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Influence of Auto Mechanic Workshops on the Pollution Status of Soils within Calabar Metropolis, Nigeria

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Abstract

Influence of auto mechanic workshops on the heavy metals pollution status of soils within Calabar metropolis was investigated from February to July 2023. Thirty-six soil samples were collected from six auto mechanic workshops at the depths of 0 - 5 cm using soil auger. Metals concentrations were determined using atomic absorption spectrophotometer (Shimadzu, model AA-6800, Japan) after wet digestion. Mean soil metals concentrations (mg/kg) ranged between 41.51±4.43 and 96.26±5.52, 3.16±0.69 and 9.82±0.15, 6.76±0.19 and 36.27±2.5, 11.23±0.80 and 34.23±2.49, and, 13.91±0.53 and 47.42±1.80 for lead, cadmium, chromium, nickel and copper respectively. Mean metals concentrations were below WHO/FAO soil guidelines values, cadmium being the only exception. Significant variation in metals concentrations was observed between the different workshops suggesting anthropogenic influence. The significant, strong positive correlation between the different metals indicate strong association between them and mirror the probability of their related or common origin. The significant difference in metals levels between the workshops and the control suggest activities of the workshop could be responsible for elevated metals concentration. The average contamination factor (5.72 and 3.89) for cadmium corresponds to Considerable contamination factor suggesting significant anthropogenic contribution. Ecological risk factor revealed that cadmium contamination of soil poses a range of moderate potential ecological risk to considerable potential ecological risk to the other components of the environment. Average values of index of geo-accumulation (I_{geo}) for cadmium (1.78 and 1.65 for both seasons) corresponds to pollution intensity 'moderately polluted'. The study concludes that auto mechanic workshops in Calabar have significant averse influence on geochemical pollution status of soils. To safeguard environmental and human health, creation of an auto-mechanic village in Calabar is here by recommended.

Key Words: Auto-mechanic workshop, soil, heavy metals, pollution status, ecological risk.

1.0: Introduction

In most developing countries, the impact of the activities of auto-mechanic workshops on the state of the environment, has become a major issue of environmental and health concern. Due to the rising demand for vehicles, both for personal and commercial purposes, there has also been an increase in mechanic workshops (Ololade, 2014). In Nigeria, auto mechanic workshop activities can be classified among the top sources of increased heavy metals contamination in the environment (Nwachukwu, Huan, & Achilike, 2010; Yahaya, Nnachi & Yusuf, 2023). These workshops create wastes in the course of their day-to-day operations, most of which are hazardous and also expensive to dispose of. These wastes include, but are not limited to; fluids, used oils, asbestos and other chemicals used there. Most automobile workshops or motor servicing centres consist of mechanics, auto-electricians, vulcanizers and panel beaters (Diagi, Okorondu, Ajiere, Ekweogu, Odokpac, Acholonu & Edeh, 2023). These workers get involved in activities that generates gaseous, liquid and solid pollutants that in turn affect the surroundings. Among these pollutants, heavy metals create serious concern, mainly due to their high level of toxicity and also the threat they pose to the environment and even human life (Ma & Rao, 1997; Vincent, Manu, Chessed, Vandi, Francis & Norah, 2022).

Hazardous wastes commonly created in auto mechanic workshops are mostly from the solvents that are used to clean parts. According to Imevbore and Adeyemi (1981), the composition of some of the chemicals that are found in the solvents that are used to clean vehicle parts are very dangerous to humans and the environment. Used oils may even contain; lead, cadmium, barium and other metals that have the potential of being toxic. Without proper control, these chemicals can actually penetrate directly or indirectly, into the air we breathe, the water we drink, our soils on which we grow our crops (Adeniyi and Afolabi, 2002; Ajiere, Diagi and Edokpa, 2021). Some of the adverse effects of these heavy metals include; kidney and liver damage, bone and fracture effects, neurotoxic effects in children, damage of heart, circulatory, reproductive system and nerve tissues (Pam, Rufus, & Offem, 2013).

Industrialization, together with the activities of humans, have given rise to heavy metal concentrations in both surface and subsurface soils, as against the concentration of the metals contributed from processes that are natural (Dasaram, Satyanarayanam, Sudarshan, & Krishna, 2011). The impact of some of these industrial activities have resulted in long term cumulative health effects, which is unarguably part of the leading causes of health issues worldwide (Hutton and Symon, 1986). Pollution is the production or introduction of substances by man into the environment that results in harmful effects to the health of humans, other living things in the ecosystem and interference with the proper use of the environment (Maduka, 2004). It is the adverse change of the environment due to wastes from human activities, physical and chemical features, radiation levels and the abundance of organisms (Miller, 1988). Pollution is very potent because every aspect of the living system is affected by it. Urbanization, pollution and loss of fertility is a major cause for concern in Nigeria, as soil resources cannot be sustained effectively (Bankole, 2005). Soil pollution decreases soil fertility, alters soil structure, contaminates groundwater and becomes a serious threat to living organisms. In the world over, heavy metal contamination in soils, sediments, sludge, water and food products have been a serious environmental concern both in developed and underdeveloped countries, particularly because of the potential health and ecological risk associated with such contamination (Ihejirika, Njoku, Ebe, Enwereuzoh, Izunobi, Ashiegbu, & Verla, 2016). In

Sample Collection: Soil samples were collected from six different mechanic workshops within Calabar metropolis, three from Calabar Municipality (Ikot Ansa, Effio-Ette and Diamond Hill) and three from Calabar South (Nelson Mandela, Ewa Ekeng and Afokang), using University of Calabar residential quarters as control site. Soil samples were obtained from three points, 10 metres apart, within each mechanic workshop at a depth of 0 – 15 cm using hand auger. Sampling was done once in a month for a period of six months (February to July 2023), three months in the dry season and three months in the wet season. The samples were stored in black poly ethylene bags, labelled, placed in ice-chest and transported to Lab 249, Department of Zoology and Environmental Biology, University of Calabar, Nigeria

cities of advanced countries and some Nigerian cities, auto mechanic workshops are located in areas known as "mechanic village". These are locations and places officially designed and built, to suit the activities that are involved in the servicing and repairs of auto mobiles (Nwachukwu, Feng, & Alinnor, 2011; Ogunkola, Oyetunji & Bashir, 2019). In Calabar, a city in the southeastern part of Nigeria, the absence of this important infrastructure has resulted in the sprawling of small and medium clusters of auto mechanic workshops in nooks and crannies of the metropolis. This is done with negligence to the impacts of these activities to the environment. The study is therefore designed to assess the concentrations of copper (Cu), cadmium (Cd), lead (Pb), chromium (Cr) and nickel (Ni) in soil around auto mechanic workshops in Calabar.

Materials and Methods: ***Study Area***

Calabar, the capital of Cross River State, Nigeria, is located between latitudes 8°.15' and 80°.25'E and longitudes 24°.15' and 5°.15'N. Odukpani Local Government Area, Great Kwa River and Calabar River form its northern, eastern and western boundaries, respectively. It is 406 square kilometres in size and 32 meters (105 feet) above sea level with a population of 579,000 as at 2020 (Population Stat, 2020). Calabar has a tropical climate with permanently tropical rainforest vegetation. A 1600mm annual rainfall average and temperatures ranging from 26°C to 36°C are typical for the region. Calabar has distinct dry and wet seasons. While the latter occurs between November and March, the former occurs between April and October. Calabar Municipality and Calabar South LGAs are the two administrative divisions of the city. Calabar metropolis has not mechanic village. Small and medium-sized clusters of car mechanic workshops, therefore adorn the city, filling every available space.

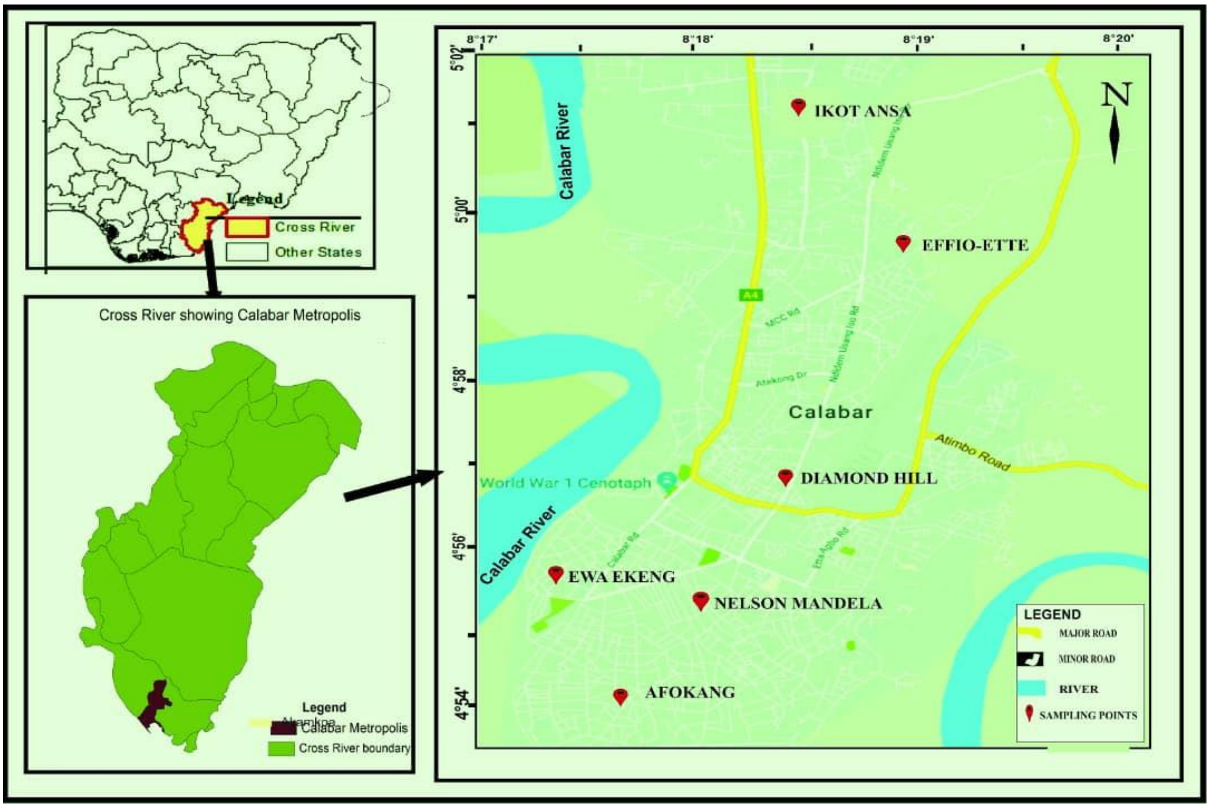

FIG. 1: Map of Calabar metropolis showing sampling points

Table 1: Coordinates of sample location

Location	Latitude (N)	Longitude (E)	Elevation
Ikot Ansa	N 5^{0}0’48.44052”	E 8^{0}20’19.97376”	70 m
Effio Ette	N 4^{0}59’43.1808”	E 8^{0}20’54.44124”	57 m
Diamond hill	N 4^{0}58’27.2208”	E 8^{0}19’52.7826”	50 m
Afokang	N 4^{0}56’10.23972”	E 8^{0}19’9.83316”	33 m
Ewa Ekeng	N 4^{0}57’10.96596”	E 8^{0}18’56.1708”	45 m
Nelson Mandela	N 4^{0}56’50.17812”	E 8^{0}19’43.12992”	25 m
Unical residential quarters	N 4^{0}56’46.83156”	E 8^{0}20’39.63876”	41 m

Sample Preparation: The soil samples obtained from the three sampling points at each auto mechanic workshop were mixed together, air dried for five days, then crushed into fine powder. 1g was digested using 20ml of hydrofluoric acid, nitric acid and perchloric acid, ratio 1:3:1 on a hot plate.

Sample Analysis: Atomic Absorption Spectrophotometry (Shemadzu, model AA- 6800, Japan) was used to determine concentration of metals in the digest at National Research Institute for Chemical Technology, Zaria, Nigeria.

Analytical Quality Assurance: One blank and combined standards were run with every batch to assess the accuracy of the analytical techniques used to determine the metals concentration, detect background contamination and monitor batchs consistency. Only analytical-grade reagents - nitric acid, perchloric acid, and hydrofluoric acid (all from Riedel-deHaen, Germany) were used for sample preservation and digestion. The validity of the results of the study was confirmed by digesting and analyzing Standard Reference Materials (lichen coded IAEA- 336) using the same method.

Statistical analysis: IBM SPSS version 23.00 for windows was used for statistical analysis. The Analysis of Variance (ANOVA) test was performed to determine whether there was a significant difference in metal concentrations between the mechanic workshops and the control. The difference in metal levels between the dry and wet seasons was evaluated using an independent t-test. Probabilities less than 0.05 significance level (p 0.05) were regarded as statistically significant in both cases.

Ecological Risk Assessment: Contamination factor (Cf) : The Contamination Factor (CF), expressed by Equation 1, was used to describe soil contamination. It compares the mean content of a specific metal in soil from the sampling sites (Cs) with the pre-industrial reference level for that metal (Cp) (Hakanson, 1980; Qingjie, Jun, Yunchuan, Qingfei, & Linqung, 2008).

$$Cf = \frac{Cs}{Cp}$$ ……………………………………………………........ .... (1)

Cs = mean content of a given metal from at least five sampling sites, while

Cp = pre-industrial reference level for the metal.

Ecological risk factor: The potential ecological risk posed by the metals to the living components of the environment was evaluated using ecological risk factor (Hakanson, (1980); Qingjie *et al.*, 2008). The formula below was applied to calculate it:

Er = Tr x Cf x Cfx Cf=Tr x Cf………………………………………………… (2)

Tr = toxic response factor for a given substance, while

Cf = contamination factor.

Index of geo-accumulation: This was used to describe metal contamination in soil, by analyzing the present concentrations of the metals with the pre-industrial levels (Hakanson, (1980) and Qingjie *et al.*, (2008). Below is the equation that was used in calculating it;

$$I_{geo} = \log_2 [C_l / (1.5C_{rl})]$$ -- (3)

Where C_l is the measured concentration of the examined metal in soil, and C_{rl} is the geo-chemical background concentration or reference value of the metal. The factor 1.5 was introduced because of possible variation in background value for a given metal in the environment as well as very small anthropogenic influences on the value. Background levels as inferred by Hakanson (1980), was used in calculation of Contamination factor, Ecological risk factor and Index of geo-accumulation.

Pollution load index: The pollution load index from the study area was evaluated also, for the level of heavy metal pollution, as devised by Thomilson, Wilson, Harris, & Jeffrey, 1980)

PLI = n√ (CF1 ×CF2 ×CF3 ×……CFn),

Where PLI = Pollution Load Index, CF = Contamination Factor and n = Number of metals studied

The PLI gives a comparative, yet simple way for assessing the pollution status of a site (Thomilson *et al.*, 1980).

PL1 < 1 - Perfection

PL1 = 1 - Presence of pollutants at baseline levels

PL1 > 1 – shows decline of site quality.

Results: *Analytical quality assurance*: Results of the certified standard reference materials (Lichen coded IAEA-336) digested and analyzed concurrently with our samples, presented in Table 2, indicates that, the analyzed values were within the confidence interval of the certified reference values of the metals studied, thus validating the accuracy and precision of the methods employed for metals determination

Table 2: Result of analysis of reference material (Lichen IAEA-366) comparing the analyzed values and the certified reference values (mg/kg).

Elements mg/kg	Pb	Cr	Cd	Ni	Cu
Analyzed value	5.10	0.95	1.21	1.39	4.00
Reference value	4.3-5.5	0.89-1.23	0.10-0.134	1.00-1.50	3.1-4.1

Total heavy metal concentration in soil within auto mechanic workshops in Calabar Metropolis: Mean soil metals levels around auto mechanic workshops ranged between 41.51±4.43 and 96.26±5.52, 3.16±0.69 and 9.82±0.15, 6.76±0.19 and 36.27±2.5, 11.23±0.80 and 34.23±2.49, and, 13.91±0.53 and 47.42±1.80 for lead, cadmium, chromium, nickel and copper respectively for both dry and wet seasons (Table 3). The lowest concentration of each metal during wet season was recorded at Nelson Mandela but during dry season, lead, cadmium and chromium recorded lowest concentrations at Diamond Hill while that of Nickel and copper were at Nelson Mandela. Metals concentrations displayed the following sequence:

Table 3: Mean Soil Total Heavy Metal Concentration within Auto Mechanic Workshops in Calabar Metropolis

Season	Metal	Ikot Ansa	Effio-Ette	Diamond hill	Afokang	Ewa Ekeng	Nelson Mandela	Control
Dry Season	Lead	83.43 ± 8.74^{a}	74.43 ± 8.28^{ab}	44.48 ± 1.03^{c}	96.26 ± 5.52^{ad}	69.02 ± 0.70^{ab}	46.34 ± 0.64^{c}	23.27 ± 0.17^{e}
	Cadmium	8.42 ± 0.05^{a}	5.86 ± 0.13^{b}	3.16 ± 0.69^{c}	9.82 ± 0.15^{ad}	3.88 ± 0.24^{c}	3.18 ± 0.68^{c}	0.70 ± 0.12^{e}
	Chromium	13.34 ± 1.64^{a}	12.15 ± 0.58^{a}	7.3 ± 0.63^{b}	17.76 ± 1.68^{c}	9.30 ± 0.95^{bd}	6.76 ± 0.19^{be}	1.68 ± 0.30^{f}
	Nickel	27.01 ± 2.74^{a}	20.23 ± 2.21^{b}	13.75 ± 1.24^{c}	34.23 ± 2.49^{d}	15.85 ± 0.65^{ce}	12.43 ± 0.39^{cf}	5.43 ± 0.45^{g}
	Copper	41.99 ± 2.32^{a}	32.36 ± 2.73^{b}	25.06 ± 0.71^{c}	47.42 ± 1.80^{d}	26.18 ± 0.61^{c}	22.80 ± 1.37^{c}	11.37 ± 0.80^{e}
Wet Season	Lead	80.72 ± 16.06^{a}	66.66 ± 11.52^{b}	41.78 ± 4.42^{c}	95.89 ± 5.07^{d}	62.13 ± 6.87^{b}	41.51 ± 4.43^{c}	19.44 ± 6.14^{e}
	Cadmium	8.27 ± 0.25^{a}	5.03 ± 1.10^{b}	3.25 ± 0.35^{c}	8.77 ± 0.70^{a}	3.38 ± 0.52^{c}	2.67 ± 0.54^{c}	0.56 ± 0.15^{a}
	Chromium	12.04 ± 2.00^{a}	25.47 ± 1.34^{b}	15.68 ± 0.14^{a}	36.27 ± 2.5^{c}	22.56 ± 1.51^{b}	15.28 ± 0.72^{a}	6.95 ± 0.31^{d}
	Nickel	23.73 ± 0.69^{a}	19.33 ± 0.87^{b}	12.99 ± 0.41^{c}	28.15 ± 1.52^{d}	15.80 ± 0.60^{d}	11.23 ± 0.80^{c}	4.55 ± 0.58^{e}
	Copper	27.90 ± 1.28^{a}	23.06 ± 1.41^{b}	14.94 ± 0.39^{c}	33.26 ± 1.49^{d}	19.77 ± 1.20^{e}	13.91 ± 0.53^{c}	6.47 ± 0.34^{f}

Means with different superscripts across the rows indicates significant ($p < 0.05$) difference

Lead: Afokang > Ikot Ansa > Effio-Ette > Ewa Ekeng > Nelson Mandela > Diamond Hill

Cadmium: Afokang > Ikot Ansa > Effio-Ette > Ewa Ekeng > Nelson Mandela > Diamond Hill

Chromium: Afokang > Effio-Ette > Ewa Ekeng > Ikot Ansa > Nelson Mandela >Diamond Hill

Nickel: Afokang > Ikot Ansa > Effio-Ette > Ewa Ekeng > Diamond Hill > Nelson Mandela

Copper: Afokang > Ikot Ansa > Effio-Ette > Ewa Ekeng > Diamond Hill > Nelson Mandela

The difference in metals concentrations between auto mechanic workshops and the control was significant (ANOVA, $p < 0.05$, Figure 2). The difference in soil metals concentrations between the different auto mechanic workshops was also significant (ANOVA, $p < 0.05$, Figure 2). The difference in soil metals concentration between dry and wet seasons on the other hand was however, not significant ($p > 0.05$) except for chromium and copper.

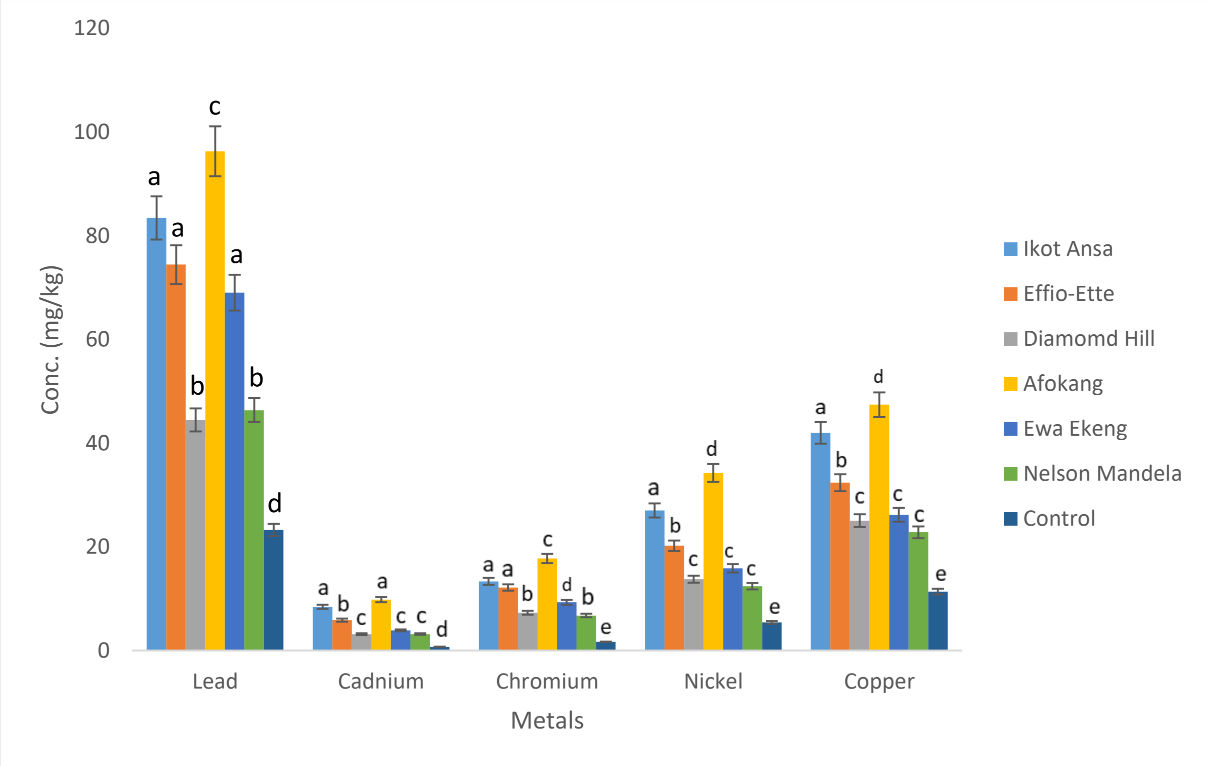

Figure 2: Comparison of metals concentrations between auto-mechanic workshops

Relationship between heavy metal in soil within mechanic workshops in Calabar metropolis

A significant ($P < 0.01$) strong positive correlation was observed between lead and cadmium ($r = 0.938$), Lead and chromium ($r = 0.968$), lead and nickel ($r = 0.951$) and between lead and copper ($r = 0.950$) (Table 4). A significant ($P < 0.01$) strong positive correlation was also observed between cadmium and chromium ($r = 0.953$), cadmium and nickel ($r = 0.975$) and between cadmium and copper ($r = 0.986$). Strong positive correlation was also observed between chromium and nickel ($r = 0.976$), chromium and copper ($r = 0.966$) and between nickel and copper ($r = 0.983$), the correlations were significant at 99% confidence level.

Table 4: Relationship between metals in soil within auto mechanic workshops in Calabar metropolis

		Lead in soil	Cadmium in soil	Chromium in soil	Nickel in soil	Copper in soil
Lead in soil	Pearson Correlation	1				

	Sig. (2-tailed)					
	N	42				
Cadmium in soil	Pearson Correlation	.938**	1			
	Sig. (2-tailed)	.000				
	N	42	42			
Chromium in soil	Pearson Correlation	.968**	.953**	1		
	Sig. (2-tailed)	.000	.000			
	N	42	42	42		
Nickel in soil	Pearson Correlation	.951**	.975**	.976**	1	
	Sig. (2-tailed)	.000	.000	.000		
	N	42	42	42	42	
Copper in soil	Pearson Correlation	.950**	.986**	.966**	.983**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	42	42	42	42	42

**. Correlation is significant at the 0.01 level (2-tailed).

Ecological risk assessment of metals in soil around auto mechanic workshops: The pre-industrial reference level and the toxic response factor determined by Hakanson, (1980), used for the computation of the contamination factor and the ecological risk factor in this study, are given in Table 5.

Table 5The "Pre-industrial reference level (μgg^{-1}) and Toxic- Response factor" determined by Hakanson (1980) and used for the computation of the contamination factor and the ecological risk factor

Elements	Ni	Hg	Cd	As	Cu	Pb	Cr	Zn
Pre-industrial reference level	50	0.25	1.0	15	50	7.0	90	175
Toxic-response factor	5	40	30	10	5	5	2	1

Source: (Hakanson, 1980)

The result of ecological risk assessment of lead, cadmium, chromium, nickel and copper in soil within auto mechanic workshops in Calabar metropolis using single pollution indices are presented in Table 6 to Table 10.

Table 6 revealed that the average contamination factors for both dry and wet seasons were 0.99, 0.93 for lead, 5.72, 3.89 for cadmium, 0.13, 0.07 for chromium, 0.42, 0.37 for nickel and 0.65, 0.49 for copper. The highest contamination factor (8.25) as recorded by cadmium at Ikot Ansa during dry season and the lowest contamination factor (0.03) by chromium at Diamond Hill and Nelson Mandela during wet season. The average contamination factors of the metals followed the trend Cd > Pb > Cu > Ni > Cr.

The average values of ecological risk factor for both dry and wet seasons were 4.93, 4.63 for lead, 171.6, 116.7 for cadmium, 0.25, 0.14 for chromium, 2.08, 1.85 for nickel and 3.26, 205 for copper. The highest ecological risk factor of 294.6 was recorded at Afokang by cadmium in the dry season. While the lowest value (0.06) was recorded by chromium at Diamond Hill and Nelson Mandela (Table 7) The average ecological risk factors of the metals also followed the trend Cd > Pb > Cu > Ni > Cr.

Table 8 indicates that the average values of index of geo-accumulation for both dry and wet seasons were -0.66, -0.76 for lead, 1.78 1.65 for cadmium, -3.70, -2.69 for chromium, -1.96, -2.09 for nickel and -1.26, -1.83 for copper. The highest values o

Table 6: Contamination Factor (CF)

	Pb		Cd		Cr		Ni		Cu	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Ikot Ansa	1.19	1.15	8.42	5.65	0.15	0.10	0.54	0.47	0.84	0.56
Effio-Ette	1.06	0.95	5.86	3.84	0.14	0.08	0.41	0.39	0.64	0.45
Diamond hill	0.64	0.60	3.16	2.17	0.08	0.03	0.28	0.26	0.50	0.26
Afokang	1.38	1.37	9.82	6.75	0.20	0.12	0.69	0.56	0.95	0.57
Ewa Ekeng	0.99	0.89	3.88	2.78	0.10	0.06	0.32	0.32	0.52	0.39
Nelson Mandela	0.66	0.60	3.18	2.15	0.08	0.03	0.25	0.22	0.46	0.23
Average	**0.99**	**0.93**	**5.72**	**3.89**	**0.13**	**0.07**	**0.42**	**0.37**	**0.65**	**0.49**

Table 7: Ecological Risk Factor (EC)

	Pb		Cd		Cr		Ni		Cu	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Ikot Ansa	5.95	5.75	252.60	169.50	0.30	0.20	2.70	2.35	4.20	2.80
Effio-Ette	5.30	4.75	175.80	115.20	0.28	0.16	2.05	1.95	3.20	2.25
Diamond hill	3.20	3.00	94.80	65.10	0.16	0.06	1.40	1.30	2.50	1.30
Afokang	6.90	6.85	294.60	202.50	0.40	0.24	3.45	2.80	4.75	2.85
Ewa Ekeng	4.95	4.45	116.40	83.40	0.20	0.12	1.60	1.60	2.60	1.95
Nelson Mandela	3.30	3.00	95.40	64.50	0.16	0.06	1.25	1.10	2.30	1.15
Average	**4.93**	**4.63**	**171.6**	**116.70**	**0.25**	**0.14**	**2.08**	**1.85**	**3.26**	**2.05**

Table 8: Index of geo-accumulation (Igeo)

	Pb		Cd		Cr		Ni		Cu	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Ikot Ansa	-0.33	-0.38	2.49	2.46	-3.34	-3.49	-1.47	-1.66	-0.84	-1.43
Effio-ette	-0.50	-0.66	1.97	1.75	-3.47	-2.41	-1.89	-1.96	-1.21	-1.70
Diamond hill	-1.24	-1.33	1.08	1.12	-4.21	-3.11	-2.45	-2.53	-1.58	-2.33
Afokang	-0.13	-0.13	2.71	2.55	-2.93	-1.90	-1.13	-1.41	-0.66	-1.17
Ewa Ekeng	-0.61	-0.95	1.37	1.17	-3.86	-2.58	-2.24	-2.25	-1.52	-1.92
Nelson Mandela	-1.18	-1.34	1.08	0.83	-4.32	-3.14	-2.59	-2.74	-1.72	-2.43
Average	**-0.67**	**-0.80**	**1.78**	**1.65**	**-3.69**	**-2.77**	**-1.96**	**-2.09**	**-1.26**	**-1.83**

Table 10: Pollution Load Index (PLI)

	Ikot Ansa	Effio-Ette	Diamond hill	Afokang	Ewa Ekeng	Nelson Mandela
Dry season	4.12	2.40	0.71	6.67	1.22	0.71
Wet season	2.06	1.12	0.27	2.96	0.71	0.22
Average	**3.09**	**1.76**	**0.49**	**4.82**	**0.97**	**0.47**

index of geo-accumulation (2.71) was recorded at Afokang by cadmium in dry season. While the lowest value (-4.32) was recorded by chromium at Diamond Hill and Nelson Mandela.

Average value of pollution load index was 3.09, 1.76, 0.49, 4.82, 0.97 and 0,47 for Ikot Ansa, Effio Ette, Diamond Hill, Afokang, Ewa Ekeng and Nelson Mandela respectively (Table 10). The PLI therefore followed the trend Afokang > Ikot Ansa > EffioEtte > Ewa Ekeng > Diamond Hill > Nelson Mandela.

Discussion : Total heavy metal concentration in soil around auto mechanic workshops in Calabar Metropolis: Lead concentrations in soils within auto-mechanic workshops under study ranging from 36.75 to 102.46 mg/kg, were observed to be lower than the USEPA guidelines for the levels of lead in soil (400 mg/kg). However, the mean soil levels for lead at the workshop located at Afokang (Table 3) was observed to be higher than the Dutch Target value (85 mg/kg), values regarded as benchmark for soil quality during both dry and wet season. The range of values obtained for lead from this study, are higher than that reported by Adebayo, Oguntimehin, Lajide, & Jayeoye, (2017) but below 1162 mg/kg reported by Nwachukwu *et al.* (2011) for mechanic workshops in Owerri, Nigeria and Yahaya *et al.*, 2023 for mechanic workshops at Ayingba, Kogi State Nigeria. Prolonged exposure to low levels of lead can lead to chronic poisoning. There is no exposure level below which lead can be said to be safe. Lead absorption is detrimental to public health, as it affects the intellectual performance and generally reduces the cognitive development of children, and also causes kidney and liver dysfunction and cardiovascular diseases in the lives of adults (Udiba, Ogabiela, Hammuel, Magomya, Yebpella, Ade-Ajayi, Odey, & Gauje, 2012a).

Elevated soil cadmium levels in soils around auto mechanic workshops is likely to come from scrapped car paints, dusts, batteries and welding activities. The Soil Guideline Values for cadmium is 10 mg/kg for the residential areas and the value for the commercial areas is 230 mg/kg. The USEPA maximum permissible limits for cadmium in soil is 3ppm. Cadmium concentrations in the present study ranging from 2.13 to 9.97 mg/kg were found to be lower than the Soil Guideline Values and the USEPA maximum permissible limit. The values were higher than those obtained from the control (0.42 to 0.77 mg/kg). These values for cadmium were higher than 0.6- 3.5 mg/kg reported for refuse dumps and auto mechanic shops in Makurdi, Nigeria (Luter, Akaahan, & Attah, 2011), a mean value of 2.89mg/kg reported for auto-mechanic workshops at Nekede and Orji in Owerri, Nigeria (Diagi *et al.*, 2023) and a range of 1.52-3.12 reported for soils around mechanic village dumpsite, Yenagoa, Nigeria (Ukpe and Johnson, 2020). Acute exposure to cadmium can also result in disfunctioning of the kidney, liver, lungs, the nervous and immune system (Somer, 1994).

Measured chromium ranging from 5.01 to 19.45 mg/kg, were found to be low, when compared to the WHO guidelines for soil chromium levels (300 mg/kg) and FAO guidelines for soil chromium levels (100 mg/kg). A similar range (8.12-22.81mg/kg) was recently reported for soils around mechanic village dumpsite, Yenagoa, Nigeria (Ukpe and Johnson, 2020). Chromium was not implicated in this study and does not constitute a toxicological risk to the environment when considered independently. Trivalent chromium is considered as an essential nutrient for healthy living, however ingestion has to be moderate; meanwhile, small intake of hexavalent chromium on the other hand, is considered harmful (Ezike, Udiba, Ogabiela, Akpan, Odey, Inuwa, Sule, & Gauje, 2012). High chromium levels can lead to kidney, liver and nerve damage, hemorrhage, gastrointestinal burns, it can also cause an increase in the rate of cancer in humans, as it is a toxic carcinogen.

The levels of nickel in soil ranged between 10.38 and 36.32 mg/kg. Measured concentrations were below WHO/FAO guidelines for nickel (Ni) in agricultural soils and the USEPA Maximum Permissible limit of 50mg/kg. Nickel was also not implicated in this study. Mean levels soil nickel levels of 40.6 mg/kg and 18 mg/kg, were also reported for nickel by Pam *et al.,* (2013) for soil within clusters of mechanic workshops around Gboko area and Makurdi in Nigeria. Lower values ranging from 0.01-0.11mg/kg was recently reported for auto-mechanic workshops at Nekede and Orji in Owerri, Nigeria (Diagi *et al.*, 2023). Increased levels of nickel can result in serious health issues like; respiratory failures, heart disorders and birth defects (Lenntech, 2009).

Copper concentrations in the workshops studied ranged between 19.23 and 48.98mg/kg. These values are lower than the USEPA maximum permission limit for copper levels in soil. Mean levels of 1,348.1mg/kg (GBK cluster) and 254.1 mg/kg (AP cluster), were also reported for copper by Pam *et al.*, (2013) in his study of metals in soil within clusters of mechanic workshops around Gboko area and Makurdi in Nigeria. Copper concentration was also recorded at 211.6 mg/kg for Seguru River Valley, Spain (Mico, Peris, Sanchez, & Recatala, 2006). Lower values ranging from 0.02-0.82mg/kg was recently reported for auto-mechanic workshops at Nekede and Orji in Owerri, Nigeria (Diagi *et al.*, 2023). High concentrations of copper can lead to liver and kidney failure, anaemia and gastrointestinal disorders. Acute levels of copper can cause diarrhea, vomiting, cardiovascular collapse and hypertension (Abdullah, 2011).

Relationship between heavy metal in soil within mechanic workshops in Calabar metropolis: The significant variation in metals concentrations observed between the auto mechanic workshops suggest anthropogenic influence. The significant difference in metals concentration observed between the mechanic workshops and the control suggest that, activities at the workshops may be responsible for the presence of the metals at the concentrations determined.

The significant, strong positive correlations observed between each pair of the metals (Table 4) indicates that, increase in the total concentration of any one of the metals in soil, is associated with corresponding increase in the concentration of the other metals, suggesting that same source may be responsible for their presence at the concentration determined. This further strengthens the suggestion that, auto mechanic activities which is the major anthropogenic activity in the study sites may be source of the metals studied. The increased soil metals concentration may come from metals scraps, welding, spraying of chemicals, used oils, brakes emissions, metals scraps, copper wires, pipes, alloys and electrodes from vehicle scraps, air conditioning coolants, spray paints, batteries and vanishes (Nwachukwu *et al.,* 2011; Zakir, Sultana & Akter, 2014; Zhang, Yan, Zeng, Zhang, Shrestha, Devkota, & Yao, 2012; Abidemi, 2011).

Ecological risk assessment of heavy metals in soil around auto mechanic workshops

Contamination factor (CF): Contamination factor was applied in this study to estimate the rate of anthropogenic input of the metals. The following terms were applied to explain the Contamination Factor (CF); "CF <1 = Low contamination factor, 1 ≤ CF < 3 = Moderate contamination factor, 3 ≤ CF < 6 = Considerable contamination factor and CF ≥ 6 = Very high contamination factor" (Qingjie *et al.,* 2008).

The average contamination factor (5.72 and 3.89) for cadmium during dry and wet seasons respectively corresponds to Considerable contamination factor, suggesting significant anthropogenic contribution. The average contamination factors: 0.99 ans 0.93 for lead, 0.13 and 0.07 for chromium, 0.42 and 0.37 for nickel and, 0.65 and 0.49 for copper during dry and wet seasons respectively correspond to low contamination factor suggesting low anthropogenic contribution of the metals. The order of anthropogenic contributions of the metals in soil was: Cd > Pb > Cu > Ni > Cr.

Ecological risk factor (Er): The ecological risk factor gives an overview of the response of biological communities to heavy metal contamination, and also indicates the possible ecological risks generated by it. The terms applied to describe the Ecological risk factor (Er) are as follows; "Er < 40 = Low potential Er, 40 ≤ Er < 80 = Moderate potential Er, 80 ≤ Er < 160 = Considerable potential Er, 160 ≤ Er < 320 = High potential Er and Er ≥ 320 = Very high potential ecological risk" (Qingjie *et al.,* 2008). Given the ecological risk factor for wet and dry season (171.6, 116.7), cadmium contamination of soil within auto mechanic workshops in Calabar poses a range of moderate to considerable potential ecological risk to other components of the Calabar geochemical environment. Lead, chromium, nickel and copper contamination (Table 8) on the other hand pose low potential ecological risk to the environment

Index of geo-accumulation (I_{geo}): According to Muller's model, seven classes of index of geo-accumulation (Igeo) were set; "Igeo ≤ 0 = unpolluted, 0 < Igeo ≤ 1 = unpolluted to moderately polluted, 1 < Igeo ≤ 2 = moderately polluted, 2 < Igeo ≤ 3 = moderately polluted to strongly polluted, 3 < Igeo ≤ 4 = strongly polluted, 4 < Igeo ≤ 5 = strongly polluted to extremely polluted and Igeo > 5 = extremely polluted" (Qingjie *et al.,* 2008). From the values of Index of geo-accumulation (I_{geo}), the intensity ranking of metal pollution in soil within auto mechanic workshops in Calabar metropolis is as follows: cadmium > lead > copper > chromium > nickel. The average value of index of geo-accumulation (I_{geo}) for cadmium across soils within auto mechanics workshops were found to be 1.78 and 1.65 for dry and wet seasons respectively, corresponding to pollution intensity 'moderately polluted' indicating that the soils are moderately polluted with respect to cadmium. However, lead, chromium, nickel and copper were not implicated as the average value of index of geo-accumulation (I_{geo}) for the metals across soils within auto mechanics workshops were found to be less than zero (Table 9), corresponding to pollution intensity 'unpolluted'.

Pollution load index (PLI): The PLI was adopted in this study, to assess pollution quality of the workshops. The following terms were used to explain the Pollution Load Index (PLI); PLI > 1 = Polluted, PLI < 1 = Not polluted, PLI = 1 suggest pollutant are present at background levels. The PLI computed in this study indicates that auto mechanic workshop at Ikot Ansa, Effio-Ette and Afokang were polluted while Diamond hill and Nelson Mandela were not polluted. It should also be noted that the workshop at Ewa Ekeng, showed PLI approximately equal to unity indicating that the metals are present at background levels.

Conclusion: Mean metals concentrations were below WHO/FAO, United State Environmental Protection Agency (US-EPA) guidelines, Dutch soil intervention soil guidelines values, cadmium being the only exception. Significant variation in metals concentrations was observed between the different workshops suggesting anthropogenic influence. The significant, strong positive correlation between the different metals indicate strong association between them and mirror the probability of their related or common origin, mutual dependence and identical linear behaviour. The significant difference in metals levels between the workshops and the control suggest activities of the workshop could be responsible for elevated metals concentration. The average contamination factor (5.72 and 3.89) for cadmium corresponds to Considerable contamination factor suggesting significant anthropogenic contribution. Ecological risk factor revealed that cadmium contamination of soil poses a range of moderate potential ecological risk to considerable potential ecological risk to the other components of the Calabar geochemical environment. Average values of index of geo-accumulation (I_{geo}) for cadmium (1.78 for dry and 1.65 for wet seasons), corresponding to pollution intensity 'moderately polluted' indicates that the soils are moderately polluted with respect to cadmium. The Pollution Load Index indicates that mechanic workshops at Ikot Ansa, Effio-Ette, Afokang were polluted. The study concludes that auto mechanic workshops in Calabar have significant averse influence on geochemical pollution status of soils. To safeguard environmental and human health, creation of an auto-mechanic village in Calabar at safe distance from residential areas is here by recommended.

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