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Original Research Article

An Assessment of Soil Physicochemical and Trace Metal Profiles around Welding Fabrication Areas of Abraka, Delta State, Nigeria

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KEYWORDS
Welding activities,
Metals,
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ABSTRACT
This study assessed the physicochemical and trace metal profiles of soils around from welding fabrication areas in Abraka, Delta state, Nigeria. Soil samples were collected from a welding (contaminated site) and a control site. Standard laboratory methods (APHA) and (AOAC) were used to analysed soil parameters and metal concentrations, with results compared against World Health Organization (WHO) limits. The welding-affected soils exhibited higher electrical conductivity and organic matter but lower bulk density content compared to the control site, suggesting better water retention in less-disturbed soils. Moisture content was notably higher in the control soil, suggesting better retention in undisturbed soils. Soil temperature, pH, and water holding capacity also varied between sites. Chemical analysis revealed lower calcium in the contaminated soil but higher magnesium and nitrogen, while phosphorous was reduced relative to the control, all within WHO acceptable ranges. Trace metal analysis showed extremely high levels of nickel and cadmium in the welding-affected soils, far above WHO limits. Other metals, including zinc, iron, lead, cobalt, manganese, copper, chromium, and arsenic, were also elevated relative to the control, although some remained within acceptable limits. The study concludes that welding activities substantially degrade soil quality and increase metal contamination, recommending periodic monitoring, safer waste management, and community awareness to mitigate impacts.

CITATION
Udo, M. W., Egboduku, W. O., Agbogidi, O. M., Micheal, O., & Obogbayiro, I. O. (2025). An Assessment of Soil Physicochemical and Trace Metal Profiles around Welding Fabrication Areas of Abraka, Delta State, Nigeria. *Journal of Science Research and Reviews*, *2*(4), 79-84. https://doi.org/10.70882/josrar.2025.v2i4.114

INTRODUCTION

Soil is a critical natural resource that serves as the foundation for terrestrial ecosystems, agricultural productivity, and environmental sustainability. If functions not only as a medium for plant growth but also as a natural sink for various environmental contaminants, including trace metals (Pam *et al.*, 2024). With the rapid increase in human activities such as urbanization, metal fabrication, and small- scale industrial operations, soils are increasingly exposed to different forms of pollution. Among these, contamination by trace metals has become a major concern due to the non- biodegradable and persistent nature of metals in soils (Ajeh *et al.*, 2022). Trace metals, including lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), Zinc (Zn), and nickel (Ni), occur naturally in soils at low concentrations but can reach toxic levels due to anthropogenic activities (Musa and Abdullahi, 2023). One of the most significant but often overlooked contributors to soil metal contamination is welding and metal fabrication activities. During welding, metallic fumes, slag, and particulates are released into the surrounding environment. These emissions eventually settle on nearby soils, increasing the concentration of trace metals over time (Onanuga *et al*., 2023). Improper disposal of metal scraps and welding residues further exacerbates the problem, creating hotspots of soil contamination in urban and semi-urban areas. The environmental and agricultural consequences of trace metal contamination in soils are profound. When metals accumulate in soil, they alter the soil's pH, cation exchange capacity, and microbial activity (Shah *et al*., 2021). Plants grown in contaminated soils are also at risk of bioaccumulating trace metals through root absorption, which negatively impacts plant physiology, causing stunted growth, chlorosis, reduced yields, and in severe cases, plant death (Huang *et al*., 2020). Soil, the uppermost layer of the earth's crust, provides essential ecosystem services such as biomass production, biodiversity support, and nutrient cycling. However, it is increasingly threatened by human activities, including welding operations. Studies show that welding releases significant amounts of metal -laden particulates and slag residues into soils. In Nigeria, soils around welding workshops and mechanic sites have been reported to contain elevated levels of Pb, Cd and Zn (Abdullahi and Musa, 2023; Onanuga *et al*., 2023). Similar results were documented in Port Harcourt, where soils near fabrication workshops showed altered pH and high EC (Eldori *et al*., 2021). Trace metals such as Cd and Ni are of particular concern because they persist for decades in soils, are highly mobile in sandy soils, and bioaccumulate in plants and humans. Humans exposure arises mainly from ingestion of contaminated food, inhalation of dust, or leaching into water bodies. Cd exposure is linked to kidney damage and cancer, while Ni poses carcinogenic risks and respiratory issues (Das *et al*., 2023; Bishnu Angon *et al*., 2024).

Mitigation strategies have been developed, including phytoremediation- using hyperaccumulator plants to absorb or stabilize metals (Yan *et al*., 2020) and bioremediation, which employs microbes to detoxify soils (Nedjimi, 2021). Despite these strategies, in Abraka, Delta State, there is little baseline data on the extent of welding-related soil contamination. This study therefore aimed to assess the physicochemical properties and trace metal profiles of soils in welding areas of Abraka, compare results with WHO/FAO (2010) limits, and evaluate potential ecological risks.

MATERIALS AND METHODS

Study Area

This study was carried out in Abraka, located in Ethiope East Local Government Area of Delta state, Nigeria. The study location is located between latitude 5º 45' and 5º 5 0' N and longitude 6º and 6º 15' E. This area is characterized by total annual rainfall of about 3.098mm with mean monthly rainfall ranging from 28.8mm. The soil temperature in this area is about 28℃ and the soil pH ranging from 4.5-8.

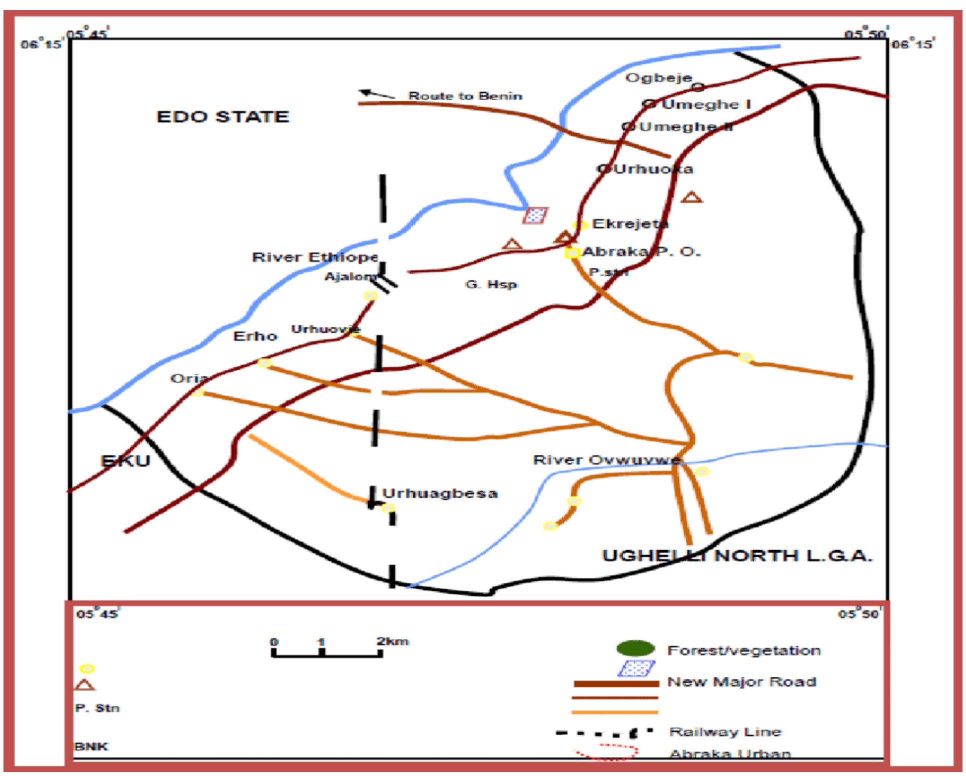

Figure 1: Map showing study area
Source: Ozabo and Obaro (2016).

Sample collection
Soil samples were collected from three active welding sites and two control sites into polythene bags at Abraka, Delta State.

Sample preparation
Samples were air -dried, sieved, and analysed following APHA (2012) and A0AC (2016) methods.

Physicochemical parameters measured included pH, organic matter, EC, bulk density, moisture content, porosity, soil texture, soil temperature, Ca, Mg, P, and N. Heavy metals (Fe, Cd, Pb, Zn, Cr, Mn, Cu, As, Ni, Co) were determined using Atomic Absorption spectrophotometry (AAS). Results were compared with WHO/FAO (2010) permissible limits.

RESULTS AND DISCUSSION

Table I: Physicochemical properties of controlled and contaminated soil compared to WHO/FAO (2010) Limit

Parameters	Control soil	Contaminated soil	WHO/FOA Limit
Soil Texture			
Sand	69.0	78.0	__
Clay	19.0	12.0	__
Silt	12.0	10.0	__
Soil Temperature	28.4	29.3	20-30
Water-Holding Capacity	13.5	10.6	10-60
pH	6.45	6.60	6.0-7.5
Electrical Conductivity	0.28	6.40	<4.0
Organic Matter	0.54	0.78	1.6
Moisture Content	13.5	10.6	10-30
Bulk Density	1.48	1.34	1.0- 1.6
Total Porosity	43.56	4.56	5-50
Calcium	5.40	4.20	2-20
Magnesium	3.96	5.62	2-15
Phosphorus	57.2	42.3	20-100
Nitrogen	0.03	0.04	0.02-0.5

Table (1) presents the physicochemical properties of soil samples collected from the uncontrolled (welding) site and the control site in Abraka, Delta State, Nigeria. The results obtained were compared with the standard limit recommended by WHO/FAO (2010) for soil quality assessment.

Table 2: Heavy metal concentrations in control and contaminated soil compared with WHO/FAO (2010) Limit

Trace metals	Control soil	Contaminated soil	WHO/FAO Limit (mg/kg)
Iron	0.058	16.76	50000.0
Manganese	___	0.67	2000.0
Copper	___	2.84	100.0
Cadmium	0.000	24.7	3.0
Cobalt	___	0.025	50.0
Lead	1.308	25.6	100.0
Nickel	___	786.34	50.0
Zinc	0.229	16.71	300.0
Chromium	0.015	0.24	100.0
Arsenic	____	0.11	20.0

Table (2) presents the concentrations of selected heavy metals (Cd, Pb, Fe, Zn, Mn, Cu, Co, Ni, As and Cr) in the contaminated (welding) soil and the control soil in Abraka, Delta State, Nigeria.

Discussion
The assessment of the physicochemical and heavy metal properties of soils collected from welding (uncontrolled) and control sites in Abraka, Delta State, provides valuable insight into the influence of welding fabrication activities on soil quality. The results were compared with the WHO/FAO (2010) soil quality limits to determine potential environmental and health risks. Overall, the findings indicate that welding activities have caused measurable changes in the soil's physical, chemical, and metal profiles.

Soil Physicochemical Properties

pH is a critical factor affecting soil fertility, microbial activity, and the mobility of heavy metals. The uncontrolled soil exhibited a pH of 6.60, while the control soil had 6.45, both within the slightly acidic to neutral range. These values align with the WHO/FAO (2010) recommended pH range for agricultural soils (6.0–7.5). A slightly acidic pH can enhance the solubility of certain heavy metals, increasing their bioavailability and potential toxicity to plants. Eldori *et al*., (2021) reported similar observations in semi-urban soils impacted by welding and metal fabrication, where pH fluctuations influenced the behaviour and mobility of trace metals.

Electrical conductivity (EC) indicates the concentration of soluble ions and serves as an indirect measure of soil salinity. The EC of the welding site soil (6.40 µS/cm) was substantially higher than that of the control soil (0.28 µS/cm), suggesting an accumulation of salts and metal ions from welding residues, metallic dust, and industrial effluents. High EC levels may inhibit plant growth by reducing water availability due to osmotic stress. This agrees with the findings of Ajeh *et al*., (2022), who linked elevated EC in industrial soils to the deposition of metal particulates.

Soil organic matter (OM) plays a vital role in nutrient cycling, water retention, and heavy metal immobilization. The welding site recorded 0.78%, slightly higher than the control (0.54%). Owamah *et al*., (2023) emphasized that organic matter can temporarily bind heavy metals, reducing their immediate bioavailability. However, under certain environmental conditions, such as flooding or acidification, these metals may be re-released. This explains why soils with moderate OM levels in contaminated areas can still exhibit significant metal bioavailability.

Soil texture affects porosity, permeability, and metal retention. The uncontrolled soil was 78% sand, 12% clay, and 10% silt, indicating a sandy texture, while the control soil was 69% sand, 19% clay, and 12% silt, closer to sandy loam. Sandy soils have lower cation exchange capacities, making them more prone to metal leaching. Abdullahi and Musa (2023) observed similar patterns in welding-impacted soils in Yobe State, where sandy textures facilitated metal mobility and increased groundwater contamination risks.

Moisture content and Water holding capacity (WHC) were 10.6% in the welding soil compared to 13.5% in the control. The lower moisture retention in the welding soil is due to its sandy nature and reduced pore spaces. This can limit microbial activity and nutrient availability, further affecting soil fertility.

Bulk density was 1.34 g/cm^3 for the welding soil and 1.48 g/cm^3 for the control soil. Both values fall within acceptable limits for agricultural soils (1.0–1.6 g/cm^3), but the slightly lower bulk density at the welding site suggests less compaction, likely due to its coarser texture.

Total porosity was 4.56% for the welding soil and 43.56% for the control. The extremely low porosity indicates poor water retention and limited air circulation, which can hinder root development.

Soil temperature was 29.3 °C for the welding soil and 28.4 °C for the control. Slightly elevated temperatures in welding areas may result from heat absorption by metal residues and reduced vegetative cover.

Calcium content of the control soil (5.40 cmol/kg) was slightly higher than that of the welding-impacted soil (4.20 cmol/kg). Both values, however, fall within the WHO/FAO permissible range of 2-20 cmol/kg. Calcium is an essential macronutrient that supports root development and improves soil structure. The slightly lower value in the uncontrolled site suggests that welding activities and deposition of metallic residues may gradually alter the soil’s nutrient balance, but the observed concentrations still indicate adequate calcium supply.

Magnesium concentration was higher in the contaminated soil (5.62 cmol/kg) compared to the control (3.96 cmol/kg). Both values remain within the WHO/FAO limit of 2-15 cmol/kg. Elevated Mg in the welding site could be attributed to metallic dust and slag released during fabrication, which may contribute to enrichment. While adequate magnesium supports chlorophyll formation and photosynthesis, excessive accumulation over time may disrupt the balance of Ca:Mg ratio in soil, which is critical for nutrient uptake.

Phosphorous concentration was 57.2 mg/kg in the control soil and 42.3mg/kg in the contaminated soil, both within the WHO/FAO permissible limit of 20-100 mg/kg. The slightly reduced phosphorus content in the welding site may result from metal contamination leading to fixation of phosphorus, thereby reducing its availability for plants. Since phosphorus is vital for energy transfer and root growth, reduced levels in polluted soils may negatively affect vegetation diversity and productivity.

Nitrogen concentration in both soils was relatively low, with 0.03% in the controlled soil and 0.04% in the contaminated soil. These values fall within the WHO/FAO permissible range of 0.02- 0.5 %. The similarity between both sites suggests that welding activities did not significantly influences soil nitrogen. However, the low levels overall indicate poor soil fertility status, since nitrogen is crucial for protein synthesis, vegetative growth, and overall soil productivity.

Heavy metal concentrations

Heavy metals showed pronounced differences between the welding and control soils, with most exceeding WHO/FAO (2010) permissible limits.

Cadmium (Cd) was 24.7 mg/kg in the welding soil and 0 mg/kg in the control, far exceeding the 3 mg/kg

WHO/FAO limit. High Cd levels can cause chlorosis, necrosis, stunted growth, and root decay in plants. In humans, chronic exposure leads to renal damage, hormonal imbalance, and fertility issues (Bishnu Angon *et al*., 2024; Das *et al*., 2023). Its absence in the control confirms that welding activities are the main Cd source.

The concentration of Iron (Fe) in the contaminated site was 16.76 mg/kg, while the controlled site was recorded 0.058 mg/kg. Both values are far below the WHO/FAO (2010) permissible limit of 50,000 mg/kg, indicating no contamination concern for iron in either location. The much higher value in the uncontrolled site compared to the controlled site may be linked to increased metal – related activities in the area.

Manganese (Mn) was observed at 0.67mg/kg in the contaminated site, while it was not detected in the controlled site. Both levels are far below the permissible limit of 2,000 mg/kg, suggesting that manganese concentration poses no hazard to soil quality or plant growth in either site.

Copper (Cu), in the uncontrolled site had 2.84 mg/kg, while the controlled site has no detectable amount. Both values are below the permissible limit of 100 mg/kg, indicating safe concentrations; however, the slightly elevated value in the uncontrolled site could be linked to activities involving metal welding and disposal of metal scraps.

Cobalt (Co) was recorded at 0.025 mg/kg in the uncontrolled site, while it was absent in the controlled site. Both are well below the permissible limit of 50 mg/kg, implying no contamination threat. The trace amount in the uncontrolled site is likely from localized anthropogenic sources.

Nickel (Ni) concentration in the contaminated site was 786.34 mg/kg, which is alarmingly higher than the permissible limit of 50 mg/kg. in contrast, the controlled site has no detectable nickel. This excessive level in the uncontrolled site suggests severe contamination, possibly from welding and mechanical activities. According to Abdullahi and Musa (2023), soils near welding shops in yobe state has Cu and Ni contamination factors above 200, with incremental lifetime cancer risk (ILCR) posing significant concerns for human hazards associated with the nickel contamination observed in the present study.

Lead (Pb) was detected at 25.6 mg/kg in the contaminated site, exceeding the permissible limit of 10mg/kg, while the controlled site recorded 1.308 mg/kg, which is within safe limits. The elevated value in the contamination site may be linked to battery waste, soldering, and other e-waste materials, posing a risk to soil health and human safety.

Arsenic (As) in the contaminated site was 0.11 mg/kg, and it was absent in the controlled site. Both values are below the WHO/FAO limit of 20 mg/kg, showing no immediate contamination concern for arsenic in either location.

Zinc (Zn) levels were 16.71 mg/kg in the contaminated site and 0.229 mg/kg in the controlled site, both of which are far below the permissible limit of 300 mg/kg. This indicates that zinc is within safe limits and poses no environmental or health risks.

Chromium (Cr) was 0.24 mg/kg, in the contaminated site and 0.229 mg/kg in the controlled site, both of which are far below the permissible limit of 300 mg/kg. This indicates that zinc is within safe limits and poses no major environmental or health risks.

The findings suggest that prolonged welding activity contributes to soil degradation, fertility loss, and ecological risks, with direct implications for agriculture and human health

CONCLUSION

The study concluded that welding fabrication activities in Abraka, Delta State, has significant effects on soil physicochemical parameters (soil texture, soil temperature, pH, moisture content, bulk density, total porosity, electrical conductivity,) etc. and heavy metal profiles (Cadmium, Lead, Nickel) etc. which some was below or exceeded the WHO/FAO (2010) permissible limits. The current study has great implication on soil degradation and environmental management.

RECOMMENDATIONS

Based on the findings, the followings are drawn:

1. Awareness programs for welders and local residents should be organized to educate them on the environmental and health hazards for improper waste disposal.
2. Periodic environmental assessment of soils in areas with high concentrations of welding and metal fabrication should be conducted. Routine monitoring will help identity early signs of contamination and allow for timely remediation efforts to reduce environmental and health risks.

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