada Formation exceed 3,000 meters in some places

Akata Formation

The Akata Formation is the lowermost stratigraphic unit of the Niger Delta Basin in southern Nigeria. It lies beneath the Agbada and Benin Formations and plays a crucial role in the geological framework of the delta. The Akata Formation is predominantly composed of dark grey to black, organic-rich shales, with occasional interbeds of siltstone and sandstone. It was deposited in a pro-delta to deep marine environment (Diab et al 2023).

Akata Formation is of Paleocene to Recent age and can be several thousand meters thick, in some parts of the delta which occurs through burial, heat, and pressure over geological time,

Due to high clay content and low permeability of the Akata Formation, the Formation acts as a source rock and a seal rock, trapping hydrocarbons in structural and stratigraphic traps (Adedapo et al.,2014; Ilevbare and Omorogieva, 2020).

Figure 1: Map of the study area with sampling points in red
(Modified after Google map of 23-4-2025.12:10pm)

Sampling Techniques and Methodology

Soil samples were collected for laboratory analysis, using standardized procedures to ensure quality assurance. The soil samples were collected at heavy solid waste dump sites at Aluu environ. Twelve samples were analyzed for heavy metals and the waste dump is categorized into Waste dump A, B and C. They are evacuated waste dumps. Waste dump A is in proximity to university environment, market and automobile workshop, waste dump B is far from university environment but in proximity with residential houses and market, while Waste dump C is far from university environment and does not have any market around, it is very close to industries and also it serves as a receptor of wastes from diverse areas of the city.

Sample Collection Procedure

The dump sites were divided into sampling points using a grid sampling method,
The top soil was cleared to be free from vegetation, debris, or top waste.
Samples were collected from the top 0-20cm deep with a trowel.

Labeling and Storage

Each sample was labeled with date, location (GPS coordinates), depth, and sample identity. The samples were Store in airtight containers and kept cool during transport to the lab to prevent chemical changes

III. Results

Sample	Cd(mg/kg)	Cr(mg/kg)	Cu(mg/kg)	Pb(mg/kg)	Ni(mg/kg)	Zn(mg/kg)	Fe(mg/kg)	As(mg/kg)	Mn(mg/kg)
WA1	4.65	15.50	50.45	7.10	2.95	26.60	-	-	-
WA2	4.50	16.30	6.05	5.30	3.00	23.95	-	-	-
WA3	2.35	17.80	30.00	119.50	7.00	169.70	9234.00	0.40	106.85
WA4	1.45	0.45	5.90	2.80	9.35	60.55	8910.30	nil	56.55
WB1	2.85	5.90	70.00	47.40	10.50	347.00	6358.75	0.45	28.75
WB2	1.45	11.60	28.65	10.60	38.75	117.20	9280.50	0.50	244.65
WB3/OASI (Ojeh and Onwualu-John,2024)	5.20	0.80	138.00	2.30	NIL	498.00	-	-	-
WB4/OAS2 (Ojeh and Onwualu-John,2024)	NIL	0.90	154.00	NIL	8.30	97.00	-	-	-
WC1	-	58.00	26.00	32.00	24.00	32,00	-	-	-
WC2	-	38.00	60.00	73.00	2.00	19.00	-	-	-
WC 3	0.50	12.90	8.90	5.95	7.70	37.55	10681.10	0.50	73.75
WC4	3.05	9.20	26.10	25.55	12.20	180.35	7903.35	0.55	168.55
Range	0.5-4.65	0.4-58	5-154	2-119.50	2-38.8	23-498	6358-10681	0.4-0.5	73-244
FAO/WHO standard	3mk/kg	100mg/kg	36mg/kg	85mg/kg	50mg/kg	300mg/kg	10,000-50,000mg/kg	10-20mg/kg	0.4mg/kg

IV. Discussions

Waste Dump A: University Environment and Close to Market

Most of the wastes in dump site A are probably from academic and administrative buildings, hostels, laboratories, and cafeterias as well as market. It is an evacuated heavy solid waste dump. They are characterized by Paper and plastics (Notes, books, packaging, plastic bottles, and wrappers); E-waste: (Old electronics, printers, and lab instruments); Laboratory waste (potentially hazardous chemicals and broken glassware); Organic waste (Food leftovers, fruits, vegetables, plant materials) which emanate from market, hostels, offices and cafeterias.

Plate 1 a and b: showing the evacuated dump site in proximity with university and market

Waste Dump B: Residential Area + Close to Farmland

Waste dump B is found within or beside a neighborhood. It is in proximity to agricultural fields. It is composed of crop residues, animal droppings, and pesticide containers. Food scraps, garden clippings, crop waste, domestic packaging, Batteries, and cleaning chemicals are the dominant waste at the site Plate 2a and b: shows the evacuated heavy dump site in proximity to residential house and farm land.

Waste Dump C – Industrial Area + Receptor Site

Dump C is prone to heavy metal accumulation due to industrial origin and being a receptor site for all kinds of waste. It is an industrial zone. It is used as a centralized waste receptor site. The waste comprise of Metal plating, dyeing, smelting, chemical industries, lubricants, oils, batteries, paints, Metals, solvents, heavy-duty plastics, used oils, machinery parts, Household garbage, market waste, construction debris, Chemicals, toxic substances, and some organic waste. The solid waste dump has the tendency of emitting toxic leachates which can contaminate the soil and the groundwater; it can cause air pollution, and become a super spreader site for diseases if not treated.

Heavy Metals contents:

Cadmium: Three samples (WA1, WA 2 and WB3) exceed the food and agricultural organization (FAO) in connection with World Health organization Standard (WHO) for cadmium concentration in the soil. It also exceeds the National Environmental Standard and Regulations enforcement Agency (NESREA). The Elevated concentrations of the cadmium in the soil could be due to disposal of industrial waste from the automobile workshop around WA waste dump.

The similarity between waste dump A and B is that both of them are close to market respectively, Both waste dumps (A and B) probably contained cadmium enriched materials from the market waste. Cadmium toxicity in the body is associated with kidney damage, bone demineralization and cancer (Hernández-Cruz et al., 2022, Liang-Jun and Daniel (2023)

Chromium, Nickel, Iron, Arsenic, concentrations in all the samples is below the FAO/WHO standard for soil, this is not an issue because if there is need for any of the metals to increase, probably for agriculture, it can be boosted through other measures.

Copper: five soil samples (WA1, WB1, WB3, WB4, WC2) are high in copper when compared with FAO/WHO standard. Copper toxicity in soil causes stunted growth in plants, chlorosis, nutrient deficiencies, and even plant death (Anayat et al., 2021, Shaw et al. 2020) .

Lead: one sample WA-3 is very high in lead (Pb) when compared with the FAO/WHO standard. Lead is non-biodegradable, no amount of lead(Pb) is permissible in the body, it can result to brain damage, kidney and liver damage, cardiovascular issue, neurological effect, cancer(Lisa et al,2014, Collins et al, 2022). Environmental lead toxicity is a community/public health emergency.

Zinc: WB1 and WB3 have very high content of zinc when compared with FAO/WHO standard. Zinc toxicity in soil can inhibit plant growth, cause chlorosis, reduce crop yield (Yusha et al. 2023, Laura et al., 2010) and also can contaminate the underground water. In human, zinc toxicity can cause nausea, vomiting, diarrhea, immune system suppression.

Manganese: six samples from the waste dumps (WA3, WA4, WB1, WB2, WC3, WC4) have manganese values higher than FAO/WHO standard. Excess manganese in the soil can results to chlorosis, stunted growth of the crops, poor yield, nutrient imbalance (Kovacik et al., 2014, Millaleo et al., 2010) as well as altering the soil pH. If the manganese toxicity in the soil incorporate into the crop and enters human through food chain, it can result to health challenge such as neurological effect.

V. Conclusion

Solid waste dumps at Aluu study area is characterized by indiscriminate disposal of waste which pose significant environmental and health risks to both ecosystems and human populations. The sites lack waste segregation, and treatment measures which can result to leaching and percolation of toxic substances into soil and probably, the groundwater.

The solid waste dumps serve as breeding grounds for disease vectors such as rodents, flies, and mosquitoes, which can contribute to the spread of communicable diseases such as cholera, dysentery, and malaria.

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