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Analysis of Soil Heavy Metal Pollution in Automobile Workshops in Nnewi North, Anambra State

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Abstract

Heavy metal contamination from activities in automobile workshops is of public health concern. These heavy metals can remain in the environment over time. This study examined the concentration of soil heavy metal pollution in automobile workshops. To achieve the main objective, purposive sampling was adopted and 8 sites were identified of which 5 out of eight automobile workshops were selected and another sampling site which has no influence of automobile workshop activities was selected as the control. Soil samples from these areas were collected at a depth of 0-15cm using a locally fabricated stainless soil auger and a control sample was also collected for result comparison. The contamination level of the soil was calculated using the geo-accumulation index, the 5-sample site for Cd ranged from 1.6⁻ 73.93 mg kg^{-1},0.84 mg kg^{-1}- 6.39 mg kg^{-1} Cu, 0.06 – 5.28 mg kg^{-1}Pb, 1.16 – 1.99 mg kg^{-1} Zn, 0.4 – 2.13 mg kg^{-1} As, 1.56 – 3.03 mg kg^{-1}Hg. Samples 1,2,3,4,5 indicated a non-contamination level for Ni while Zn and As values for sampled site 1, 2, 3 and 4 ranging from 0.4 -2.13 mg kg^{-1}indicate an uncontaminated to moderately contaminated level. One-tailed ANOVA was employed to test the statistical difference in the concentration of heavy metals in the sampled sites. The result from the statistics showed a p-value of 0.002 which is <0.05. This suggests that the different sampled sites contribute differently to the concentration of heavy metals. There is a need for strict enforcement of safe waste-handling methods to reduce soil contamination around automobile workshops.

Keywords: Heavy metals, automobile workshop, soil, pollution, contamination

Introduction

Metals are persistent pollutants which when biomagnified in the food chain, become increasingly dangerous to humans and wildlife (Ali et al, 2019). The concentration of heavy metals in the soil is a significant risk and cannot be underrated because soil serves as the initial link in the food chain. When these metals are translocated into plants and animals, they can have detrimental effects. The rapid pace of urbanization has led to an increase in transportation and industrialization, which in turn contaminates the environment and contributes to various types of pollution, including land pollution. Land pollution remains one of the most challenging burdens in the world, often resulting from the indiscriminate disposal of waste through industrial processes and other human activities, such as those occurring in automobile workshops. For instance, automobile waste products, including gasoline, chemicals, and effluents from car batteries (containing various heavy metals) generated during auto repair or maintenance are frequently discharged indiscriminately into the environment.

These practices lead to ecosystem pollution, as most of the metals are absorbed into the soil, subsequently contaminating groundwater or other parts of the environment to which they are transported. These contaminants can then enter the food chain, affecting humans and animals through the consumption of plants and other substances that have absorbed these heavy metals. Myriads of studies have highlighted the effect of these heavy metals. In humans, these metals are present in body tissues, proteins and nucleic acids which leads to disturbance in bodily function (Jaishankar et al., 2014) when consumed. Automobile workers are at risk of experiencing health issues such as abdominal colic, impending lead toxicity, fatigue, constipation and central nervous system dysfunction (Adela et al. 2012). Research by Itanna (2002) and Naser et al. (2011) demonstrated that plants and leafy vegetables grown in contaminated soil or irrigated with polluted water can accumulate toxic heavy metals above the maximum limit stated by FAO (Food and Agricultural Organisation) in 1985and the United States Environmental Protection Agency.

Automobile services and repair shops are large generators of hazardous waste. These include used oil, fluid papers and plastic rapper, scrap metals, dirty shop rags, used parts, asbestos from brake pads, waste from solvents used for cleaning parts, greases, petrol, diesel, battery electrolyte, paints and other materials containing heavy metals. The major environmental wastes generated by the automotive manufacturing industry include machine lubricants and coolants, aqueous and solvent cleaning systems, paint, and scrap metals. If not handled and disposed of properly, these chemicals can contaminate air, water, soil, lakes and streams (Adeniyi and Afolabi, 2002). Furthermore, indiscriminate practices in automobile workshops have generally led to heavy metal contamination in soil (Adewoyin et al., 2013). Metals like nickel and zinc are essential in small quantities for the proper plant growth and human metabolism and their deficiencies can lead to disease and even death of the plant or animal (Asaah and Suh, 2005). However, due to their non-biodegradability, these metals can accumulate and persist in soils at levels harmful to the environment and public health (Lenntech, 2009). The impact of heavy metals from auto mechanic workshops has reached a disturbing level as environmental contamination is spreading widely to surface and groundwater through soil thus, significantly affecting plants, animals and man via the food chain process (Kim et al., 2022). Ojuri and Ogundipe (2012) reported that about 20million gallons of waste engine oil are generated annually in Nigeria from mechanic workshops, often discharged carelessly into the environment. Engine oil and other carbonated fluids, which contain heavy metals, become contaminated and transformed into used oil during use in automobiles (Nwachukwu 2010). When improperly disposed of, they increase the concentration of heavy metals in soils, particularly in auto-mechanic villages. Onianwa (2001) specifically indicated that awareness of the effects of soil pollution due to anthropogenic activities in most mechanic workshops in Nigeria has not received enough attention.

In Nigeria, the establishment of the automobile industry is continually on increase and most of them lack proper waste management practices. The major challenge with this is that most of these workshop floors are unpaved, and their generated waste is discharged into the unpaved floor, thus resulting in environmental pollution and soil contamination, which poses broader ecological and public health risks. Nnewi is notable as an industrial hub particularly renowned for its automobile industry. This reputation has led to a continual increase in the establishment of automobile workshops across the state. As a significant industrial and commercial suburban community, Nnewi hosts a variety of artisans and auto mechanics. These auto repair shops offer a wide range of services, from simple change to complex engine rebuilding, as well as auto-body repair, electrical welding, and painting services. However, many of these workshops have unpaved floors and wastes are often recklessly discharged into the environment. This indiscriminate disposal of automobile waste has the potential to exacerbate environmental contamination. Given the potential environmental and health risks associated with heavy metal contamination, it is imperative to assess the extent of soil pollution in automobile workshops in Nnewi North

Materials and Methods

Study Area

The study area for this research is Nnewi North Local Government Area of Anambra State, South-Eastern region Nigeria (Fig 1). The landmass is 1,076 square miles (2789km^2), lying about 25km south of Onitsha in Anambra State, (Amanze, Eze and Okoronkwo 2015). It is located between latitudes 5°59' 41.64"N and 6°03' 28.44"N and longitudes 6°03'28.44"E and 6°52' 41.64"E. It is notable for its commercial hub for automobile parts which gave it its name "the Japan of Africa".

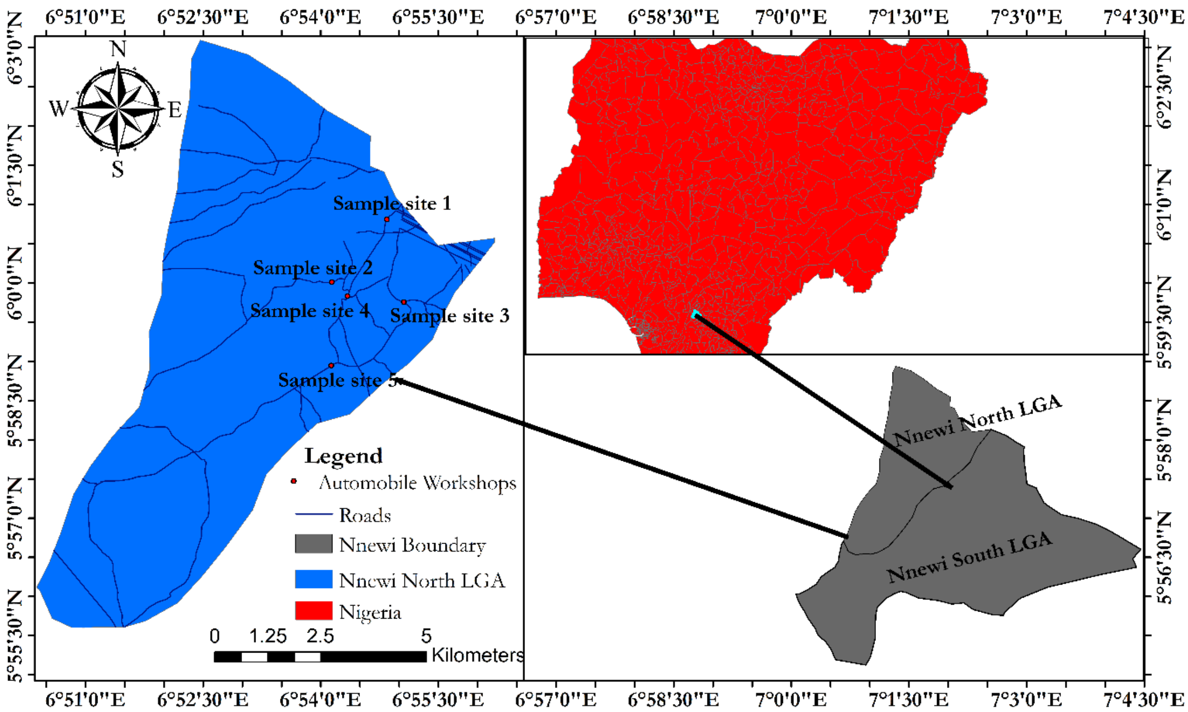

Fig 1 Map of the sample sites, with the map of Nnewi LGA and Nigeria inset

Sample preparation and analytical procedure

Out of 30 automobile workshops in the study area, five automobile workshops were selected (n=5 and 1 as a control sample). The five (5) mechanic workshops were selected based on the number of years of operation (not less than 5 years), absence of other industries within the area, presence of a drainage system (this was considered during sampling, as the presence of drainage system is a channel to remove fluids from the surface) and the type of activities carried out within the workshop. Workshops were purposively selected and studied. A total of 5 soil samples were collected from 5 workshops; with one soil sample from each of the 5 workshops collected at a depth of 0-15cm with the aid of a locally fabricated stainless depth soil auger. This equipment was thoroughly cleaned after each sampling to prevent cross-contamination. The samples were stored in clean polythene bags immediately after collection to avoid cross-contamination and transported to the laboratory. All samples were subsequently air-dried to constant weight to avoid microbial degradation of the soil content. They were homogenized (blended), to make lump-free by gently crushing repeatedly using an acid pre-washed mortar and pestle (to reduce contamination) and passed through a 2mm plastic sieve before analysis. About 30g dry soil samples were digested and stored at 4°C. The samples were then diluted using distilled water in a 100 ml Pyrex glass beaker and the filtrates were tested for concentration of heavy metals of cadmium (Cd), Copper (Cu), lead (Pb), Nickel (Ni), Zinc

(Zn), Arsenic (As) and Mercury (Hg) using Atomic Absorption Spectrophotometer (AAS). After the test, the data collected were compared with WHO Standards and further analysed statistically to check the significance in the measure of the chemical parameters of the soil samples.

Analysis of Variance (ANOVA) test is designed for simultaneous testing of equality of three or more populations of independent groups to determine if each group mean is identical on the assumption that each has a normal distribution around its mean (Helsel and Hirsch, 2002). Hence, the data obtained were analyzed using a single ANOVA. We tested if the data from the sample sites were identical or significantly different. Furthermore, the geoaccumulation index (Igeo) as proposed by Muller (1969), was employed to determine the degree of heavy metal contamination in the soils of the mechanic workshop. The control sample soil was used as a background value for Igeo calculation. The Igeo of metal in the soil was calculated using Equation 1

Igeo = log2 (Cn / 1.5Bn) ………………………………….. (1)

where Igeo is geo-accumulation index of the metal, Cn is the measured concentration of heavy metal in the sample, and Bn is the geochemical background value. The constant value, 1.5, is the background matrix correction factor due to the lithological variations. The geo-accumulation index (Igeo) values are shown in Table 1

Determination of heavy metal pollution level in the soil

The soil heavy metal pollution level can the determine using various indies. For this study the Igeo were employed to calculated and determined.

Table 1. Classification for Igeo values

Igeo	Class	Terminology
≤ 0	0	Uncontaminated
0-1	1	Uncontaminated to moderately contaminated
1-2	2	Moderately contaminated
2-3	3	Moderately to heavily contaminated
3-4	4	Heavily contaminated
4-5	5	Heavily to extremely contaminated
>6	6	Very extremely contaminated

Source: Muller 1969

Results and Discussion

Heavy metal concentration

The concentration of heavy metals from soil samples collected from different automobile workshops within the study area are shown in Table 2. The heavy metals explored in this study include Cd, Cu, Pb, Ni, Zn, As and Hg. These metals were determined and analysed from the sediment samples of five automobile workshops.

Table 2. Heavy metal concentration (mg kg^{-1}) of automobile workshops sampled

Soil Sample	Cd	Cu	Pb	Ni	Zn	As	Hg
1	1.169	0.479	0.061	0.028	2.021	0.006	0.176
2	0.218	0.114	0.227	0.001	2.679	0.012	0.212
3	0.029	0.132	0.222	0.00	3.344	0.032	0.132
4	0.020	0.399	0.475	0.00	3.450	0.009	0.109
5	0.024	0.063	0.055	0.00	2.542	0.026	0.126
Control	0.003	0.015	0.018	0.00	0.347	0.003	0.014
WHO	0.005	0.05	0.05	0.02	5.0	0.009	0.05

Soil sample (**automobile workshop**) sample site, Control (**control site sample**), WHO (**WHO standard value**)

The soil sample from the 5 sampled sites showed a ranging concentration of heavy metal (Table 2) of 0.024-1.169 mg $kg^{-1}$for Cd, 0.063-0.479 mg kg^{-1} Cu, 0.55-0.031 mg kg^{-1}Pb, 2.542-2021 mg kg^{-1} Zn, 0.026-0.006 mg kg^{-1}As and 0.126-0.176 mg kg^{-1}Hg. There was a detection of Ni heavy metal of 0.028 mg $kg^{-1}$and 0.001 mg kg^{-1} for sampled site 1 and 2 and no data or absence of Ni heavy metal for sample site 3, 4 and 5. The control sample were collected at a site away from auto workshop disturbances and this was also used as the background value. The control sample showed a concentration of 0.003, 0.015, 0.018,0.347, 0.003 and 0.014 mg kg^{-1}which is below the WHO permissible limits of0.005, 0.05, 5.0, 0.009 and 0.05for Cd, Cu, Pb, Zn, As and Hg, respectively. The control sample also showed absence of Ni at the permissible limit of 0.02 for WHO.

Index of geo-accumulation (Igeo)

Table 3. Igeo values for heavy metals (mg kg^{-1}) in soil samples

Soil Sample	Cd	Cu	Pb	Ni	Zn	As	Hg
1	73.93	6.39	0.68	0	1.16	0.4	2.52
2	14.53	1.52	2.52	0	1.54	0.8	3.03
3	1.93	1.76	2.44	0	1.93	2.13	1.89
4	1.33	4.52	5.28	0	1.99	0.6	1.56
5	1.6	0.84	0.611	0	1.47	1.73	1.8

Soil sample (**automobile workshop**)

The Igeo was used to calculate the heavy metal. The results of sampling point-wise geoaccumulation index contamination levels value and of different heavy metals in the soil of the study area were given in table. 3. According to Muller (1969), this index consists of seven scales (0–6) ranging from uncontaminated to very highly contaminated. These seven descriptive classes were: ≤ 0 indicating uncontaminated; 0-1=indicates uncontaminated to moderately contaminated, 1-2=moderately contaminated, 2-3=moderately to heavily contaminated, 3-4=heavily contaminated, 4-5=heavily to extremely contaminated, >5 very extremely contaminated. Using the Igeo as the basis for comparison for the result analysed.

The contamination level for the 5-sample site (Table 3) for Cd ranged from 1.6 - 73.93 mg kg^{-1},0.84 mg kg^{-1}- 6.39 mg kg^{-1}Cu, 0.06 – 5.28 mg kg^{-1}Pb, 1.16 – 1.99 mg kg^{-1} Zn, 0.4 – 2.13 mg kg^{-1}As, 1.56 – 3.03 mg kg^{-1}Hg. Sample 1,2,3,4,5 indicated non-contamination level for Ni while Zn and As value for sampled site 1, 2, 3, 4 ranging from 0.4 -2.13 mg kg^{-1}indicates uncontaminated to moderately contaminated level.

Automobile workshop samples 1 and 2 showed the highest Igeo values of 73.93mg $kg^{-1}$and 14.93mg $kg^{-1}$for Cadmium which indicates a very high level of cadmium contamination metals. This is seen to be likely be a result of improper disposal of cadmium batteries and used motor engine oil in the auto-mechanic workshop. Mechanic workshop sample 3 also showed high Igeo values for lead and cadmium, indicating a moderate to heavy contamination of lead and moderate contamination by Cadmium. This high lead and Cadmium contamination can be attributed to indiscriminate disposal of effluent from the used car battery and used gasoline within the workshop. The presence of heavy metals like lead and cadmium is toxic to the environment and poses serious health risks to humans. For instance, lead exposure can lead to kidney damage, disrupt haemoglobin biosynthesis, and cause mental retardation in children (Ara and Usmani, 2015).Cadmium in the soil can harm microorganisms and disrupt the soil ecosystem (Ogah et al., 2020).Inhalation of cadmium can severely damage the kidneys and lungs, with acute exposure causing symptoms like headaches, weakness, fever, and muscle pain, and potentially leading to kidney damage, lung cancer, bone disease, and pulmonary disease (Jarup et al., 1998; Adriano, 2001). Although research has shown that Cu could assist in disease resistance in plants and animals, seed production, prevention of anaemia and haemoglobin production (Bernard and Ayandeji, 2020), however, high concentrations can damage the vital organs of the body such as liver and kidney and even cause brain tumor and intestinal irritation when in high concentration (Wuana and Okieimen, 2011). Moreover, contamination of plants by copper can lead to its transfer to humans and animals through the food chain. Although trace amounts of essential metals like Cu, Fe, Zn, and Cr are essential metals for the biochemical functions of living organisms, they serve as components of enzymes, structural protein pigments and also help to maintain the ionic balance of cells, these metals however become toxic at higher concentrations. In contrast, lead and cadmium are generally toxic even at trace levels.

Table 4. Descriptive statistics of heavy metals (mg kg^{-1}) soil sample and WHO

Parameters	Min value	Max Value	Mean	Range	Standard deviation	Variance
Cd	0.020	1.169	0.292	1.149	0.483	0.233
Cu	0.064	0.479	0.237	0.415	0.187	0.035
Pb	0.055	0.475	0.208	0.420	0.173	0.030
Ni	0.00	0.028	0.008	0.028	0.0045	0.0002
Zn	2.021	3.450	2.807	1.429	0.593	0.352
As	0.006	0.032	0.017	0.026	0.010	0.0001
Hg	0.109	0.212	0.151	0.103	0.045	0.002

The mean concentration of heavy metals from the analysis of heavy metals was compared with WHO permissible limit. Table 4 indicates that Cd, Pb, Hg, Cu, As and Ni have 0.292 mg kg^{-1},0.237 mg kg^{-1}, 0.208 mg kg^{-1}, 0.008 mg kg^{-1}, 0.017 mg kg^{-1}, 0.151mg kg^{-1}which is higher as compared to the benchmark or permissible limit of WHO of 0.005, 0.05, 0.05, 0.002, 0.009

and 0.05 mg kg^{-1},respectively with exception of Zn (2.807mg kg^{-1}) in comparison with 5.0mg $kg^{-1}$of the WHO limits.

To determine if data from the sampled sites and control are identical or significantly different, we employed the use of a one-tailed Analysis of variance test (ANOVA) (Muhammad et al. 2011; Helsel and Hirsch, 2002)

Table 5. Analysis of variance test (ANOVA)

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	13.91	5	2.782	4.832	0.002
Within Groups	20.727	36	0.576		
Total	34.637	41			

Table 5 presents a one-tailed ANOVA statistical comparison of heavy metal collected from the sampled sites. The test confirmed statistical differences among the sampled sites in the concentration of heavy metals (<0.05). From the statistical table, it is shown that the p-value is 0.002 which is less than the significant threshold of 0.05. This reports a statistical difference among the sampled sites. Thus, this means that there is a significant difference between the heavy metal groups, indicating that the various automobile sample sites contribute differently to levels of heavy metals in the soil. This difference can be attributed to the volume of activities performed by these workshops, the type of material and fluids, and the method and management practices of handling waste. The high level of heavy metals identified in our study pose a risk of contamination to soil and water, potentially affecting not only flora and fauna but also pose a greater health risk for communities living near these polluted workshops.

Conclusion

The results from this study show that automobile workshop activities can impact soil through indiscriminate disposal of automobile waste. The analysis revealed contamination of soil with heavy metals in all the sampled sites and a significant variation between the heavy meals in the sampled sites. Based on these findings, we recommend that the authorities should: (1) employ phytoremediation technology which involves using plant to detoxify, absorb and accumulate pollutants from the soil (2) implement policies that promote sustainable management practices within the automobile industries.

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