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Research Article

ENVIRONMENTAL EFFECTS OF IMPROPER DISPOSAL OF LEAD-ACID BATTERIES ON SOIL QUALITY IN MGBUKA OBOSI, ANAMBRA STATE

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Abstract
Lead-acid batteries are widely used in automobiles, uninterrupted power supply systems, telecommunications, and other backup applications due to their reliable electrochemical performance. These batteries operate through chemical reactions involving lead dioxide at the cathode, lead at the anode, and sulfuric acid as the electrolyte. However, used lead-acid batteries represent a significant environmental concern due to their high lead content, averaging 10.5 kg per unit. Lead is recognized as one of the most hazardous metals, posing serious risks to human health and the environment. Improper disposal and recycling of these batteries contribute substantially to soil contamination and heavy metal pollution, with global emissions estimated at 3.6 million tonnes in 2010, 65% of which originated from waste management and recycling activities. This study investigates the environmental impact of used lead-acid batteries on soil heavy metal levels in Mgbuka Obosi, Idemili North LGA, Anambra State, Nigeria. Soil samples were collected from areas surrounding disposal sites and analyzed for lead and other associated metals. The findings highlight elevated concentrations of heavy metals, emphasizing the urgent need for effective waste management, recycling regulations, and remediation strategies to mitigate environmental and public health risks associated with used lead-acid batteries.

Keywords: Lead-acid batteries, Soil contamination, Heavy metals, Environmental impact, Anambra State

INTRODUCTION

The lead-acid battery is the oldest and most commonly utilised rechargeable electrochemical unit in automobile, uninterrupted power supply systems, and backup systems for telecommunications and numerous other applications. This device functions via chemical reactions that include lead dioxide as the cathode electrode, lead as the anode electrode, and sulfuric acid, as described by Kitaronka (2022) and Venkat (2020). Used lead-acid batteries, including all types, contain an average of 10.5 kg of lead. This serves as a primary source of secondary lead. Lead is one of the most hazardous metals and has been listed among the seventeen most perilous substances. According to the United Nations Environment Programme (UNEP), global emissions from lead production, use, and recycling totalled roughly 3.6 million tonnes in 2010, with 65% stemming from waste management and recycling processes (United Nations Environment Programme, 2021).

The United Nations Environment Programme (UNEP, 2023) explains that used lead-acid battery (ULAB) recycling involves breaking down and recycling batteries typically sourced from motor vehicles. Research by Zhao et al. (2024) found that waste LABs are primarily made up of the following components: grid plates (which are pure lead), organic casings (polypropylene, polyethylene, polyvinyl chloride, etc.), lead paste (PbO, PbO_2, and $PbSO_4$), electrolyte (H_2SO_4), and separators. Furthermore, inadequate recycling methods can emit lead particles and vapors into the atmosphere, potentially leading to respiratory difficulties and other health concerns (Liu, Xu, Zhang and Huang, 2020). Improper disposal and recycling of ULABs can cause severe environmental contamination and health hazards, including soil and water pollution as stated by Gottesfeld, Pokhrel, Pokhrel, and Teli in 2018. According to United Nations Environment Programme (UNEP, 2024) Used lead-acid battery (ULAB) recycling consists of dismantling and recycling used batteries, usually acquired from motor vehicles.

Heavy metal cycling is heavily reliant on soil, and contamination arising from discarded lead-acid batteries (ULAB) presents substantial hazards. Exposure to lead can result in its accumulation in the human body via ingestion of contaminated soil, posing a risk of toxicity when concentrations surpass established safe thresholds. A study evaluating the ecological risk of heavy metal pollution in the agricultural ecosystem surrounding a lead-acid battery factory revealed that the contamination factor values for lead (Pb) ranged from 2.8 to 5.3, suggesting that the tested soils were significantly affected by Pb. (Liu et al., 2014).

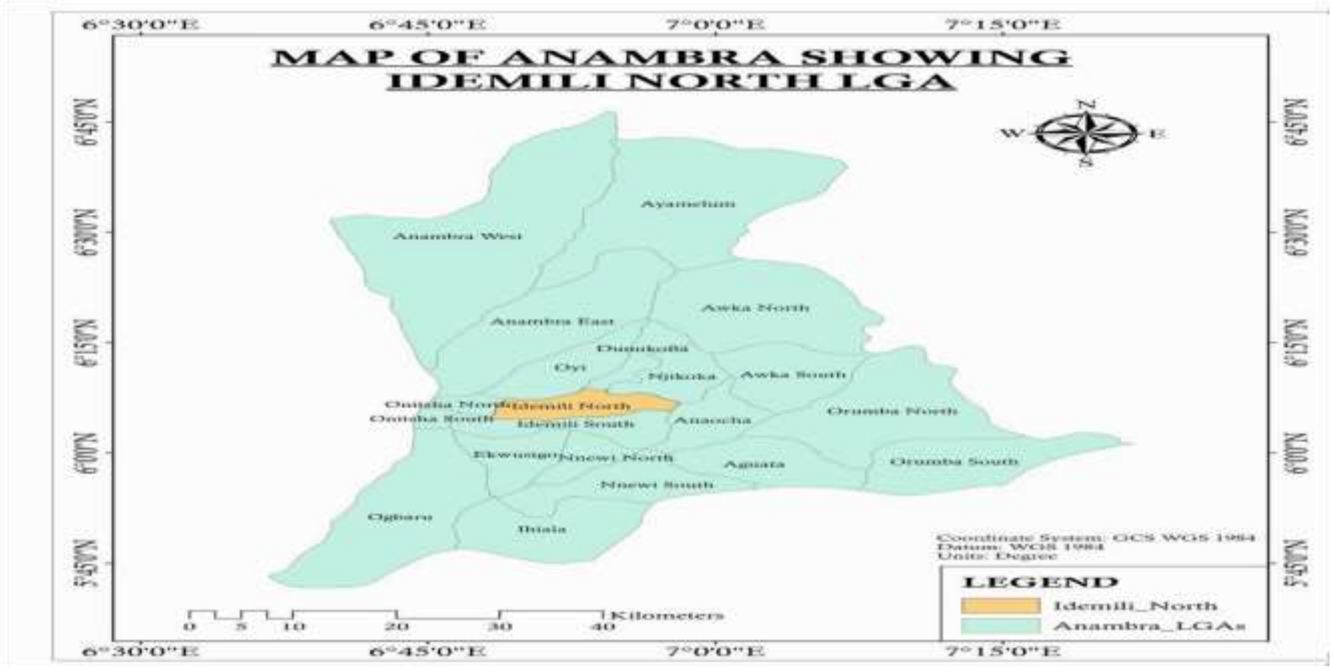
Gottesfeld et al. (2018) highlighted that soil contamination from battery recycling and manufacturing facilities in Africa represents a long-term health hazard; adding that the proximity of these facilities to residential areas exacerbates health risks for local communities. Man-made wastes, including automobile wastes, significantly amplify soil contamination, threatening ecosystems and human health.

MATERIALS AND METHODS

The study area

Mgbuka Obosi is located in Idemili North Local Government Area of Anambra State, Nigeria. Obosi is situated at coordinates 6.10341° N latitude and 6.81207° E longitude, with an elevation of approximately 95 meters (312 feet) above sea level. The area features plains with elevations ranging from 50 to 200 meters above sea level. It experiences annual rainfall between 2,500 mm and 4,000 mm, with the highest precipitation occurring in April and October. The average relative humidity is around 80%, increasing to 90% during the wet season (Obiabunmo and Obiekezie, 2023). The study area is situated within the Anambra sediment basin, located in southeast Nigeria, which spans an estimated area of 40,000 km2 (Udegbunam, 2015). Its southern boundary coincides with the deltaic swamps of the Niger Delta basin, and it extends northwards beyond the Bende-Ameki Formation. The Anambra Basin is recognized as a significant depocentre of elastic sediments and deltaic sequences formed from the second phase of tectonic activity in the lower Benue trough (Udegbunam, 2015). The economic activities of Obosi are diverse, encompassing trade, agriculture, and informal industrial activities. Key commercial centers include the Uke market and the Building Materials Market. The informal recycling of lead-acid batteries is a prevalent economic activity, which, despite its economic benefits, poses considerable environmental and health risks due to the lack of proper regulatory oversight and safe handling practices.

Fig. 1: Map of Anambra State showing Idemili North local Government Area



Methods

This study employed an experimental research approach. This method was chosen for its ability to provide objective data through measurement and analysis, which was essential for assessing environmental contamination. The study was comparative and aimed to analyze the state of soil contamination in Mgbuka Obosi and compare it with control sites to highlight significant differences in the heavy metal concentrations of the study area. The data required for this study encompassed both primary and secondary data, which facilitated a comprehensive analysis of the environmental impact of Used Lead-Acid Battery (ULAB) in Mgbuka Obosi. The primary data included soil samples collected from various locations within Mgbuka Obosi and control sites. These samples were analyzed to determine their physiochemical properties and heavy metal contents. Data obtained from the laboratory analysis of the soil samples include Lead (Pb), Calcium, Arsenic, Zinc, Sodium, Cadmium, among others.

Six (6) soil samples were collected for the purpose of this study. Four (4) soil samples were collected from Mgbuka Obosi while two (2) samples were collected from control sites about 2km away from Mgbuka Obosi. The two control sites were presumed to be unaffected by ULABrelated contamination, providing a baseline for comparison. Random sampling technique was employed in the course of this study. The technique was chosen for its ability to ensure representativeness and reduce bias in sampling processes. Soil samples were collected using a soil auger and GPS (for coordinates) and the samples were stored in plastic bags labelled with marker and masking tape, following standardized procedures to ensure consistency and reliability. From each sampling site, two samples (topsoil from 0cm to 15cm and subsoil from the depth of 16cm to 30cm) were collected. Both the topsoil and subsoil from each site were mixed to get a composite sample. The soil samples were taken to the laboratory (Docchy Analytical Laboratories and Environment Services Limited), air dried and sieved through 2mm sieve for soil analysis.

The laboratory results from the soil samples in Mgbuka Obosi and the control sites were systematically presented and analyzed to draw meaningful conclusions about the environmental impact of Used Lead-Acid Battery (ULAB) on the soil parameters. The results were presented using tables. A hypothesis was stated in the course of this study. The hypothesis which stated that there is no significant difference between the heavy metal parameters of the soils of Mgbuka Obosi and that of the control sites was tested using the Independent Samples t-test.

RESULTS AND DISCUSSION

Table 1: Geographic coordinates of the sampling locations

S/N	Mgbuka Obosi	Latitude	Longitude
1.	Soil Sample Location 1	$6^0$6’31”N	$6^0$47’52”E
2.	Soil Sample Location 2	$6^0$6’37”N	$6^0$47’49”E
3.	Soil Sample Location 3	$6^0$5’59”N	$6^0$42’51”E
4.	Soil Sample Location 4	$6^0$5’47’N	$6^0$45’52”E
5.	Control 1	$6^0$7’52”N	$6^0$47’47”E
6.	Control 2	$6^0$8’01”N	$6^0$47’39’E

The impacts of ULAB on the heavy metals parameters of the soil in the study area

Table 2: Heavy metal parameters

Heavy metals	Location 1	Location 2	Location 3	Location 4	Control 1	Control 2
Sodium (ppm)	27.937	29.674	27.200	28.910	26.474	25.111
Potassium (ppm)	18.345	16.483	17.783	18.001	21.058	23.010
Magnesium (ppm)	15.678	16.595	15.451	15.777	16.944	18.226
Calcium (ppm)	15.474	13.457	13.834	13.441	14.878	14.977
Manganese (ppm)	3.022	1.011	3.556	3.001	2.036	2.200
Zinc (ppm)	4.278	5.473	5.399	4.989	1.372	1.745
Arsenic (ppm)	0.000	0.000	0.000	0.000	0.000	0.000
Aluminum (ppm)	0.028	0.010	0.021	0.011	0.004	0.003
Lead (ppm)	3.894	3.893	3.899	3.888	0.892	0.881
Cadmium (ppm)	1.084	1.022	1.078	1.081	0.109	0.119
Copper (ppm)	0.989	1.705	1.811	1.676	0.019	0.022
Chromium (ppm)	0.648	0.705	0.755	0.722	0.048	0.046
Iron (ppm)	7.367	6.899	7.556	7.343	3.279	3.444

Docchy Analytical Laboratories and Environment Services Limited

A group of naturally occurring elements characterised by high atomic weight and density are heavy metals, many of which are hazardous or toxic even at very low concentrations. Heavy metals such as lead (Pb), cadmium (Cd), and arsenic (As), among several others, can cause significant environmental and health hazards if they are discharged into the soil, water, or air. Heavy metals persistently accumulate in soil, plants, and living organisms due to their nonbiodegradable properties, resulting in prolonged contamination and adverse effects on ecosystems and human health. Metals from hazardous waste sites, especially those involving used lead-acid batteries (ULAB), can contaminate the soil, affecting farm output and posing health hazards through the food supply. The analysis of heavy metals in the soil from various locations at Mgbuka Obosi indicates significant contamination when compared with the control sites. The levels of essential and toxic metals vary across the locations, reflecting the influence of used leadacid batteries (ULAB) on soil quality. The essential metals, such as sodium, potassium, magnesium, and calcium, show notable differences between the test and control sites. Sodium levels range from 27.200 ppm to 29.674 ppm in the test locations, slightly higher than in the control locations, where values are 26.474 ppm and 25.111 ppm. This slight increase in the test locations may be attributed to minor disturbances in the soil properties due to ULAB activities. According to Eneje (2019), high sodium concentrations can lead to soil salinization, which can affect plant growth by disrupting the soil's ability to retain water and essential nutrients. This slight increase near the ULAB processing sites suggests possible salt contamination, but it is not yet severe.

Potassium (K) is a key macronutrient required for plant growth, playing a crucial role in regulating water and nutrient uptake, enzyme activation, and overall plant health. It is abundant in the Earth's crust and is typically found in soils in adequate amounts for agricultural productivity. Unlike heavy metals such as lead or cadmium, potassium is non-toxic under standard environmental circumstances. Impacts on plant health and soil quality can result from either potassium deficiencies or excessive levels. Potassium plays a significant role in human nutrition, as it aids in muscle function, promotes heart health, and helps regulate fluid balance. Potassium concentrations are lower in the test locations, ranging from 16.483 ppm to 18.345 ppm, compared to 21.058 ppm and 23.010 ppm in the control samples. Studies have shown that lead contamination can decrease the availability of essential nutrients like potassium in soils, a finding supported by Adefila et al. (2020), who observed reduced potassium content in ULABcontaminated soils. The reduction in potassium in ULAB-affected areas might affect agricultural productivity, implying the ULAB activities could be disrupting the natural nutrient balance.

Magnesium (Mg) is a vital nutrient required by all living organisms. Chlorophyll in plants contains magnesium, which is a vital element in the process of photosynthesis. Magnesium plays a crucial role in multiple biochemical processes within both plant and animal systems, encompassing protein synthesis, the activation of enzymes, and energy generation. Magnesium in soils is usually present in minerals and becomes accessible to plants as a result of natural weathering processes. Lack of sufficient magnesium is not toxic to plants, but it can cause subpar plant development and reduced crop production. On the other hand, soil magnesium levels that are excessively high can cause nutrient imbalances, but they typically do not present any substantial environmental or health hazards comparable to those posed by heavy metals. Magnesium levels also show a slight reduction in the test locations, with values ranging from 15.451 ppm to 16.595 ppm, compared to 16.944 ppm and 18.226 ppm in the control samples. Magnesium is a stable nutrient in the soil, and its marginal decrease may be due to ULAB contamination.

Calcium (Ca) is a critical macronutrient that plays a fundamental role in plant structure and development. Calcium plays a significant role in plant health, supporting the stability of cell walls, the growth of roots and leaves, and overall plant vitality. The soil's overall health is significantly enhanced by its ability to improve soil structure and facilitate the absorption of other essential nutrients. Calcium is essential for the development and maintenance of bones and teeth in both animals and humans, as well as for proper muscle contraction and nerve transmission. In soil, calcium is typically not a contaminant and, in fact, can help alleviate the impact of toxic heavy metals by lowering their ability to move and be absorbed by living organisms. Contrary to heavy metals like lead or cadmium, calcium has a positive impact on both the environment and living organisms. Calcium concentrations follow a similar trend, being slightly lower in the test sites (13.441 ppm to 15.474 ppm) than in the control locations (14.878 ppm and 14.977 ppm). While calcium is critical for soil structure and nutrient availability, the marginal reduction observed in the contaminated areas aligns with findings from previous studies (Nwachukwu et al., 2015), where lead and other metals interfere with nutrient cycling.

Lead (Pb) is a highly toxic heavy metal that has been extensively used in various industrial processes, particularly in the production of lead-acid batteries. Improper disposal of batteries frequently results in lead contamination, as the element leaches into the surrounding environment, notably into soil and water. Lead in the soil remains present for extended periods and its ability to move is affected by factors including pH levels and the presence of organic matter. Lead exposure poses significant health risks due to its toxicity, which can cause severe effects on the nervous system, kidneys, and cognitive development, with children being particularly vulnerable. Lead absorption in plants and crops can lead to decreased growth and contamination of the food supply, presenting hazards to both ecosystem health and human welfare. Lead levels are notably higher, ranging from 3.888 ppm to 3.899 ppm in the test sites, compared to 0.892 ppm and 0.881 ppm in the control sites. This finding is consistent with several studies, such as Adegoke et al. (2019), which reported elevated lead levels in soils near battery recycling plants. Lead contamination poses severe risks to both soil health and human health, with levels exceeding the permissible limits set by international environmental standards.

Cadmium (Cd) is a highly toxic heavy metal, often found in industrial waste, including used lead-acid batteries (ULAB), though in smaller quantities compared to lead. Cadmium poses a notable threat to the environment, largely due to its capacity to endure in the environment and its ease of movement through soil and water. In polluted soil, cadmium can be taken in by plants, resulting in the buildup of toxins in the food chain, which poses significant health hazards to both humans and animals. Cadmium exposure, even in minimal quantities, can lead to kidney damage, bone-related disorders, and breathing problems, and is classified as a human cancer-causing agent by the International Agency for Research on Cancer (IARC). Cadmium contamination in the soil can interfere with the normal functioning of microorganisms, thereby decreasing soil fertility and ultimately affecting crop production. The mobility of cadmium in the soil is influenced by factors like pH and the level of organic matter present, which underscores the need to closely monitor cadmium levels in areas affected by industrial activities, notably those resulting from the improper disposal of batteries. Similarly, cadmium concentrations in the test locations are higher (1.022 ppm to 1.084 ppm) compared to the control samples (0.109 ppm and 0.119

ppm). Cadmium is a toxic metal that accumulates in soils contaminated by ULAB activities, posing risks to plant and animal life. The values observed in this study are comparable to those reported by Olayinka et al. (2018), highlighting the need for urgent remediation to prevent further environmental damage.

Zinc (Zn) is an essential trace element that plays a crucial role in various biological processes in both plants and animals. In plants, zinc is essential for enzyme activity, protein production, and growth control processes. Improving crop yield and enhancing resistance to environmental stresses are its benefits. High levels of zinc in the soil can cause toxicity, negatively impacting plant growth and development. Zinc is often present in industrial waste and can build up in soil, especially near mining operations and locations where zinc-containing goods, such as batteries, are discarded inappropriately. Although zinc is essential for human well-being, with roles including immune function and cellular metabolism, excessive amounts can be detrimental. High levels of zinc exposure can trigger gastrointestinal problems, impair the uptake of vital minerals, and result in oxidative stress within living organisms. Checking zinc levels at polluted locations is crucial as it may also react with other heavy metals, potentially making their hazardous impacts worse. Zinc levels in the test locations are also significantly higher, ranging from 4.278 ppm to 5.473 ppm, compared to 1.372 ppm and 1.745 ppm in the control samples. Zinc is an essential trace element, but at elevated concentrations, it can become toxic to plants. The high levels of zinc observed in the study may be attributed to the improper disposal of ULAB components, which release metals into the soil. This finding aligns with Adefila et al. (2020), who reported similar levels of zinc contamination in soils near battery recycling sites.

Copper (Cu) is an essential trace metal necessary for various biological functions in plants and animals. Copper has a vital function in plant processes, including photosynthesis, respiration, and the activation of enzymes. Overall development and growth are crucial. Similar to other metals, high levels of copper in the soil can result in toxicity, ultimately impacting plant health and growth negatively. Copper can contaminate the soil via multiple pathways, such as agricultural runoff from fungicides containing copper, industrial effluent releases, and the unregulated disposal of electronic waste, including discarded lead-acid batteries (ULAB). Copper plays a crucial role in human health, influencing both iron metabolism and the proper functioning of the nervous system, but excessive levels can cause health problems including liver damage and gastrointestinal discomfort. In environments contaminated with pollutants, it is crucial to monitor copper levels, as this metal can build up in the food chain and interact with other heavy metals, thereby escalating their toxic impact on ecosystems and human well-being.Copper concentrations show a similar trend, being significantly higher in the test locations (0.989 ppm to 1.811 ppm) compared to the control sites (0.019 ppm to 0.022 ppm). Elevated copper levels can lead to soil toxicity, as previously documented in studies like Obasi et al. (2019), which reported high copper levels in ULAB-impacted areas.

Chromium (Cr) is a heavy metal that occurs in several oxidation states, with trivalent chromium (Cr(III)) being an essential nutrient in trace amounts, necessary for insulin function and glucose metabolism. Hexavalent chromium (Cr(VI)) poses a substantial threat due to its high toxicity and carcinogenic properties, thus being a major environmental and health issue. Chromium can contaminate soil and water via industrial activities, including metal plating, leather tanning, and the disposal of used lead-acid batteries (ULAB). The presence of hexavalent chromium is particularly concerning because of its high solubility and mobility in the environment, which enables it to easily pollute groundwater and soil. Exposure to chromium, particularly in its hexavalent state, may result in serious health complications, encompassing respiratory difficulties, skin lesions, and a heightened danger of lung cancer. Chromium contamination in soils can have a detrimental impact on microbial ecosystems and plant development, resulting in decreased agricultural output. Comprehending the various levels and types of chromium found at polluted locations is essential for evaluating environmental hazards and developing solutions to mitigate them. Chromium concentrations in the test locations range from 0.648 ppm to 0.755 ppm, significantly higher than in the control samples (0.048 ppm and 0.046 ppm). Chromium, particularly in its hexavalent form, is highly toxic and poses long-term risks to soil quality and plant growth. The values observed in this study are comparable to those reported by Adegoke et al. (2019), who found elevated chromium levels in soils contaminated by ULAB activities.

Other metals such as manganese, iron, and aluminum also show elevated levels in the test locations. Manganese (Mn) is a vital micronutrient that has a significant function in numerous physiological processes in both plants and animals. Manganese plays a crucial role in photosynthesis, respiration, and the production of specific enzymes in plants. Chlorophyll formation and the initiation of metabolic processes are particularly crucial for growth and development. Excessive manganese concentrations in the soil can cause toxicity issues, especially in specific plant species. Exposure to high levels of manganese can disrupt the absorption of vital nutrients, including iron, thereby causing nutrient deficiencies and decreased crop production. Manganese can enter the environment due to industrial activities, mining, and the incorrect disposal of waste materials, such as used lead-acid batteries (ULAB) and other discarded items. Excessive manganese exposure can have negative effects on human health, potentially leading to neurological problems such as manganism, a condition that shares similarities with Parkinson’s disease. Maintaining low manganese levels in polluted soil is essential, as this can impact plant vitality and the quality of edible crops, ultimately influencing human health indirectly. Manganese concentrations range from 1.011 ppm to 3.556 ppm in the test locations, slightly higher than in the control locations (2.036 ppm and 2.200 ppm). Manganese is an essential nutrient, but elevated levels suggest contamination and potential toxicity.

Iron (Fe) is a vital micronutrient necessary for numerous physiological functions in both plants and animals. Iron is crucial for plants in the production of chlorophyll and also plays a vital part in photosynthesis, respiration, and the proper functioning of enzymes. Iron plays a crucial role in both nitrogen fixation and the production of specific proteins. Excessive iron is toxic, especially in certain soil conditions, despite the fact that iron is essential for life. Excessive iron levels can cause the development of insoluble compounds that lower the accessibility of other vital nutrients, which may negatively affect plant growth and agricultural output. Iron can enter the soil via natural processes, like the weathering of rocks, and also through industrial activities, which involve the disposal of waste materials and the application of iron-containing fertilizers. Iron is vital for human health, involved in oxygen transport and metabolism, yet excessive levels in drinking water or soil can result in health complications, encompassing gastrointestinal issues and oxidative stress. Maintaining iron levels in soils is crucial as they can have a significant impact on soil quality, plant health, and the wider environment (as they can affect soil quality, plant health, and the broader ecosystem). Similarly, iron concentrations are higher in the test locations (6.899 ppm to 7.556 ppm) compared to the control sites (3.279 ppm and 3.444 ppm). The higher iron levels observed in the contaminated areas are consistent with previous studies (Okoye et al., 2018), indicating metal accumulation due to ULAB activities.

Aluminum (Al) is a widely distributed metal in the environment, primarily found in soil, minerals, and water. Aluminum is not regarded as a vital nutrient for either plants or animals, yet it can impact soil characteristics and the availability of nutrients. In acidic soils, aluminum's solubility and availability for plant uptake can increase, posing a threat to plant health. Exposure to high levels of aluminum is detrimental to numerous plant species, resulting in restricted root development, diminished nutrient absorption, and a general decline in plant vitality. Aluminum toxicity can also impact soil microorganisms, thereby disrupting their natural ecological balance and consequently affecting soil fertility. Aluminum can contaminate the environment via a range of sources, including industrial operations, mining, and the uncontrolled disposal of products containing aluminum, such as used lead-acid batteries (ULAB). Generally, exposure to aluminum is seen as posing a low risk to human health, but high levels of aluminum in drinking water or food have been linked to neurological disorders and other health issues. Evaluating aluminum levels in soils is crucial for determining its effects on plant development, soil quality, and the overall functioning of ecosystems. Aluminum concentrations were generally low, ranging from 0.003 ppm to 0.028 ppm, with slightly higher values in the test locations. Aluminum is not typically considered a heavy metal, but its presence at these levels may indicate soil acidification, a phenomenon commonly observed in contaminated areas (Nwachukwu et al., 2015). Overall, the elevated levels of toxic metals such as lead, cadmium, zinc, and copper in the test locations, when compared to the control samples, are consistent with findings from similar studies conducted in Nigeria and other parts of the world. For example, Adegoke et al. (2019) reported similar contamination patterns in soils near ULAB recycling sites, with lead and cadmium concentrations significantly exceeding permissible limits. The acidification of the soil, reflected by the lower pH values in the impacted areas, further exacerbates the mobility of these heavy metals, leading to higher bioavailability and greater risks to the ecosystem (Nwachukwu et al., 2015).

The reduction in essential nutrients such as potassium and magnesium highlights the detrimental impact of ULAB activities on soil fertility. These findings are consistent with the work of Obasi et al. (2019), who documented nutrient depletion in lead-contaminated soils, resulting in reduced agricultural productivity and increased environmental hazards. In conclusion, the results of this study indicate that ULAB activities have significantly contaminated the soil at Mgbuka Obosi, leading to elevated levels of toxic metals such as lead, cadmium, zinc, and copper. These metals pose severe risks to soil health, plant growth, and human health, as they can easily enter the food chain through crops grown in contaminated soils. Additionally, the reduction in essential nutrients further underscores the degradation of soil quality in the affected areas. Remediation efforts and stricter environmental regulations are urgently needed to address this contamination and prevent further environmental degradation.

Comparison between the soil heavy metal parameters of the study area with that of WHO standards

Table 3: Heavy metal parameters

Soil Parameters	Mean Values (Mgbuka Obosi)	WHO
		≤100
Sodium (ppm)	28.430	
Potassium (ppm)	17.653	NG
Magnesium (ppm)	15.875	NG
Calcium (ppm)	14.051	NG
Manganese (ppm)	2.648	≤2000
Zinc (ppm)	5.035	≤300
Arsenic (ppm)	0.000	20
Aluminum (ppm)	0.018	NG
Lead (ppm)	3.894	≤100
Cadmium (ppm)	1.066	3
Copper (ppm)	1.545	≤100
Chromium (ppm)	0.708	<100
Iron (ppm)	7.291	300

NG = Not Given

Sources: Docchy Analytical Laboratories and Environmental Services Limited

From Table 3, the mean heavy metal concentrations in the soil of Mgbuka Obosi were compared with the World Health Organization (WHO) standards for safe levels of heavy metals in soil. This comparison highlights significant deviations from recommended limits, particularly for toxic metals such as lead (Pb), cadmium (Cd), zinc (Zn), copper (Cu), among others. It is worthy to note that the WHO standards for Potassium, Magnesium, Calcium, and Aluminum were not given. For the rest parameters such as Sodium, Manganese, Zinc, Arsenic, Lead, Cadmium, Copper, Chromium, and Iron, the mean values were all below the WHO standards.

Test of Hypothesis

The hypothesis which states that there is no significant difference between the heavy metal parameters of the soils of Mgbuka Obosi and that of the control areas was tested using the Independent Samples t-test.

Table 4: Test analysis result of the heavy metal parameters of the soil

Group Statistics

	Locations	N	Mean	Std. Deviation	Std. Error Mean
Heavy Metals	Mgbuka Obosi	13	53.1652	56.28715	15.61125
	Control	13	13.6075	19.14897	5.31097

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Heavy Metals	Equal variances assumed	3.356	.079	2.399	24	.025	39.55769	16.48992	5.52417	73.59121
	Equal variances not assumed			2.399	14.741	.030	39.55769	16.48992	4.35640	74.75899

From Table 4, the mean value for the heavy metal parameters of the soils of Mgbuka Obosi is 53.165 with a standard deviation of 56.287 while the mean value for the control is 13.608 with a standard deviation of 19.149. For the Independent Samples Test, t(24) = 2.399, p = 0.25. With the p-value of <0.05 means that the null hypothesis of no significance difference is rejected while the alternative hypothesis of significance difference is accepted. This implies that there is significance difference between the heavy metal parameters of the soils of Mgbuka Obosi and the control areas, in Idemili North L. G. A. of Anambra State.

CONCLUSION AND RECOMMENDATIONS

This research examined the detrimental impact of used lead-acid battery (ULAB) activities on the soil of Mgbuka Obosi, Idemili North L.G.A, Anambra State. Great differences exist between the heavy metals of the soil of Mgbuka Obosi with that of the control sites. The findings demonstrated significantly elevated levels of toxic heavy metals, including lead, cadmium, zinc, copper, chromium, among others, all of which showed significant difference when compared with control sites. These elevated concentrations pose serious environmental risks, affecting soil health and plant growth, and pose a potential threat to human health through the contamination of the food chain. The study also indicates that although essential nutrients such as sodium, magnesium, calcium, among others remain relatively stable, the prolonged presence of toxic metals may disrupt the overall nutrient balance in the soil, reducing fertility and agricultural productivity over time. From the findings, the study recommends that ongoing environmental monitoring should be performed to evaluate the levels of heavy metals in the soil, water, and air surrounding ULAB facilities. This will allow for the early identification of contamination and prompt action to be taken. Local authorities should conduct regular evaluations to monitor soil quality and verify adherence to environmental regulations. More so, it is crucial to inform local residents about the risks associated with the disposing of ULAB inappropriately and the resultant heavy metal pollution.

Public information campaigns should be undertaken to educate residents on the dangers linked to polluted soil, and the significance of proper recycling and waste management procedures.

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