Soil Pollution and Metal Bioaccumulation in Subterranean Organisms at a Major Lagos Landfill

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Abstract— This study looked into soil pollution and the accumulation of heavy metals in underground organisms at the Olusosun landfill in Lagos, Nigeria. The analysis of waste showed that plastics, polythene, and paper were the main components, pointing to a lack of proper segregation and recycling efforts. The physicochemical tests indicated that landfill soils had significantly higher pH levels, more organic matter, and greater total dissolved solids compared to control soils, along with lower levels of dissolved oxygen. Heavy metals like lead (Pb), cadmium (Cd), zinc (Zn), and copper (Cu) were found in higher concentrations in landfill soils, although they stayed within regulatory limits. The bioaccumulation factors revealed that different species absorbed metals differently, with earthworms (Eudrilus eugeniae) and maggots (Musca domestica) taking up more Zn and Cd. The relationship between soil characteristics and metal availability suggests possible ecological risks, including the transfer of toxic metals through the food chain. These results underscore the urgent need for better waste management policies and ongoing environmental monitoring to reduce contamination risks in rapidly urbanizing areas.

Keywords— Bioaccumulation, Heavy metals, , Lagos, Olusosun landfill, Soil pollution.

I. INTRODUCTION

Rapid urban growth and industrial expansion have caused a significant rise in solid waste production, particularly in the megacities of developing nations. Take Lagos, for instance, Nigeria's largest city, home to over 20 million people, which generates around 13,000 metric tonnes of solid waste every single day. Unfortunately, a large portion of this waste ends up in unregulated or semi-regulated landfill sites [1]. These sites often handle a mix of waste that includes hazardous materials like heavy metals, such as lead (Pb), cadmium (Cd), copper (Cu), and zinc (Zn). These substances pose serious long-term risks to both the environment and public health due to their toxic nature, persistence in the environment, and ability to accumulate in living organisms [2,3].

One of the largest open dumps in West Africa is the Olusosun landfill in Ojota, Lagos. Spanning about 100 acres, it takes in over 10,000 tonnes of municipal and industrial waste each day. This landfill is a melting pot of plastics, metals, electronic waste, organic materials, and construction debris [4]. The lack of proper waste segregation, insufficient recycling facilities, and the practice of open dumping have allowed toxic substances, especially heavy metals, to seep into the surrounding soil, groundwater, and local ecosystems [5]. Heavy metals are particularly alarming because they don't break down over time; they can linger in the soil for decades and disrupt the microbial and animal communities that are essential for maintaining soil health.

II. LITERATURE REVIEW

A wealth of research has shown that landfill soils in Nigeria and other developing areas are often contaminated with high levels of heavy metals. For instance, Gbadebo et al. found that the soils near landfill sites in Ogun State had lead and cadmium concentrations that far exceeded the safe limits set by the World Health Organization (WHO) and the Standard Organisation of Nigeria (SON) [6]. In a similar vein, Adedosu et al. discovered alarming amounts of zinc, copper, and lead in the soils and leachates at the Olusosun landfill, linking this pollution mainly to the mishandling of electronic waste and discarded car parts [2]. Other African nations have reported similar issues, highlighting the serious environmental consequences of improper waste management [7,8]. Moreover, the accumulation of heavy metals in underground creatures like earthworms (*Eudrilus eugeniae*), maggots (*Musca domestica*), and jumping spiders (*Neaetha maxima*) has proven to be a valuable method for monitoring soil contamination. These organisms take in metals either directly from the soil or by consuming contaminated food, which reflects how available these metals are and their potential to move up the food chain [9,10]. High levels of metals in these species can signal ecological risks and the possibility of biomagnification through food webs, which could ultimately threaten higher trophic levels, including humans [11].

Soil physicochemical factors play a crucial role in how metals move and how available they are for living organisms. Key elements like pH, organic matter content, temperature, and total dissolved solids (TDS) can change the way metals behave chemically and how soluble they are, which in turn affects how much they're taken up by soil organisms [12,13]. For example, soils that are acidic or low in organic matter usually boost metal solubility and uptake, while alkaline conditions might decrease or change how available those metals are [2]. Research around landfills in Lagos has shown that the alkaline pH and increased organic matter from decomposition significantly influence metal behavior and the overall health of the soil ecosystem [5].

However, despite these findings, there's still a lack of data on how heavy metals accumulate in land-dwelling animals around Lagos State landfills. Most studies have concentrated on

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soil and water contamination, with only a handful looking at bioindicator organisms in risk assessments [6,12]. This gap in research limits our understanding of ecological impacts and hinders the creation of effective remediation strategies.

Ongoing monitoring and thorough assessments of heavy metal contamination from landfills, soil chemistry, and the accumulation patterns in underground wildlife are essential. These efforts play a key role in developing sustainable waste management policies and protecting public health in Lagos, where landfills are often found right next to homes and businesses [14].

III. MATERIALS AND METHODS

This study was carried out at the Olusosun landfill in Ojota, Lagos State, Nigeria, situated at approximately 6.0200° N, 3.0200° E. Spanning around 100 acres, Olusosun stands as one of Africa's largest open dumpsites, processing up to 10,000 tonnes of municipal and industrial waste each day, which includes a significant amount of electronic waste [4].

Fresh waste samples were taken and sorted into various categories: plastics, polythene, paper, organic matter, metal items, electronics, and footwear. Each category was weighed individually to find out its percentage composition by mass. This approach is in line with the standard waste characterization methods used in landfill research [2,3].

Approximately one kilogram of composite soil from each of four representative points was obtained at depths of 0–15 cm using a soil auger. Alongside the soil, some subterranean fauna were collected, such as the earthworm *Eudrilus eugeniae*, maggots from *Musca domestica*, and the jumping spider *Neaetha maxima*, all from the same sampling sites. After rinsing the specimens with distilled water, they were identified using morphological keys, following the protocols set by Dedeke et al. [15]. The samples were then carefully packed in labeled airtight polyethylene bags and sent to the lab for bioaccumulation analysis.

To determine the soil pH, we prepared a 1:1 suspension of soil and distilled water, allowing it to equilibrate for 30 minutes before measuring with a calibrated pH meter. Soil temperature was recorded using a probe, and we averaged the daily minimum and maximum readings over two- and three-day intervals to account for any variations. The organic matter content was assessed through dichromate oxidation followed by titration, in line with the methods described by Dedeke et al. [16]. We measured total dissolved solids (TDS) and dissolved oxygen (DO) in the soil leachate using portable multiparameter devices, following recognized environmental monitoring protocols [12].

Air-dried soil samples were sieved through a 2 mm mesh to ensure uniformity. A 5 g sample was then digested in 1.0 M hydrochloric acid. The resulting digestates were analyzed for Pb, Cd, Zn, and Cu using atomic absorption spectrophotometry (AAS). The faunal samples underwent gut clearance under controlled conditions at about 14 °C for seven days, followed by drying them in an oven at 60 °C until they reached a constant weight, and then pulverizing them. Tissue digests were created using nitric and hydrochloric acid in microwave Teflon vessels,

which were then diluted to a standard volume before AAS analysis [9].

Heavy metal concentrations between landfill and control soils and fauna were statistically compared using one-way Analysis of Variance (ANOVA), with significance set at $p < 0.05$. The bioaccumulation factors for each organism-metal pair were calculated by taking the ratio of the metal concentration found in the organism to that in the corresponding soil sample (BAF = [metal]_organism ÷ [metal]_soil) [10]. These findings are crucial for evaluating ecological risks and suggest that subterranean fauna could serve as effective bioindicators.

IV. RESULTS

The analysis of the waste at Olusosun landfill showed that polythene and nylon represented the largest share of the waste stream at 33.3%, followed by plastics at 21.2% and paper at 19.4%. The remaining waste included organic matter, metal items, electronics, and footwear.

TABLE 1. Physicochemical parameters measured for landfill and control soils

Parameter	Landfill Soil	Control Soil	FEPA Limit
pH	8.1	7.3	6.0 – 7.0
Organic Matter (%)	49.5	2.86	≥3.0
Temperature (°C)	24.9	29.7	<40
TDS (mg/L)	101	8.10	≤500
DO (mg/L)	4.52	24.4	—

Table 1 provides a summary of the physicochemical parameters measured for landfill and control soils. The statistical analysis indicated that the landfill soil had significantly higher levels of pH, organic matter content, and total dissolved solids (TDS) ($p < 0.05$) compared to the control. In contrast, the dissolved oxygen (DO) was significantly lower ($p < 0.05$). However, the differences in soil temperature were not statistically significant ($p > 0.05$).

Table 2 illustrates the heavy metal concentrations present in the soil. The levels of Pb, Cd, Zn, and Cu in landfill soil were significantly elevated compared to the control soil ($p < 0.05$), although they stayed within the FEPA regulatory limits. Notably, chromium was not found in either type of soil.

TABLE 2. Heavy metal concentrations in soil

Metal	Landfill Soil (mg/kg)	Control Soil (mg/kg)	FEPA Limit (mg/kg)
Pb	0.75	0.01	<1
Cd	0.10	0.03	<1
Zn	0.04	0.01	<1
Cu	0.14	0.01	<1
Cr	ND	ND	ND

TABLE 3. Bioaccumulation factors (BAFs) for selected metals in soil invertebrates

Species	Pb	Cd	Zn	Cu
Jumping Spider	0.48	0.13	0.75	ND
Earthworm	0.51	0.39	3.50	ND
Maggots	0.23	1.30	7.75	1.60

Table 3 presents the BAFs for selected metals in soil invertebrates. Zinc had the highest bioaccumulation factors across the different species, with maggots showing the most significant accumulation of Cd, Zn, and Cu. A statistical comparison of metal concentrations in the soil versus those in the faunal tissues revealed no significant differences for most metals within the species (p > 0.05), indicating that the levels are fairly comparable.

V. DISCUSSION

At the Olusosun landfill, the waste is primarily composed of plastics, polythene, and paper, which underscores the ongoing struggles with inadequate waste sorting and recycling systems in Lagos [3]. This observation aligns with Fabunmi and Osibanjo's findings regarding the high levels of non-biodegradable waste in Nigerian dumps, complicating landfill management and leading to long-term environmental issues [3]. The limited amount of organic matter further restricts natural biodegradation processes, resulting in a buildup of recalcitrant materials, as highlighted by Adedosu et al. [2].

The elevated soil pH of 8.1 and the organic matter content of 49.5% in landfill soils point to ongoing decomposition and mineralization of organic waste. This results in alkaline leachates and a rise in salinity, which is consistent with what Longe and Balogun-Adeleye observed at the same site [12]. Furthermore, the significantly lower dissolved oxygen (DO) levels in landfill soils compared to control samples indicate that microbial respiration is heightened and anaerobic conditions are present. These conditions can significantly influence how heavy metals are mobilized and their forms in contaminated soils [2]. These physicochemical changes have important implications for the availability of metals and the health of soil organisms.

The levels of Pb, Cd, Zn, and Cu were found to be significantly higher in landfill soils compared to control samples, even though they remained below the regulatory limits set by FEPA. This aligns with research noting increased heavy metal concentrations at landfill sites in Nigeria, attributed to e-waste and industrial activities [6,2]. While the current levels are within acceptable limits, ongoing accumulation could contaminate groundwater and crops, posing potential health risks, as highlighted for nearby groundwater [14]. The BAFs indicate that different species absorb metals in varying amounts. For instance, earthworms (*Eudrilus eugeniae*) and maggots (*Musca domestica*) showed particularly high BAFs for zinc and cadmium.

Moreover, the interaction between heavy metals and soil properties, such as organic matter content and pH, critically influences metal speciation, mobility, and toxicity [12]. For instance, alkaline conditions can make some metals, such as lead, less soluble, while simultaneously increasing the availability of others like cadmium and zinc [2]. This shifting landscape can have significant impacts on microbial communities and soil-dwelling invertebrates, ultimately changing ecosystem functions and biogeochemical cycles [11].

Additionally, the accumulation of metals in organisms like maggots and earthworms poses a complex issue. While these creatures can be beneficial for bioremediation efforts, their

consumption by higher-level predators, such as birds and small mammals, raises serious concerns about the transfer and buildup of toxic metals through the food chain [10]. This highlights the need to combine ecological risk assessments with waste management strategies to prevent unintended harm to the environment.

The findings highlight the urgent need for policy changes focused on better managing landfill sites in Lagos. It's essential to implement systematic waste segregation right from the source, raise public awareness about proper disposal of hazardous waste, and improve landfill designs to reduce leachate production [3,6]. Regulatory agencies need to step up and enforce existing environmental standards more strictly to curb the growing issues of soil and water contamination.

In summary, this study sheds light on the intricate relationship between heavy metal contamination from landfills, the physicochemical properties of soil, and how these factors affect key soil organisms. These findings are crucial for shaping sustainable environmental management strategies in Lagos and other rapidly urbanizing areas facing similar waste disposal issues. Future research should focus on long-term studies and incorporate advanced biomonitoring techniques to gain a deeper understanding of the lasting ecological effects of landfill pollution.

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