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Utilizing Eco-Innovation Practices to Mitigate Urban Soils Contamination from Heavy Metals: A Land Use-Based Sampling Study in Ijebu Ode, Nigeria.

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Abstract

This study investigates the utilization of Eco-Innovation practices within Nigerian industries to mitigate urban soil contamination. Soil samples were collected from various urban land uses in Ijebu Ode town, specifically mechanic workshops (MW), roadsides (RD), industrial areas (IL), and market zones (MT). Ten composite soil samples were randomly gathered from each land use at a depth of 0-30cm and subjected to analysis for heavy metal concentrations (copper Cu, iron Fe, lead Pb, zinc Zn, cadmium Cd, manganese Mn) using an Atomic Absorption Spectrophotometer. This facilitated the calculation of contamination levels and pollution load index. The findings indicate that the concentration of Cu, Zn, Fe, and Mn is highest in soils from mechanic workshops, with the degree of soil contamination ranking as follows: Mechanic Workshop > Industrial land use > Roadside > Market land use. The study concludes that elevated levels of heavy metals in the sampled urban soil are closely linked to improper land use practices and other human activities. It advocates for the promotion of sustainable environmental practices through comprehensive stakeholder engagement aimed at educating the populace on the management and preservation of urban soils against harmful practices.

Key words: Contamination Soil. Eco-innovation Heavy Metals

INTRODUCTION

Industrialization has led to local and global changes in biodiversity and biogeochemical cycles (Liu *et al*., 2022; Byrne, 2008; Kanianska, 2016, Omoyajowo *et al*., 2017). This directly or indirectly affects the soil biota, the physical and chemical properties, and increases the heavy metal concentration in soil (Bach *et al*., 2020; Nanganoa, 2019; Li *et al*., 2022); and exacerbate the mobilisation of potentially toxic elements (Famuyiwa *et al*., 2022; SEPA, 2021; Blume *et al*., 2016). In the face of these challenges, understanding and mitigating industrial impacts on soil health is crucial for sustainable development and environmental stewardship (Farinmade *et al*., 2019; Omoyajowo *et al*., 2023).

Lehmann (2004) defines urban soils as those strongly influenced by human activities such as construction, transportation, manufacturing processes, industrial production, mining or similar activities. Scheyer and Hipple (2005) reckon that soils in urban areas can be divided into two general types: (i) natural soils which are formed from material naturally deposited by water, wind, or ice or material weathered from the underlying bedrock, (ii) anthropogenic soils which are formed from human deposited materials or fill, for example, natural soil materials; that have been moved around by humans; construction debris; ash materials dredged from waterways; coal; municipal solid waste; and combination of any of the above (NRCS/USDA 2005). These soils remain an integral part of the local ecosystem and play a critical role in the long-term sustainability and resiliency of cities (Cheng *et al*., 2021). These soils can filter, buffer, attenuate and degrade contaminants if protected and managed.

Urban soil contamination resulting from industrial activities represents a significant hazard to human health, ecosystems, and sustainable urban development (Farinmade *et al*., 2019; Ogunyebi *et al*., 2019; Omoyajowo *et al*., 2022). Various naturally occurring and synthetic elements and compounds are released into the environment, both intentionally and unintentionally, posing risks to human health and the environment. These contaminants can be absorbed by crop plants, potentially entering the food chain and posing risks to consumers. The processes of urbanization and industrialization have amplified soil contamination issues, even in developing countries such as Nigeria. Elements like Lead (Pb), Cyanide (CN), persistent organic pollutants like DDT, and polycyclic aromatic hydrocarbons (PAHs) are among the substances released due to industrial activities. Once released, these pollutants can persist in soil or migrate to other environmental compartments, including air, water, and the broader biosphere (Farinmade *et al*., 2019; Ogunyebi *et al*., 2019).

Addressing urban soil contamination requires comprehensive strategies that integrate pollution control measures, environmental monitoring, and sustainable urban planning. Efforts should focus on minimizing industrial emissions, implementing effective waste management practices, and promoting remediation techniques to safeguard public health and environmental integrity amidst rapid urban growth and industrial expansion. Considering the increasing contribution of industrialization and industries to soil contamination, and the alarming health risk it poses to humans, plants, animals, and the ecosystem in general, there is a need to advocate for sustainable strategies that will help prevent or mitigate soil contamination from industrial activities.

The concept of eco-innovation can be adopted by industries to mitigate soil contamination. Eco-innovation involves the development and implementation of new, environmentally friendly technologies, products, and business models. It highlights the potential of eco-innovation in reducing soil contamination in Nigerian industries through pollution prevention, resource efficiency, and the adoption of cleaner production practices. Strategies such as cleaner production techniques, waste recycling and reuse, and the use of phytoremediation to restore polluted soils are appropriate in mitigating urban soil pollution. This calls for the development of supportive regulatory frameworks, financial incentives for eco-innovation, capacity-building programs, and the establishment of collaborative platforms between industries, academia, and government agencies. It is worthy of note that soil contaminants emanating from industries and related industrial activities can be divided into inorganic and organic contaminants as depicted in Figure 1. These cover a range of heavy metals, non-metals, halogenated and non-halogenated organic contaminants.

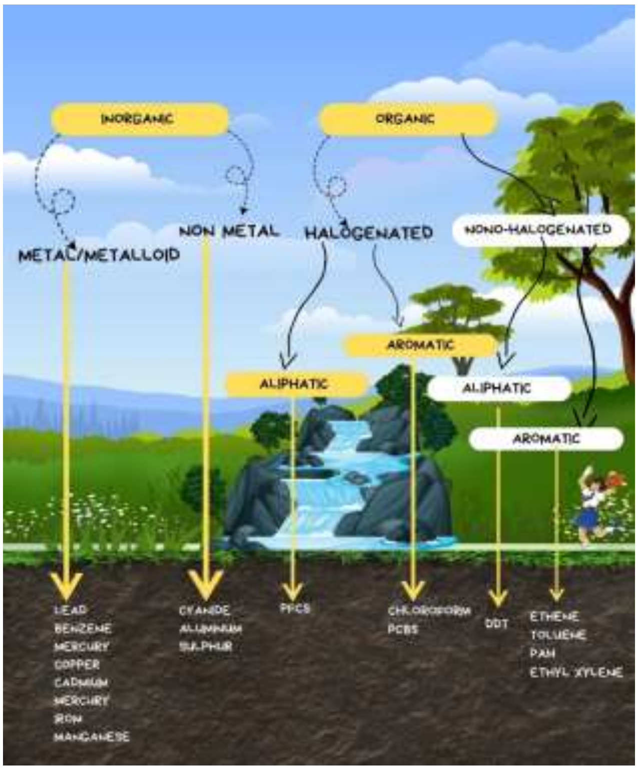

Figure 1: Nature of contaminants in urban soil
Source: Adapted from FAO/UNEP (2021) and Swartjes (2011).

Trace elements being the focus of this paper constitute inorganic compounds that are ubiquitous in nature including some elements such as iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), nickel (Ni), boron (B), selenium (Se) and molybdenum (Mo) which are essential micronutrients to soil microorganisms, plants, and animals. (Viets, 1962), and other elements such as lead (Pb), cadmium (Cd) and mercury (Hg) that have no known metabolic function to the soil. (Eisler, 2006; Flora *et al*., 2012). The WHO (1996) differentiates between trace elements that are (i) essential (chromium, copper, molybdenum, selenium, zinc; iron (ii) probably essential (manganese, nickel, vanadium); and (iii) toxic elements (aluminium, arsenic, cadmium, lead, lithium, mercury, and tin). Despite the natural occurrence of trace elements, they can be hazardous to the environment and human health if present at concentrations and/or in a chemical form that can be toxic to living organisms. Inorganic contaminants are by nature persistent and can occur in many different forms such as salts, oxides, sulphides, or organo-metallic complexes, or in the form of ions dissolved in soil solution. Trace elements cannot be degraded by metabolic processes, unlike organic contaminants, which can be degraded when metabolized by different organisms.

The release of trace elements into the environment is primarily attributed to human activities such as mining, smelting, ore processing, gas works, metallurgical industries, sewage application, fertilizer production and utilization, as well as the combustion of fossil fuels for power generation This occurs both from atmospheric emissions and due to direct release in soil and effluents (Cho *et al*., 2019; Hernandez *et al*., 2003; Hołtra *et al*., 2020; Kabir *et al*., 2012). In addition to emission to the air, illegal dumping or dumping without proper containment of industrial waste poses a threat to the soil environment (Hołtra *et al*., 2020).

Conceptual Framework

The Quintuple Helix Concept (QHC) of the Human-Natural Ecosystem provides an understanding of the dynamics and interaction of environmental pollution and its mitigation. Humans, being an integral part of the earth's ecosystem interact with the lithosphere, atmosphere, hydrosphere, and biosphere. Similarly, their activities advertently or inadvertently impact ecosystem functions, processes, and structures either at the macro-scale or micro-scale. These impacts are often negative or malevolent to the environment. A critical observation of the interactive nature of the earth system reveals a spiral effect of humans' impact on the earth's ecosystem. These impacts trigger perturbations and dysfunctionalities in the natural system, affecting other components of the earth. These often lead to damage and/or death of humans, flora, and fauna. The anthroposphere which largely refers to human societies, economies and socio-cultural landscape has daily generated various human activities with increasing impact on the processes that govern ecosystem properties.

The effect of human activities on the earth's system consequently results in a helical chain of reactions on humans, and on biotic and abiotic components which include soils at a temporal and spatial scale. The four spheres of the earth; namely the atmosphere, hydrosphere, lithosphere, and biosphere though have unique boundaries but are also interlinked and connected through various ecosystem processes and services such as the hydrological cycle, biogeochemical cycle, nutrients cycle and energy flow. This suffices that release of pollutants into the atmosphere may also contaminate the soil, as a result of atmospheric deposition. Urban soil as a critical component of the urban ecosystem impacts and is being impacted by other components of the urban environment.

The helical interactions among the components of the urban ecosystem suggest that any introduction of harmful substances, or other injudicious use of the urban environment would have deleterious consequences on soil which is a major sink for waste and pollutants in urban areas. The QHC in Figure 2 depicts the helical interactions among the earth's components and the impact on each component on one hand, and humans and their anthropologic environment on the other hand. Humans are major drivers in the modification and destruction of the ecosystem, as humans and biophysical agents drive urban socio-economic and biophysical processes that control ecosystem function. The urban ecosystem is predominantly controlled by humans and the entirety of the socio-economic landscape leading to modification and pollution of the earth's natural system; which often negatively affects human health and the socio-economic environment directly or indirectly. The Quintuple Helix Concept (QHC) underscores the synergy among government - academia - pressure groups and society as critical to environmental sustainability. This means that societal orientation or psychology on protecting the environment is correlated to implementing and enforcing sustainable environmental laws and policies emanating from any geographical entity's political leadership or hierarchy. Of relevance are the systemic dimension of the QHC to understanding urban soil pollution and degradation, its impact on the natural and anthropologic environment, and the role of the anthroposphere in providing leadership to managing and protecting urban soils (Akiyama *et al.*, 2013). This calls for the adoption of eco-innovation in industries in developed societies and supports the global drive for environmental sustainability as highlighted in the Sustainable Development Goals (SDGs) 2030. The interconnectedness of the soil to other components of the urban ecosystem accentuates the need for the Quintuple Helix Concept and why urban soil should be holistically managed as an integral component of the urban ecosystem (Haase, 2021).

Figure 2: Quintuple Helix Concept of Humans – Natural Environment Interactions

Study Area

The city of Ijebu-Ode is located within latitude 6º 50′ and longitude 3º 45′ as shown in Figure 3. Ijebu Ode is the second settlement respectively after Abeokuta, with a population of 222,653. The land use of this town areas varies from residential to industrial land use. The road network and connectivity to other States make the city a hub for transportation activities and inter-related commercial activities. The road network is connected to Ore/Benin Expressway, Shagamu/Lagos Express Way, Epe and Ijebu-Ode. Soils of the study area are derived from sedimentary rocks, which may vary in structure because of the differences in human activities.

Figure 3: Map of the study area

METHODOLOGY

For this study, urban land uses that reflect and are connected to industrial activities in Ijebu Ode town were identified and selected for study; mechanic workshops (MW), roadsides (RD), industrial land use (IL), and market area (MT). The map of the study area is shown in Figure 3.

Ten soil samples were randomly collected as a composite from each identified land use at a depth of 0-30cm, except roadsides (RD) where 10 soil samples (10 from major roads were collected from 0-30cm at a varying distance of 1metre to the road edge, 2metres, 3metres, 4metres, 5metres, 6metres, 7metres, 8metres, 9metres and 10metre.

Soil samples were digested and filtered to extract cadmium, zinc, manganese, iron, copper, and lead. Air-dried samples were ground using mortar and pestle and sieved with 2mm mesh size. 2 g of each of the soil samples was accurately weighed and treated with 10 ml of high purity concentrated HNO_3 The mixture was heated on a hot plate until the sample was almost dry and then cooled. This procedure was repeated with another 10 ml of concentrated HNO_3 followed by 10 ml of 2M HCl to re-dissolve the residue. The extracts were then filtered through Whatman filter paper (no. 42) into a 50 ml capacity bottle and brought up to volume with doubled distilled water. Heavy metal concentrations were determined using an Atomic Absorption Spectrophotometer (Buck 210 AAS, 2005, USA). Extractable copper, iron, lead, zinc, cadmium, manganese.

The mean and standard deviation of trace elements in each land use were calculated, in addition to the degree of contamination and pollution load index for each land use, while simple regression analysis was carried out for each heavy metal as the distance increased from the roadside.

The enrichment factor (EF) was calculated to assess the enrichment extent of elements in soils (Dantu 2009; Vega *et al.*, 2009; Reimann and de Caritat 2005)

EF = (Cm /Cref) sample/(Cm /Cref) background.

Where;

Cm is the average concentration of metal of interest

Cref refers to the average concentration of the reference metal.

EF was calculated using iron (Fe) as a reference metal (Iqbal and Shah, 2015).

The degree of contamination (CDeg) formula in this study was proposed by Håkanson (1980). Where; ∑CF is the summation of all contamination factors of each heavy metal in the soil samples. This is to provide a measure of the degree of overall heavy contamination in a sampled site.

The pollution load index (PLI) for the soil samples is calculated following the method proposed by Tomlinson *et al.* (1980).

This parameter is shown thus:

$$\mathbf{PLI = (CF_1 * CF_2 * CF_3 * CF_4 * \text{--} CF_n)^{1/n}}.$$

Where;

n is the number of metals identified in this study which is 6.

PLI < 1 denotes perfection;

PLI = 1 present that only baseline levels of pollutants are present and

PLI > 1 would indicate deterioration of site quality Tomlinson *et al.* (1980).

The background values according to Turekian and Wedepohl (1961) are given thus:

Pb= 7; Cu= 32; Cd= 0.2; Zn= 127; Fe= 9800; Mn= 750

RESULT AND DISCUSSION

Lead (Pb) concentration is highest in roadside soil at 13.96mg/kg, followed by industrial land use with 12.16mg/kg as shown in Table 1. High concentrations of Pb in the roadside soil of Ijebu Ode is similar to that reported by Osunmuyiwa *et al.* (2021) with 11.8–28.6 mg/kg of Pb in the roadside soils of Akure this could be due to intense vehicular activity and use of lead-based product. Also, the Pb levels in Lagos dumpsites was found to be 4.3–19.8 mg/kg, consistent with urban contamination from battery disposal and paints (Famuyiwa *et al*., 2022). According to Siccama and Smith (1978) extractable lead observed in soil is mostly from anthropogenic emission, considering that lead since ancient times has been mined for different purposes (Nriagu, 1983). Moreover, lead had been globally used as an anti-knock agent in gasoline until banned in many countries in the 1990s (UNEP, 2019d).

Despite national and international regulations, old houses and even newly produced paints still have high concentrations of lead and are widely commercialized mainly in low- and middle-income countries (LMIC) (Clark *et al*., 2006; IPEN, 2017, 2020; Lin *et al*., 2009). Similarly, lead was a major element of commercial and domestic paint and plumbing and is presently found in older buildings due to these uses. Despite the international regulations against lead constituents in paints, old houses and newly produced paints still have high concentrations of lead and are widely commercialized in low- and middle-income countries (LMIC) (IPEN, 2017, 2020) consequently finding its ways as leachates and exudates in urban soil. Some other primary lead sources include lead–zinc smelting, ammunition, solder, glass, piping, and batteries (Yong and Mulligan, 2019).

Cadmium has its highest concentration in soils of industrial land use with a mean value of 0.96mg/kg, followed by mechanic workshop with a mean value of 0.77mg/kg. Cadmium concentration in agricultural areas of Lagos was found to be 0.2–0.6 mg/kg (Adeyi *et al.*, 2020) similar to that of Ijebu ode while Cadmium in soils near tanneries in Kano reached levels as high as 3.2 mg/kg (Muhammad *et al.*, 2020). Cadmium at trace concentrations can affect ecosystem function due to its toxicity (Smolders and Mertens, 2013). Cadmium is a non-essential element naturally present in all soils (Smolders and Mertens, 2013) and is the seventh most toxic trace element (Jaishankar *et al.*, 2014). Cadmium is naturally found in soil mainly via atmospheric deposition from volcano eruptions (Mulligan *et al.*, 2001), and is usually associated with zinc, lead or copper in sulphide form (Cameron, 1992). However, the anthropogenic sources of cadmium are a major concern for urban soil contamination. These include alloys, polyvinyl chloride plastic (PVC) manufacture, solders, fungicides, enamels, motor oil, textile manufacturing, electroplating and rubber, steel plating, nickel-cadmium batteries, sewage sludge and phosphate fertilizers (Smolders and Mertens, 2013). The levels of toxic elements (table 1) were higher than values gotten for dumpsite soil in previous study (Ogunyebi *et al.*, 2019)

Table 1: Heavy metal incidence in urban soil[a]

Sample sites	Pb (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
Mechanic workshop	11.63±1.30	67.01±9.98	0.77±0.17	94.66±11.72	130.28±18.24	100.03±14.35
Roadsides	13.96±1.30	42.92±2.93	0.37±0.03	82.34±4.77	88.96±5.66	71.31±6.27
Industrial land use	12.16±0.89	24.54±1.62	0.96±0.08	91.71±10.10	91.79±9.57	78.80±6.67
Market landuse	5.55±0.53	38.14±3.69	0.31±0.04	84.56±6.38	81.17±6.03	76.41±6.37

[a] ***Values are means ± standard errors.***

The concentration of copper, zinc, iron and manganese is highest in soils of the mechanic workshop as depicted in Figure 4.

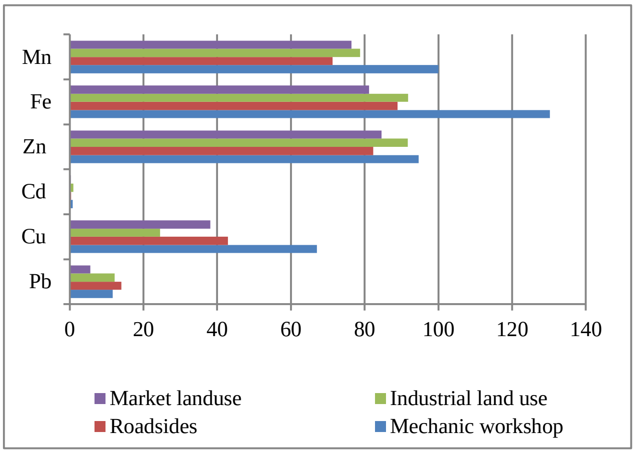

Figure 4: Distribution of Heavy Metals in Land Uses

Zinc and copper are mainly associated with atmospheric deposition of transport emissions; including vehicle exhaust gases, tyre and brake abrasion residues, and road wear emissions (Ferreira *et al.*, 2016; Kadi, 2009; Lee *et al.*, 2006). The high incidence of manganese observed in soil of the mechanic workshop could be linked to the waste and lubricant sludge, emissions from alloy, steel, and iron works, combustion of fossil fuels, and emissions from the combustion of fuel additives.

Heavy metal enrichment in urban soils of the study area showed lead as having preponderance in the enrichment level as shown in Table 2. The Soil samples from both mechanic workshops and roadsides revealed Pb>Zn>Cu>Cd.>Fe>Mn enrichment. Similarly, soil samples from industrial land use in Ijebu-Ode town showed Pb >Zn>Cd>Cu>Fe> Mn enrichment. The market area revealed a Pb>Zn>Cu>Cd.>Fe>Mn enrichment order. This corroborates the findings of the Toxic Sites Identification Program (TSIP) by Pure Earth (2019b) that lead is the most reported soil contaminant in the global database of contaminated sites. This has grave consequences on the global mortality rate, as lead exposures result in over a million deaths annually according to the latest Global Burden of Disease Study by the Institute for Health Metrics and Evaluation (IHME, 2017). Sadly, ninety-two percent of deaths attributable to lead exposures occur in low- and middle-income countries, even as exposures to lead are estimated to cost the economies of low- and middle-income countries nearly USD 1 trillion in GDP annually (Attina and Trasande, 2013)

Table 2: Enrichment level of trace elements in urban soil

	EF values					
	Pb	**Cu**	**Cd**	**Zn**	**Fe**	**Mn**
Soils in Mechanic workshop	52.13****	2.20**	1.87*	3.67**	1*	2.18**
Roadside soils	67.50****	1.38*	0.98*	3.46**	1*	1.99*
Soils in Industrial land use	51.35****	1.19*	4.03**	4.88**	1*	2.49**
Soils in Market land use	21.30***	1.99*	1.16*	4.97**	1*	2.97**

*EF<2 = minimal enrichment; **EF= 2-5 moderate enrichment; ***EF = 20-40 very high enrichment; ****EF > 40 = extremely high enrichment

Degree of contamination (Cdeg) is simply the summation of the entire contamination factors in a given soil sample. It has four categories which are used to assess the extent of contamination. From the categories, Cdeg value of <5 implies low contamination; 5 to <10 means moderate contamination; 10 to <20 shows considerable contamination, while Cdeg values of >20 imply very high contamination (Hakanson, 1980 cited in Yekeen and Onifade, 2012). The degree of contamination (Cdeg) of metal in each land use is shown in Figure 5.

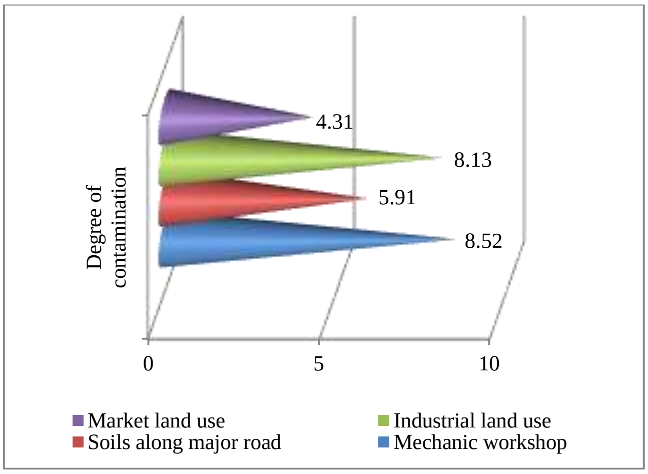

Figure 5: Degree of contamination of urban land uses

Mechanic workshop, major road, and industrial land use showed moderate contamination by heavy metal (Cdeg of 8.53 and 8.31 respectively) However, both mechanic workshop and industrial land use recorded a much higher value than the roadside soils (Cdeg value of 5.91), which also experienced a high volume of vehicular movement, and emission along the transport corridor. These soils need to be properly managed and monitored to mitigate contamination. More importantly, eco-innovation policies need to be adopted by industries in the utilisation of green technologies in production process, and in the production of novel environmentally friendly products that are decomposable and recyclable.

A further appraisal of the degree of contamination was calculated, using the pollution load index (PLI) which symbolises the number of times the content of metal in the soil is above the average natural background of metal concentration. PLI provides a cumulative indication of the overall level of heavy metal toxicity or pollution in a given soil sample. The PLI was also assessed to effectively determine which land use is most contaminated (Likuku *et al.*, 2013). Angulo (1996) cited in Ololade (2014) opined that PLI gives a clue of the status of metal contamination in the soil which enables necessary remediation action to be put in place. The result on PLI of all the land uses was far lower than unity (<1) except for the mechanical workshop in Ijebu Ode. The soil from the mechanic workshop in Ijebu Ode are indication of pollution concern which is attributed to the indiscriminate disposal of vehicle spare parts, used engine oil, leachates from automobile scraps and panel beating works, including deposition from automobile body painting. A similar result was also reported by Ololade (2014). The charts depicted in Figures 5 and 6 showed the degree of soil contamination in Mechanic Workshop > Industrial land use >

Roadside > Market land use. Soils in the mechanic workshop showed a strong indication of contamination by heavy metals. This calls for a holistic land management approach that holds eco-innovation as central to mitigating urban soil contamination.

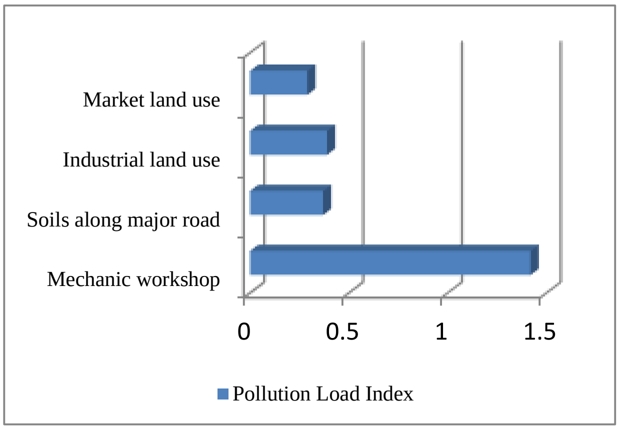

Figure 6: Pollution load index in urban land uses

Adopting Eco-Innovation in Mitigating Urban Soil Contamination

To improve urban soil quality in Nigeria amidst the severe impact of heavy metal contamination, Eco-Innovation practices play a crucial role. Eco-innovation refers to the development and implementation of new products, processes, or services that lead to environmental benefits, such as reduced pollution, resource conservation, and improved sustainability. This is recommended for this study, as all the urban land uses showed a certain degree of contamination, with roadside soils, industrial land use, and the mechanic workshop showing considerable contamination. In these instances, green infrastructure, green parks, and green technologies should be adopted to filter contaminants and catalyze phytoremediation which allows plants to absorb, degrade, and stabilize trace elements in urban soils. Figure 7 shows the distribution of lead, cadmium, copper, zinc, iron, and manganese on the roadside as distance increases from the road. It was observed that generally there is an inverse relationship between trace elements in roadside soil and distance from the road. Nonetheless, there are pockets of high concentration of trace elements as distance increases. These outliers are a combination of anthropogenic and natural factors which can be mitigated by adopting eco-innovation strategies, such as the production of environmentally friendly products for industrial and domestic use. There should be a ban on the use of lead in the production of paints and as an additive in fuel as operable in developed nations. Unfortunately, Nigeria and a large percentage of low- and medium-income countries according to UNEP and WHO (2011) are yet to have legally binding legislation that controls or bans the use of lead. Similarly, based on the observations in Figure 7, plants that are hyperaccumulators of trace elements should be planted from 0-10 metres from the roadside to mitigate heavy metal contamination in soil along transport corridors. Furthermore, industries should invest on product and process innovation that will lead to eco-friendly products, thereby eliminating toxic trace elements like lead, cadmium, mercury, and arsenic in biological media.

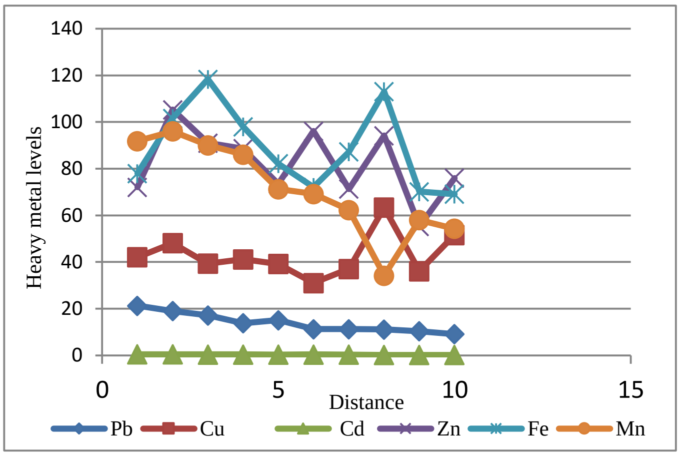

Figure 7: Trace element levels in roadside soil against distance

Additionally, green infrastructure initiatives, such as implementing green roofs and urban gardens, offer effective mechanisms to enhance soil quality by filtering pollutants and facilitating natural remediation processes. Additionally, employing phytoremediation techniques with suitable plant species capable of efficiently absorbing and relocating heavy metals is essential for detoxifying urban environments. It is imperative that these plants meet stringent criteria as effective phytoremediators and are not intended for human or livestock consumption to prevent inadvertent exposure to contaminants. Sustainable waste management practices integrated into industrial and urban settings further mitigate soil contamination by ensuring proper disposal and recycling of waste materials, thereby minimizing new contaminant introductions. Furthermore, Eco-Innovation practices foster community engagement and awareness through educational initiatives and collaborative partnerships, empowering residents to adopt sustainable practices and advocate for policies that safeguard urban soil health. Embracing these strategic Eco-Innovation approaches represents a deliberate and innovative path for Nigeria to effectively manage urban soil contamination dynamics and cultivate healthier, more sustainable urban environments.

CONCLUSION

Soil being a crucial component of urban environments, requires effective and efficient land management in both geographical space for healthy soil and functional ecosystem in general. Though, heavy metals occur naturally but at background levels. The toxic levels are highly associated with injudicious use of land uses and other human activities. It has been established that heavy metal accumulation in soils is toxic to humans, and could lead to mental lapse, kidney and liver diseases, skin diseases, and nervous breakdown. To however avoid such morbid consequences; excess heavy metal incidence in the soils should be prevented and remediated. Cleaning up contaminated soils is highly expensive and rigorous; hence land use policies will ensure that land use activities do not increase heavy metals beyond the permissible levels as specified by the Food and Agriculture Organization, which itself is relative as countries have their peculiarities.

Considering the pockets of elevated heavy metal levels extending from 1m to 10m in the adjoining roadside soil, it is recommended that sustainable land use planning such as designing urban spaces to minimize exposure to contaminated soils and prioritize redevelopment of brownfield sites to create healthier and more resilient cities. Sustainable environmental practices should be driven through political leadership over space and time (Akiyama *et al*., 2013). Even as the academia has a responsibility to enlighten the political leadership and the citizenry on the management and protection of urban soils from malevolent practices, consumers on their part must be active in demanding eco-friendly products and services, while holding industries accountable for polluting urban soils through their activities.

Industries can adopt cleaner production technologies to minimize waste and emissions. For example, using non-toxic substitutes for heavy metals in industrial processes, such as lead-free paints or cadmium-free batteries. Develop circular waste management systems that focus on recycling and reusing materials. For instance, collecting and recycling used motor oil and metal scraps from mechanic workshops. Establishing urban green spaces, such as green roofs and bio-barriers, to trap airborne heavy metals and reduce deposition on soil surfaces.

Plant hyperaccumulators (e.g., sunflowers, Indian mustard) in contaminated areas like mechanic workshops and roadsides to absorb heavy metals such as lead and cadmium from the soil. Use chemical solutions, such as chelating agents, to extract heavy metals from contaminated soils. This can be applied in industrial areas with high concentrations of cadmium or zinc. Phytoremediation which employs like Indian mustard or sunflower to extract and stabilize metals like Pb, Cd, and Zn from soils could also be used to address heavy metal contamination of soil. These plants can improve soil health while reducing heavy metal bioavailability. Also, Microbial Bioremediation by introducing metal-tolerant microbes to promote heavy metal adsorption, immobilization, or transformation into less toxic forms.

Soil washing using biodegradable chelating agents for extracting metals like Cu and Cd from soils in industrial zones. This technique is effective but should be paired with proper disposal of wastewater. Green Infrastructure through Installation of permeable barriers and biofilters in urban areas to trap heavy metals from runoff, preventing soil contamination. These infrastructures also support sustainable urban drainage systems.

By combining green infrastructure, advanced soil management techniques, and collaborative policy frameworks, urban areas can effectively tackle heavy metal contamination, enhance ecological health, and promote resilience to climate challenges Urban greening projects, such as tree planting and creating vegetative barriers, also mitigate urban heat island effects while reducing pollutant deposition.

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