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HEAVY METALS CONTAMINATION IN SOILS AT AUTOMOBILE WORKSHOPS IN BENUE STATE, NIGERIA

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Abstract: **Heavy metal pollution in the biosphere is an increasing human and environmental health concern due to anthropogenic sources of contamination. Automobile workshops continue to take the lead in heavy metal contamination in both rural and urban areas. This study determined the heavy metal concentration in soil located in automobile workshops in Benue State. The concentration of different metals including lead (Pb), cadmium (Cd), iron (Fe), copper (Cu), zinc (Zn), Manganese (Mn), arsenic (As), mecury (Hg), chromium (Cr), nickel (Ni) and cobalt (Co) were analyzed using a Flame Atomic Absorption Spectrophotometer (AAS) with proper digestion method. All the metal contents were compared with the established permissible limit provided by NESREA, WHO/FAO, EU, USEPA and as reported by different authors. The total mean concentrations in soil samples from the various automobile workshops were in the following order Fe>Cu>Zn>Pb>Mn>Cr>Ni>Cd>Co>As>Hg. The mean heavy metal pollution index (HPI) values at the various automobile workshops were obtained at 3.022, 3.110 and 3.553 at automobile workshops in Makurdi, Gboko and Otukpo respectively, which are higher than the critical value 1. In conclusion, heavy metal accumulation levels of soil in the selected experimental sites are significantly higher than their corresponding control samples.**

Keywords: **Heavy metals; Pollution index; Automobile Workshop; Environmental Pollution; Contamination.**

1. INTRODUCTION

In the last hundred years, the world has seen a rapid increase in urbanization and industrial development (Ozturk, *et al.*, 2017). This has resulted in the contamination of the environment by heavy metals. Their rates of mobilization and transport in the environment have greatly accelerated since 1940s (Ali *et al.*, 2019). Heavy metals are non-biodegradable, hence they are not readily detoxified and removed by metabolic processes. This leads to their build up (bioaccumulation) to toxic levels in the ecosystem (Adebawo, *et al.*, 2016). Heavy metal pollution in the biosphere is now one of the most serious environmental concerns due to its severe long-term implications on human health and the environment (Ali *et al.*, 2019). As such, Identifying areas with higher concentrations of heavy metals, guidelines, and effective legislation are necessary.

To control pollution, the origin of pollutants and emission must be identified, critical emissions must be controlled and techniques developed that are sufficiently sensitive and low-cost. To allow simultaneous measurement of multiple contaminants, risks and economic factors must be considered.

Heavy metals of highest concern may include arsenic, cadmium, cobalt, chromium, copper, mercury, manganese, nickel, lead, tin and thallium (Balali-Mood, 2021). Some of these elements are necessary for humans in little quantities while others are very toxic and not needed by the body. They can affect the central nervous system, kidneys, liver, skin, bones or teeth. Plants growing in polluted areas with increasing impartation of heavy metals may serve as bio-indicators of Pollution Index (Onyedikachi *et al.*, 2019).

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With improved socioeconomic development, increase in population, consumerism and travel, there is a massive rise in the global number of cars on the road. Consequently, the demand for car repair shops also known as automobile workshops have been on the increase. Automobile workshops carry out various types of activities related to the repair and maintenance of automotive vehicles, such as mechanics, electronics, painting, lights, or oil changes. These activities generate solid wastes, effluents and air pollutants, resulting in heavy metals pollution (Dutra and Victorio, 2020).

This study will therefore assess the presence and concentration of heavy metals in soil in automobile workshops located in Benue state. The detected levels of the heavy metals in the experimental sites will be compared with safety standards to determine their safety and value in supporting agricultural activities and other purposes. Heavy metals under consideration include; arsenic (As), cadmium (Cd), copper (Cu), chromium (Cr), Cobalt (Co), Iron (Fe), lead (Pb), Manganese (Mn), Mecury (Hg), Nickel (Ni), and zinc (Zn).

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in Benue State Nigeria, covering three (3) Local Government areas, one from each of the three Senatorial Zones in the State. Benue is a State in the Middle-belt region of Nigeria (Fig 1). It has a population of about 2.8 million based on the 1999 census record. Its total land area is 34,059 km^2 and it is among the 11th in the country. Benue State has its capital at Makurdi and its GDP was estimated in 2007 to be $6.86 billion. The name Benue came from the River Benue and the State was formed from Benue Plateau on the 3rd of February 1976 along with Igala and some parts of Kwara State which were carved out to become part of the present Kogi State. Some popular towns in the state include Otukpo, Gboko, Otukpa, Katsina-ala, Obi and Makurdi which is the state capital of Benue.

Benue State lies within the lower river Benue trough. Its geographic coordinates are longitude 7° 47' and 10° 0' East. Latitude 6° 25' and 8° 8' North; and shares boundaries with five other states namely: Nasarawa State to the north, Taraba State to the east, Cross-River State to the south, Enugu State to the south-west and Kogi State to the west. Benue occupies a landmass of 34,059 square kilometres. The area is inhabited by the Tiv (the largest ethnic group in the state), the Idoma, and a number of smaller groups; all are mainly agricultural people, cultivating sesame seed, soybeans, shea nuts, cotton, yams, corn (maize), and rice as cash crops. Yams, sorghum, millet, peanuts (groundnuts) and cassava are raised as staple foods.

Mining is important in several scattered areas: south of the Benue River there are lead deposits near Akwana and limestone deposits near Yandev; north of the river there are saline springs in the Benue valley and major deposits of tin, niobium, and marble.

2.2 Selection of Sites

Three Local Government Areas were selected for this study, they are the largest urban and cosmopolitan cities in the state (Fig 1). Table 1 shows the longitude and latitudes of the experimental sites.

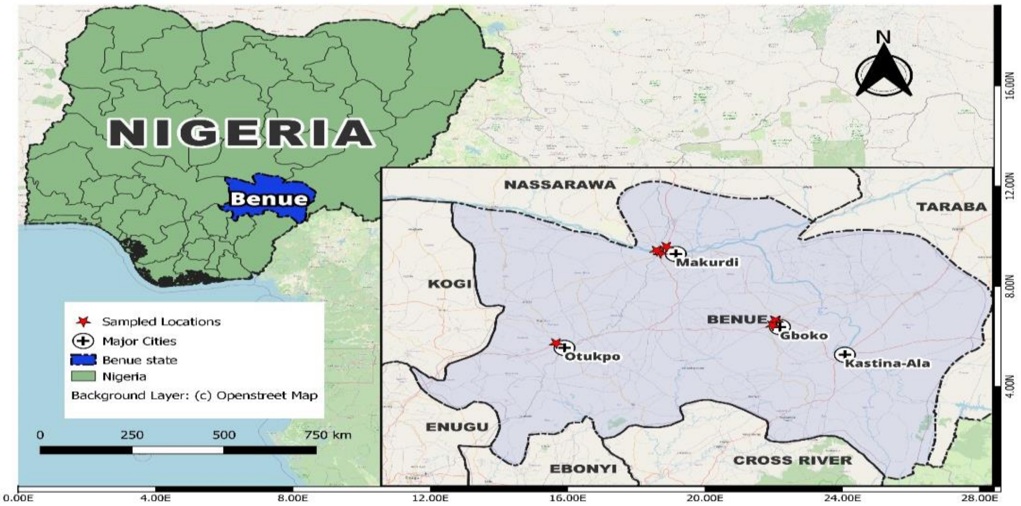

Figure 1: Map of Nigeria showing Benue State

Source: Authors illustrations based on data from OpenStreetMap and Global Administrative Areas (GADM, 2022).

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Table 1: Longitude and latitude of experimental sites.

Location	Address	Latitude	Longitude
Makurdi	Automobile Workshop in North Bank	7.770421	8.55783
Makurdi	Automobile Workshop in Ministry of Agriculture	7.735095	8.53175
Makurdi	Automobile Workshop in GRA	7.748064	8.516976
Otukpo	Automobile Workshop in Enugu Road	7.218117	8.098565
Gboko	Automobile Workshop in Adekaa	7.348173	9.015604
Gboko	Automobile Workshop in Mango Garden, Abagu.	7.348247	9.011967
Gboko	Automobile Workshop in GRA.	7.320617	9.000632

2.3 Sample Collection

Soil samples were collected at 0-15 cm depth from the various automobile workshops, and the control sites across the three Local Government Areas. Control samples were collected from quiet residential areas. All samples were labelled appropriately and transported to the laboratory for elemental analysis. Plates 1 and 2 shows pictures of some sites from which samples were collected.

2.4 Laboratory Analysis

Samples were digested according to the method described by Association of Official Analytical Chemists (AOAC, 2015). The concentrations of heavy metals were measured using Perk-Elmer Analyst AAS (Atomic Absorption Spectrophotometer).

Soil Analysis - The soil samples were air dried to remove the moisture content. After drying, the samples were crushed with a clean dry mortar and pestle and then sieved through a 2-mm sieve to fineness. Thereafter, three grams (3g) of the sieved soil samples were weighed and then digested with a mixture of 10 ml concentrated hydrochloric acid (HCL) and 3.5 ml concentrated nitric acid (HNO_3). The mixtures were left overnight without heating under the switch-on fume cupboard and heated for 2 hours at 104°C on the next day. Distilled water was added to the digested samples, then filtered and made up to 100 ml volume with distilled water. The solution was transferred into sampling bottles for analysis. Then concentrations of these heavy metals in the soil samples were analyzed using a Perk-Elmer Analyst AAS (Atomic Absorption Spectrophotometer).

2.5 Data Analysis

Data generated was transposed using Minitab 16.0 and was used to determine Pollution index. Excel workbook was used for computations and graphs.

2.6 Pollution index:

Pollution Index was used to evaluate the degree of multi-element contamination. It was computed by the average ratio of elements concentration in both soils and plant samples (Edori and Kpee, 2017).

$$PI = \frac{\frac{(Cr)}{0.30} + \frac{(Cd)}{0.30} + \frac{(Pb)}{1.00} + \frac{(Ni)}{0.30}}{4}$$

Soil with >1.00 PI after phytoremediation is contaminated

Soil with <1.00 PI after phytoremediation is remediated

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Plate 1: Soil in New GRA Automobile workshop showing freshly dumped engine oil.

Plate 2: Soil of Automobile Workshop showing Engine Oil Spillage.

3. RESULTS

3.1 Mean Concentration of Heavy Metals in Soil Samples from Automobile Workshops.

Table 2 shows the mean concentration of heavy metals in soil samples collected from automobile workshops in Gboko, Otukpo and Makurdi Local Government Areas in Benue State. The elements show varying concentrations in the soil samples. Iron (Fe) has the highest heavy metal mean concentration in across Gboko, Otukpo and Makurdi Automobile workshop soil (11.838 mg/kg, 11.747mg/kg and 10.926 mg/kg respectively). Mercury (Hg) has the least heavy metal concentration (0.001 mg/kg) across all automobile workshop soil samples. From the highest to the least mean concentration, heavy metals are present in this order across: Fe > Cu > Zn > Pb > Mn > Cr > Cd > Ni > Co > As > Hg. The lowest concentrations are seen in the control samples, with some elements like Cadmium, Arsenic, Mercury, Nickel and Cobalt showing zero concentrations (Not detected). Cadmium showed it highest concentration (1.487 mg/kg) in Makurdi automobile workshop and is above its WHO permissible limit (0.8 mg/kg).

Heavy metal concentrations in all soil samples investigated across the 3 local government areas fell below the NESREA and WHO recommended permissible limit with the exception of Cadmium.

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Table 2: Mean Concentration of Heavy Metals in Automobile Workshops across 3 Local Government Areas in Benue State.

	Gboko Automobile Workshop Soil	Otukpo Automobile Workshop Soil	Makurdi Automobile Workshop Soil	Control Soil	Pm Limits
Pb	2.887	3.073	2.537	0.083	**85.0^{W}**
Cd	0.0377	0.617	1.487	0	**0.8^{W}**
Fe	11.838	11.747	10.926	7.68	**20^{N}**
Cu	3.795	4.013	3.672	2.64	**36.0^{W}**
Zn	2.908	3.297	3.042	4.66	**42^{N}**
Mn	2.132	2.462	2.105	0.27	**5.0^{N}**
As	0.015	0.033	0.012	0	**20^{N}**
Hg	0.008	0.001	0.008	0	**NS**
Cr	2.098	2.136	1.726	0.009	**100^{W}**
Ni	0.418	0.415	0.381	0	**50^{N}**
Co	0.141	0.1055	0.198	0	**0.2^{w}**
∑	**26.277**	**27.909**	**26.094**		

Legends: **CT**= Control; **W** = WHO; **N**= NESREA; **Pm**= Permissible limit; **NS**= Not stated

3.2 Comparative Pollution Indices

Fig. 2 This Bar Chart that shows the pollution indices of the soil in automobile workshop across 3 Local Government Areas of Benue State. The pollution indices of the soil is highest across the soil samples taken from the automobile workshop in Otukpo. The order of pollution indices from the highest to lowest in automobile workshop in Otukpo is from Moringa soil (3.51) to Neem soil (3.44) to Cashew (3.41) and to Mango (3.28).

The second highest pollution indices is seen across soil samples taken from automobile workshop in Gboko. The order of pollution indices from the highest to lowest in automobile workshop in Gboko is from Neem soil in Adekaa (2.91) to Mango soil in G.R.A (2.85) and to Neem soil in Abagu (2.79).

The second highest pollution indices is seen across soil samples taken from Mechanic Villages in Gboko. The order of pollution indices from the highest to lowest in Mechanic Villages in Gboko is from Neem soil in Adekaa (2.91) to Mango soil in G.R.A (2.85) and to Neem soil in Abagu (2.79).

The lowest pollution indices are seen across soil samples taken from Mechanic Villages in Makurdi. The order of pollution indices from the highest to lowest in the Mechanic Villages in Makurdi is from Neem and Mango soil in North Bank (2.76) to Neem, Mango and Moringa soil in Ministry of Agriculture (2.74) and then to Cashew soil in Northbank (2.70). Pollution indices are insignificant across all the control soil samples.

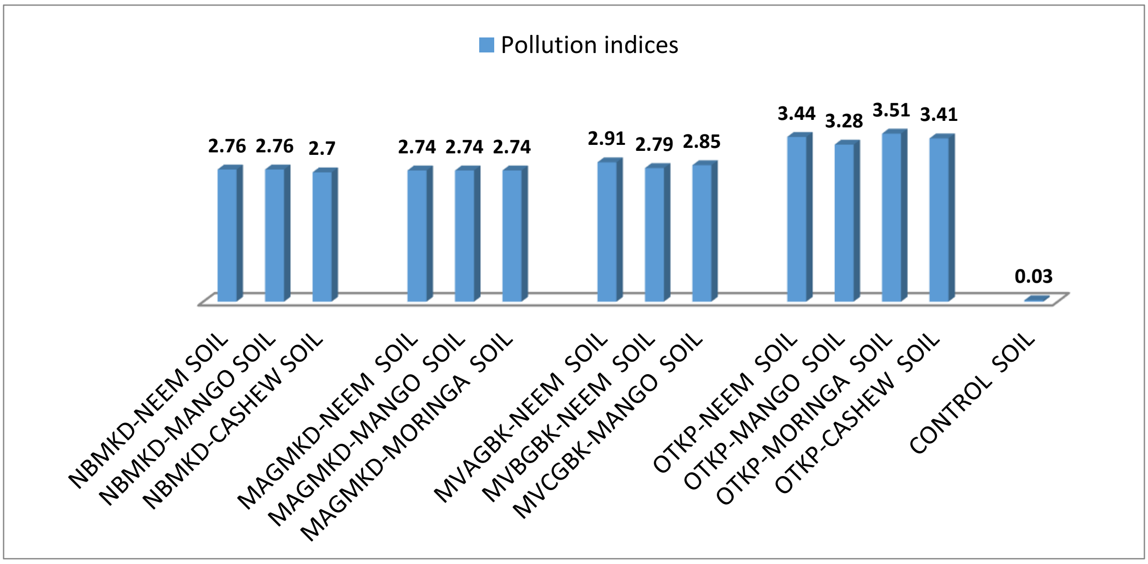

Figure 2: Bar Chart showing pollution indices of the soil in the Automobile Workshop across 3 Local Government Areas of Benue State.

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3.3 Average Level of Contamination at Automobile workshop sites.

Fig 2 is a bar chart showing the average level of contamination at automobile workshops in Three Local Government Areas of Benue State. Otukpo automobile workshop leads in the pollution indices and is closely followed by Gboko automobile workshop. Makurdi automobile workshop have the least average pollution indices across the state.

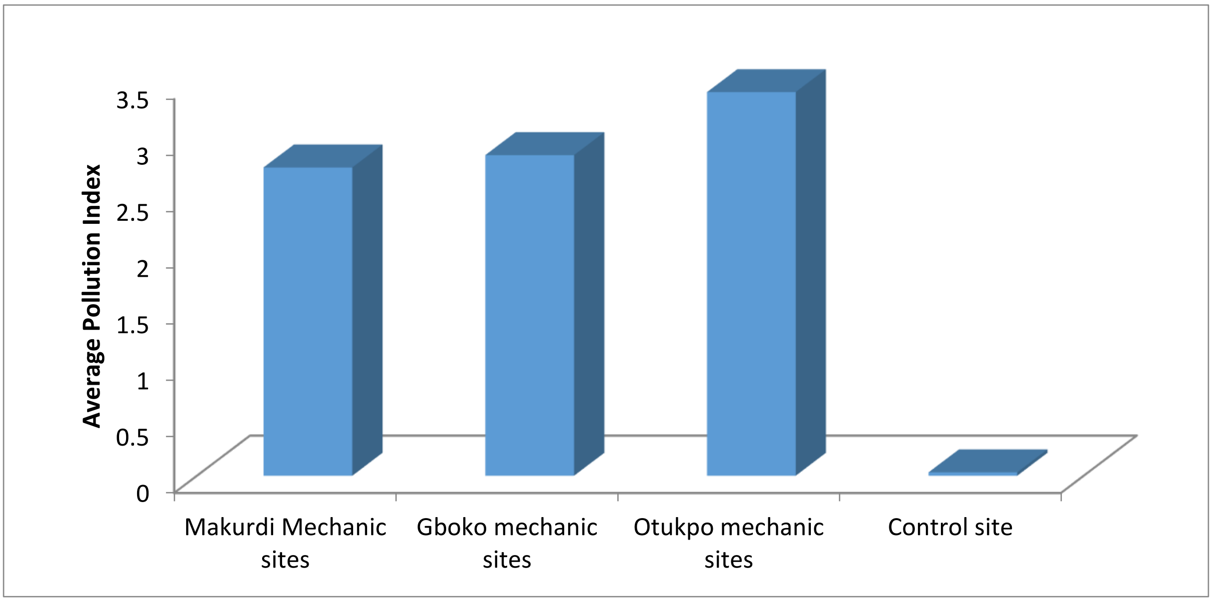

Figure 3: Bar chart showing the Average Level of Contamination at Automobile Workshops in Three Local Government Areas of Benue State.

3.4 Descriptive Statistics: Heavy Metals in Soil.

Table 3 is a descriptive statistics of the concentration of heavy metals in soil samples within the mechanic sites. Elements with the highest and lowest mean concentrations in soil were Fe (11.844±0.024 mg/kg) and Co (0.126±0.005 mg/kg) respectively. In the order of the highest to the lowest mean concentrations, we have Fe (11.844±0.024 mg/kg), Cu (3.920±0.034 mg/kg), Zn (3.133±0.053 mg/kg), Pb (2.823±0.061 mg/kg), Mn (2.233±0.061 mg/kg), Cr (2.101±0.011 mg/kg), Ni (0.415±0.003 mg/kg), Cd (0.201±0.083 mg/kg), and Co (0.126±0.005 mg/kg). The element with the highest Co-efficient of Variation is Cd (148.70%) and the element with the least Co-efficient of Variation is Fe (0.77%). From the highest to the lowest CV, we have Cd (148.70%), Co (12.92%), Mn (9.84%), Pb (7.81%), Zn (6.14%), Cu (3.16%), Ni (2.98%), Cr (1.90%), and Fe (0.77). Fe has the highest concentration in soil (11.97 mg/kg) and Cd has the lowest concentration in the plants (0.004 mg/kg).

Table 3: Descriptive Statistics of the Concentration of Heavy Metals in Soil Samples from Automobile Workshops in Benue State.

Heavy Metal	Mean±S.E	CV%	Min	Max
Pb	2.823±0.061	7.81	2.583	3.090
Cd	0.201±0.083	148.70	0.004	0.724
Fe	11.844±0.024	0.77	11.653	11.970
Cu	3.920±0.034	3.16	3.583	4.050
Zn	3.133±0.053	6.14	2.780	3.350
Mn	2.233±0.061	9.84	1.947	2.553
Cr	2.101±0.011	1.90	2.060	2.187
Ni	0.415±0.003	2.98	0.397	0.443
Co	0.126±0.005	12.92	0.103	0.153

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3.5 Correlations: Heavy Metals in Soil

Table 4 shows the correlation matrix of the concentration of elements in study. Elements with the strongest positive correlation are Zn and Cu (0.879), and is followed by Mn and Zn (0.783), Cd and Pb (0.781), Mn and Pb (0.781), Mn and Cu (0.752), Mn and Cd (0.712), Co and Fe (0.673), Cr and Pb (0.656). Elements with moderately positive correlation are Cr and Cd (0.484), Cu and Cd (0.458), Co and Ni (0.420). Elements with the strongest negative correlation are Cu and Cd (-0.871), and is followed by Fe and Cd (-0.773) and Fe and Pb (-0.636). Elements with moderately negative correlation are Co and Pb (-0.542), Co and Mn (-0.515).

Table 4: Correlation Matrix of Heavy Metals in Soil Samples from Automobile Workshops in Benue State.

Heavy Metal	Pb	Cd	Fe	Cu	Zn	Mn	Cr	Ni	Co
Pb									
Cd		0.781							
Fe		-0.636	-0.773						
Cu		0.346	0.458	-0.002					
Zn		0.392	0.557	-0.095	0.879				
Mn		0.781	0.712	-0.246	0.752	0.783			
Cr		0.656	0.484	-0.255	0.300	0.348	0.577		
Ni		0.185	-0.115	0.286	0.316	0.050	0.394	0.220	
Co		-0.542	-0.871	0.673	-0.500	-0.656	-0.515	-0.407	0.420

4. DISCUSSION

Heavy metal presence was detected in varying concentrations in soil, water and trees from all the sampled Automobile workshops in Benue State. The elevated levels of heavy metals compared to samples from the control site is probably as a result of the various activities at these automobile workshops which lead to the release of heavy metals in the surrounding environment.

In the soil samples the higher concentrations of heavy metals were recorded in the experimental sites can be traced to generated waste in these workshops, which may include dumping of iron (Fe) scraps, unused body parts of vehicles, cans, and many others, most of which are dumped directly into the soils. Abandoned corroding vehicles which is common sight in automobile workshops, may also be a major cause of Iron release into the environment as iron is a major component of many vehicle parts. Steel alloy which is the material used in manufacturing of the body of vehicles has iron as its major component (Edori 2012 and Abidemi 2011). Higher concentrations of iron in soils relative to other metals have been reported by many including, Dara (1993); Oguntimehin *et al.* (2008); Adebayo (2017); Bala *et al.* (2019); and Amaechi *et al.* (2021). This indicates that natural soils contain high levels of iron, as the control samples also showed iron as the element with the highest concentration. These notwithstanding, all concentrations of iron recorded were below its permissible limits.

Across the automobile workshops copper (Cu) had the second highest concentration. This agrees with Amaechi and Onwuka (2021), who reported copper as having the second highest concentration of heavy metals analyzed after iron in soils of automobile workshops in Awka. This may be because, the automobile industry uses a lot of copper due to its inherent properties, hence its popular choice for manufacturing automobile parts, such as wire harness, starter motor, alternator; and radiator and break tubes. (Chokor, 2016). According to Pam *et al.* (2013), Copper was present in samples of experimental soils above permissible limits while showing very little concentrations in the control in Gboko and Makurdi. Ajeh *et al.* (2022) also reported high percentage of copper above permissible limits in soils around automobile workshops in Benin City. Chokor (2016) also reported elevated levels of copper in soils in automobile workshops studied. In this study, all concentrations of copper in soil samples were below NESREA, US-EPA and WHO permissible limits suggesting safer health outcomes following consumption.

Chromium showed very high concentrations, far above WHO recommended limits for soils (0.08 mg/kg) in samples collected from the Automobile workshops in Makurdi. This agrees with Bala *et al.* (2019) and Amaechi *et al.* (2021), who both reported chromium exceeding permissible limits in all automobile workshops studied at Benin City and Awka respectively. Soil samples from Gboko and Otukpo automobile workshops also showed very low levels of Chromium but were slightly below permissible limits. In this study, the higher levels of chromium recorded in Makurdi may be because it is a State capital and therefore has a high propensity for environmental pollution. Chromium is plated on steel and many automobile parts to give shine, prevent corrosion and make objects scratch resistant (Byjus, 2023). With no known biological role in plants physiology, chromium when in excess in the soil can affect plants nutrient uptake, causing nutrient imbalance, root injury and leaf chlorosis. It also targets chlorophyll biosynthesis by inhibiting the activity of vital enzymes (Sharma, 2020).

Cobalt showed the least concentration in all test soil samples, far below NESREA, US-EPA and NESREA permissible limits. This may be because, cobalt is a very rare element, with only trace amounts in the Earth's crust (Barceloux, 1999) but usually found in steel, batteries and magnets. In concentrations above permissible limits, cobalt decreases nitrification and reduced soil microorganism.

The level of heavy metals contamination in auto mobile workshops depends on the age of the workshop (Abidemi, 2011; Edori and Edori 2012; Usman *et al*., 2013). Otukpo automobile workshop had the highest pollution index compared to workshops in other locations (Gboko and Makurdi). This may be because it is one of the largest and most strategically located Automobile workshop in the State, being a corridor town and major trade route linking the South-East and South West to Northern Nigeria. (Dam *et al*., 2020). Since these metals do not easily decay, they continue to accumulate over the years, thereby increasing their concentrations in the soil. (Pam *et al.*, 2013).

5. CONCLUSIONS

Investigations in this study have indicated that automobile workshops are indeed polluted with heavy metals. All the indices considered reveal some level of contamination. This contamination can be traced to anthropogenic origins which point to the activities in the auto mobile workshops. The presence of heavy metals in soils may change the physical, chemical and biological properties of the soil. Soil runoffs containing heavy metals seep into aquatic environments, and are harmful to aquatic plants and animals as well as humans who consume them. These metals are in turn taken up by terrestrial plants from the soil and ground water. In the plants, it reduces productivity by inhibiting its physiological metabolism. Heavy metals uptake by plants and successive accumulation in human tissues as well as its bio-magnifications through the food chain causes both human and environment health concerns.

Author Contributions:

Conceptualization – Mfam A. N

Methodology – Mfam A. N

Analysis – Olasan J. O.

Investigation – Mfam A. N. and Mfam N.N.

Resources – Mfam A. N.

Data curation – Olasan J.O.

Writing – Mfam A. N.

Review – Ogbonna I. O., Okoh T.

Supervision – Aguoru C. U., Ogbonna I. O, and Okoh T.

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