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Assessment of the Heavy Metal Concentrations in Soil around Some Welding Workshops in Hwolshe, Jos South LGA, Plateau State, Nigeria

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Abstract

Heavy metal pollution of soil has become a primary concern due to welding activities including metal production, auto repair, and battery recycling. This research examines the concentration of heavy metals in soil samples collected from welding workshops in Hwolshe, Jos South LGA, Plateau State. The levels of lead (Pb), titanium (Ti), zinc (Zn), vanadium (V), cobalt (Co), manganese (Mn), chromium (Cr), and iron (Fe) were analyzed using x-ray fluorescence (XRF). Results revealed mean levels of 104.58 mg/kg for Pb, 8032.97 mg/kg for Ti, 126.32 mg/kg for Zn, 34.16 mg/kg for V, 228.88 mg/kg for Co, 415.98 mg/kg for Mn, 21.68 mg/kg for Cr, and 141603.58 mg/kg for Fe. These values were significantly higher than the control, confirming contamination from industrial activities. The levels of the metals decreased in the order: Fe > Ti > Zn > Co > Mn > Pb > Cr > V. Pollution Index (PI) and Enrichment Factor (EF) analyses categorized the metals under slight to moderate contamination, with Fe showing the highest contamination levels. The results indicate that in order to lessen the negative effects of heavy metal pollution on the environment, it is urgently necessary to adopt eco-friendly materials, improve waste management procedures, and conduct routine soil quality testing.

Keywords: Assessment; Concentration; Heavy Metal; Welding & Workshop.

Introduction

Soil pollution by heavy metals is an increasing environmental concern due to its harmful effects on human health and ecosystems [1, 2]. Industrial activities, particularly those carried out in workshops, are major contributors to soil contamination [3, 4]. These activities often release heavy metals such as lead (Pb), cadmium (Cd), zinc (Zn), copper (Cu), and nickel (Ni) into the soil. Such metals are toxic, persistent, and pose serious health risks [5, 6].

Their presence can reduce soil quality, hinder plant growth, and affect human health through the food chain [7]. High concentrations also inhibit microbial activity and diversity, weakening soil health and resilience [8]. This disruption reduces soil fertility and impairs plant development, creating a cycle of environmental degradation [9].

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Prolonged exposure leads to bioaccumulation, which worsens toxicity. Therefore, monitoring and managing heavy metal levels in soils, especially in industrial areas, is essential.

Many studies have shown that industrial areas in Nigeria often display elevated levels of heavy metals in the soil, surpassing international safety standards and leading to adverse health effects [10, 11]. This underscores the need for regular monitoring and assessment of soil quality in industrial regions to prevent adverse health and environmental outcomes. In industrial areas, these metals often accumulate to harmful levels due to improper waste disposal practices and emissions from machinery and vehicles. Studies have shown that industrial soils can have heavy metal concentrations several times higher than those in non-industrial areas, posing significant ecological and health risks [12].

Managing soil contamination efficiently requires an integrated approach involving regulatory frameworks, community awareness, and technological solutions. Implementing policies to control emissions and ensure the safe disposal of industrial waste is fundamental. Furthermore, public awareness campaigns can educate local communities about the dangers of soil contamination and promote practices that minimize exposure [13].

This study aims to contribute to the body of knowledge on soil contamination in industrial areas by assessing the level of heavy metals contamination in the soil around welding workshops in Hwolshe, Jos South Local Government Area (LGA), Plateau State, Nigeria.

Materials and Methods

Description of Study Area

Hwolshe is a commercial and industrial area located in Jos South LGA, Plateau State, Nigeria. The area is characterized by numerous workshops engaged in metalworking, vehicle repair, and battery recycling, which are potential sources of heavy metal contamination. The geographical coordinates of Hwolshe are approximately 9^0 52' 52" N latitude and 8^o 52' 02" E longitude.

Methods

Sampling Design and Collection

A stratified random sampling approach was adopted to ensure representative soil samples from different workshop sites in Hwolshe. The study area was divided into several zones based on the density and type of industrial activities. Within each zone, random sampling points were selected. Soil samples were collected from ten (10) different locations within the study area. At each location, samples were taken from the topsoil (20 cm depth) using a clean shovel to avoid contamination. Approximately 1 kg of soil was collected at each sampling point and stored in clean, labelled polyethylene bags. The samples were then transported to the laboratory for analysis.

Sample Preparation and Analysis

In the laboratory, soil samples were air-dried at room temperature for 72 hours. The dried samples

were then sieved through a 2 mm mesh to remove debris and homogenized to ensure uniformity. The concentrations of the heavy metals in the soil samples were then quantitatively determined using X-ray fluorescence spectrophotometer (Thermo Fisher Scientific, USA) [2, 14, 15].

Statistical Analysis

Mean concentrations and standard deviation of heavy metals in soil collected from different locations were computed using Statistical Analysis system Software (S.A.S 9.0, 2008).

Results and Discussion

The results of the analysis of heavy metal concentrations around welding workshops in Hwolshe, Jos South LGA, Plateau State is presented in Table1.

Lead (Pb)

The mean lead (Pb) concentration obtained in this study was 104.58 mg/kg, which was considerably higher than the control value of 34.52 mg/kg. This indicates that anthropogenic activities, particularly those associated with welding workshops, are a major source of lead contamination. Lead may have been introduced through soldering flux, metallic waste, and welding emissions, all of which facilitate its release into surrounding soils. The measured concentration exceeded the [16] threshold of 85 mg/kg, though it remained below the [17] permissible limit of 300 mg/kg. This raises concerns about potential health risks, especially in areas with a high concentration of welding activities.

In comparison, [18] reported Pb levels of 150 mg/kg in welding workshop soils in Ibadan, which is higher than that recorded in this study, suggesting regional variations in contamination levels due to differences in workshop density and industrial practices [19]. Similarly, [20] observed a Pb concentration of 120 mg/kg in Port Harcourt, closely aligning with the present findings and highlighting the widespread nature of lead pollution associated with welding operations across Nigeria.

The Enrichment Factor (EF) for Pb was 0.95, classifying it within the range of deficiency to minimal enrichment. This suggests that although natural sources contribute slightly, human activities are the dominant input. The Pollution Index (PI) of 0.35 indicates slight contamination, implying that while Pb contamination exists, it is not yet at a level posing immediate environmental danger. To mitigate lead pollution, welding workshops should adopt lead-free materials, improve waste management practices, and undertake periodic soil remediation.

Chromium (Cr)

The mean chromium (Cr) concentration of 21.68 mg/kg in this study was higher than the control value of 10.76 mg/kg, indicating localized contamination likely linked to welding activities. Despite this increase, the concentration remained well below the USEPA limit of 180 mg/kg and the

WHO permissible limit of 100 mg/kg, meaning the levels are still within international safety standards. Compared with other regions, [20] reported 30 mg/kg in Lagos, while [23] found 25 mg/kg in Abuja—both slightly higher than the values recorded in this study. This suggests that chromium contamination in the study area is relatively lower than in other industrial locations.

The Enrichment Factor (EF) of 0.63 indicates deficiency to minimal enrichment, while the Pollution Index (PI) of 0.22 classifies the contamination as slight. The observed Cr levels are likely due to welding fumes and improper disposal of chromium-containing materials. To prevent further accumulation, improved waste management and the adoption of eco-friendly welding practices are recommended.

Zinc (Zn)

The mean concentration of zinc (Zn) in this study was 126.32 mg/kg, slightly higher than the control value of 116.04 mg/kg, indicating localised contamination likely arising from welding residues and poor handling of Zn-containing materials such as coatings and scrap metals. Although Zn levels were below the FEPA permissible limit of 300 mg/kg, they exceeded the FAO/WHO Recommended Maximum Level for Vegetation (RMLV) of 99.4 mg/kg, suggesting possible risks to plant and soil health. Comparable studies reported similar concentrations, with [21] recording 140 mg/kg in Kano and [22] reporting 110 mg/kg in Abuja, aligning closely with this study.

The Enrichment Factor (EF) of 0.34 indicates deficiency to minimal enrichment, while the Pollution Index (PI) of 0.42 classifies Zn as slight contamination. The elevated Zn levels may be attributed to prolonged deposition of welding residues and inadequate site management. To mitigate zinc contamination, the use of less Zn-intensive welding materials, coupled with strict enforcement of environmental waste disposal practices, is strongly recommended.

Vanadium (V)

The mean vanadium (V) concentration of 34.16 mg/kg was notably higher than the control value of 12.90 mg/kg, indicating contamination likely associated with industrial activities, particularly the use of welding electrodes and metal alloys that contain vanadium [19]. Although the value remained below the FEPA limit of 100 mg/kg, it exceeded the WHO permissible limit of 20 mg/kg, suggesting potential environmental and health concerns. Similar studies have reported comparable levels, with [20] recording 40 mg/kg in Lagos and [19] documenting 35 mg/kg in Port Harcourt, underscoring the widespread presence of vanadium near industrial areas.

The Enrichment Factor (EF) of 0.83 indicates deficiency to minimal enrichment, while the Pollution Index (PI) of 0.34 classifies vanadium levels as slight contamination. The elevated

concentrations may result from the accumulation of welding residues and inadequate waste disposal practices. To reduce vanadium pollution, improved handling, proper disposal, and recycling of welding by-products are strongly recommended.

Cobalt (Co)

The mean cobalt (Co) concentration of 228.88 mg/kg, with no detection in the control sample, indicates that the metal originates primarily from industrial activities, likely from cobalt-containing welding rods [8]. Although the value falls below the FEPA permissible limit of 300 mg/kg, it remains a concern due to cobalt's known toxicity. Similar concentrations have been reported in other industrial areas, with [20] noting 200 mg/kg in Lagos and [8] documenting 210 mg/kg in Enugu, closely aligning with the findings of this study.

Because cobalt was absent in the control sample, the Enrichment Factor (EF) could not be calculated. However, the Pollution Index (PI) of 0.23 categorizes the contamination as slight. The elevated levels are likely linked to the improper disposal of cobalt-based welding consumables. To reduce cobalt pollution, the adoption of cobalt-free welding materials, stricter enforcement of waste management regulations, and environmentally responsible industrial practices are recommended.

Table 1: Concentration of Heavy Metals Around Welding Workshops in Hwolshe, Jos South LGA, Plateau State

Sample	Pb	Ti	Zn	V	Co	Mn	Cr	Fe
A	187.67	4856.32	170.35	68.20	505.62	413.89	38.98	106168.6
B	27.33	378.77	112.83	10.14	ND	247.28	15.24	36804.70
C	34.27	2051.86	144.26	41.71	200.46	727.32	23.87	73429.45
D	169.06	746.02	77.84	16.59	209.46	275.46	8.64	35011.54
Average	104.58 ±4.82	8032.97 ±18.85	126.32 ±8.34	34.16 ±5.5	228.88 ±81.53	415.98 ±45.41	21.68 ±2.07	141603.58 ±212.52
Control	34.52	981.34	116.04	12.90	ND	317.80	10.76	4238.38

ND= Not Detected
Sample A = Jiyep
Sample B = Jeka Kadima
Sample C = Hwolshe ringroad
Sample D = Old airport behind NITEL office

Table 2: Heavy Metal Enrichment Factor (EF) and Pollution Index (PI) around Welding Workshops in Hwolshe, Jos South LGA, Plateau State

Heavy Metal	Enrichment Factor	Pollution index
Pb	0.95	0.35
Ti	2.56	0.95
Zn	0.34	0.42
V	0.83	0.34
Co	-	0.23
Mn	0.41	0.49
Cr	0.63	0.22
Fe	1.00	2.83

Manganese (Mn)

Manganese (Mn) recorded a mean concentration of 415.98 mg/kg, which was higher than the control value of 317.80 mg/kg, suggesting contamination likely arising from welding residues and metal scraps. These manganese levels were well below the FAO limit of 850 mg/kg, indicating that they remain within an acceptable range, though still concerning due to the elevated concentrations. Comparatively, [18] in Ibadan reported manganese levels of 400 mg/kg, and [20] in Port Harcourt reported 350 mg/kg, which aligns closely with the findings of this study.

The Enrichment Factor (EF) for manganese was 0.41, signifying minimal enrichment, while the Pollution Index (PI) of 0.49 places it in the moderate contamination category. To mitigate manganese contamination, the use of Mn-free welding electrodes and improvements in site remediation and waste disposal practices are recommended. The observed manganese contamination can largely be attributed to prolonged welding activities and inadequate management of metal waste.

Chromium (Cr)

The mean chromium (Cr) concentration in this study was 21.68 mg/kg, significantly higher than the control value of 10.76 mg/kg, indicating localized contamination potentially linked to industrial activities such as welding. These levels are well below the USEPA limit of 180 mg/kg and the WHO permissible limit of 100 mg/kg, suggesting that while the contamination is notable, it remains within the internationally accepted safety thresholds. When compared to other studies, [20] recorded chromium levels of 30 mg/kg in Lagos, also [23] found in a separate study found the concentration of 25 mg/kg in Abuja, both of these studies as compared were higher than the findings in this study, indicating

relatively lower chromium contamination in this area.

The Enrichment Factor (EF) for Cr is 0.63, suggesting deficiency to minimal enrichment, and the Pollution Index (PI) of 0.22 categorizes the contamination as slight. The moderate chromium levels observed in this study are likely as a result of welding fumes and the improper disposal of chromium-containing materials. To minimize further contamination, it is recommended to improve waste management systems and adopt more eco-friendly welding practices that reduce the release of hazardous materials into the environment.

Iron (Fe)

The mean concentration of iron (Fe) in this study was 141,603.58 mg/kg, markedly higher than the control value of 44,238.38 mg/kg, indicating substantial contamination likely resulting from welding activities and accumulation of metallic waste. Given the permissible soil limit of 50,000 mg/kg, the elevated concentration raises concerns regarding potential ecological impacts, including alterations to soil pH and nutrient availability. Comparable studies reported similar findings, with [18] recording 130,000 mg/kg and [8] noting 120,000 mg/kg, supporting the widespread occurrence of iron contamination in industrial zones.

The Enrichment Factor (EF) of 1.00 indicates deficiency to minimal enrichment, while the Pollution Index (PI) of 2.83 classifies the soil as experiencing moderate pollution. The high iron levels are likely due to improper disposal of welding slag and scrap metals, which accumulate over time. To mitigate the impact of iron contamination, it is recommended to recycle iron-rich industrial wastes, improve waste management practices, and conduct regular soil quality monitoring [23].

The order of metal concentrations in the study, from highest to lowest, is as follows: iron (Fe) > titanium (Ti) > zinc (Zn) > cobalt (Co) > manganese (Mn) > lead (Pb) > chromium (Cr) > vanadium (V). This ranking reflects the varying degrees of contamination in the soil, with Fe exhibiting the highest concentration, likely due to its substantial presence in welding slag and metallic waste. Ti follows closely, indicating significant contamination from industrial activities, particularly welding electrodes. Zn, Co, and Mn show moderate levels of contamination, while Pb, Cr, and V exhibit relatively lower concentrations, but still above control levels, with Pb posing particular concern due to its toxicity.

The overall results of the Enrichment Factor (EF) and Pollution Index (PI) in this study indicate a mix of minimal to moderate contamination from various heavy metals in the soil around welding workshops. The EF values, ranging from 0.34 for zinc (Zn) to 2.56 for titanium (Ti), suggest mostly minimal to moderate enrichment, with titanium showing the highest enrichment, pointing to significant

anthropogenic input. The PI values further reflect this, with most metals falling under slight to moderate contamination categories. Lead (Pb), cobalt (Co), and vanadium (V) showed slight contamination, while iron (Fe) exhibited moderate pollution. Overall, the findings highlight the impact of industrial activities, particularly welding, on soil contamination, with several metals exceeding permissible limits and requiring attention for mitigation through better waste management and industrial practices.

Conclusion

Soil contamination around welding workshops is significantly influenced by anthropogenic activities, with elevated levels of Pb, Ti, Zn, V, Co, Mn, Cr, and Fe. EF and PI assessments indicate minimal to moderate enrichment, while iron shows moderate pollution. Although some metal concentrations, such as lead, fall below USEPA limits, they exceed WHO thresholds, posing potential health and environmental risks. Elevated titanium and cobalt reflect intensive industrial activity, whereas zinc and manganese point to poor waste management practices.

Mitigation requires sustainable waste handling, the use of low-metal or lead-free welding materials, and regular soil remediation. This study highlights the urgent need for stricter regulatory enforcement and greater awareness of the long-term impacts of industrial pollution on surrounding ecosystems.

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