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Potentials of Earthworm (*Lumbricus terrestris*) as A Tool for Monitoring Heavy Metals in Soils within Auto Mechanic Workshops in Calabar Metropolis, Nigeria

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Abstract

The potentials of Earthworm as a tool for monitoring heavy metals in soils around auto mechanic workshops in Calabar was assessed between February and July 2023. Soil and earthworm samples were collected from six selected auto mechanic workshops at the depths of 0 -15 cm using soil auger. Metals concentrations were determined using atomic absorption spectrophotometer (Shimadzu, model AA-6800, Japan) after wet digestion. Concentrations (mg/kg) of lead, cadmium, chromium, nickel and copper in both soil and earthworm were of the ranges: 14.02- 102.46, 0.74-9.97, 1.23-19.45, 7.21-7.21 and 9.81-48.98 respectively. The metals concentrations were below WHO/FAO soil guidelines, cadmium being the only exception. Significant variation in metals concentrations was observed between the different workshops suggesting anthropogenic influence. Mean earthworm metals contents were below concentrations known to be hazardous to fowls and rodents except for lead. Earthworm metals contents followed same pattern as the soil metals concentration, thus, insinuating soil metal concentration has significant influence on the earthworm tissues content. The significant positive correlations observed between soil metals concentrations and earthworm metals contents at 99% confidence levels, suggests, same source may be responsible for the presence of these metals in both soil and earthworm, and that earthworm could be a good bio-monitor for the metals in soil. The study concludes that, metal bioaccumulation in earthworms could be an ecological indicator and monitor for heavy metal contamination in soil. Further studies to identify species of earthworms, whose abundance/absence, behaviour (preference, avoidance, activity) when in contact with a soil substrate and ability to bio-accumulate could be used as ecological indicators and monitors for specific heavy metal in soil is hereby recommended

Key Words: Earthworm, ecological indicator, bio-monitor, heavy metals, soil

1.0 Introduction: The ability of a soil to maintain biological productivity, preserve environmental quality, and advance plant and animal health within the confines of an ecosystem is termed soil quality (SSSA 1997). Sustainable soil quality is a state at which all the functional properties of the soil to support humans, animals and plants life are fully intact. Monitoring the ability of soils to effectively deliver desired ecosystem services in a sustainable manner is necessary to ensure the protection, conservation and preservation of the environment. Detecting early stages of soil contamination is a vital stage to improve soil quality and ensure safer geochemical environment (European Commission, 2006). Monitoring helps identify existing and emerging contamination or pollution problems, gather relevant information that help policy makers or local actors design prevention or remediation strategies and respond adequately to emergencies. Monitoring and evaluation of soil quality has most often been based on sampling of the physical components of the environments and subsequent analysis for soil quality parameters (Peres, Vandenbulcke, Guernion, Hedde & Beguiristain, 2011). Rarely are biological tools utilized in soil monitoring projects despite the fact that soil organisms are known to react swiftly to both natural and anthropogenic pressures and to numerous influences, making them potential early warning indicators (Peres *et al.*, 2011; Gestel and Brummelen, 2004). According to Markert, Breure & Zechmeister HG (2003), bio-indication is a qualitative indication of environmental characteristics, while biomonitoring is a quantified bio-indication used to identify trends over time and space. In both cases, biodiversity could be reliable tools.

In terms of population density, earthworms are well represented in the soil system, respond quickly to environmental and ecological factors, have strong impact on soil and can be considered as good bioindicators and monitors of soil functioning (Tondoh, Monin, Tiho & Csuzdi., 2007). A site's earthworm fauna's abundance and species composition, individual earthworms' behaviour (preference, avoidance, activity) when in contact with a soil substrate, the build-up of soil chemicals in the body, and biochemical/cytological stress-biomarkers in the earthworm are all ways that earthworms can indicate the quality of the soil. Earthworms are ideally suited to act as accumulation indicators for the presence of bioavailable compounds in the soil for a number of reasons: (1) Earthworms live in the soil and come into contact with the soil on a fairly regular basis, (2) Because earthworms live in hazardous areas, field testing of chemical bioavailability is possible, (3) A wide range of soil types and horizons contain earthworms, (4) The earthworm's external epidermal surface is vascularized and free of cuticles, enabling it to directly absorb pollutants from the soil, (5) Earthworms consume soil or specific soil fractions, allowing pollutants to be ingested through food, (6) Because earthworms have a considerable mass, it is possible to measure the pollutant concentrations in specific individuals. Cadmium, mercury and zinc have been reported to have the tendency to bioaccumulate in earthworm with BAF greater than 1 (Tischer, 2009). This study was designed to assess the Potentials of Earthworm (*Lumbricus terrestris*) as A Tool for Monitoring lead, cadmium, chromium, nickel and copper in Soils Around Auto Mechanic Workshop in Calabar Metropolis. There are two important considerations when using earthworms as accumulation indicators: The earthworm's body concentration provides information on bioavailability of the metals in the soil as well as possibility of secondary poisoning for predators (small mammals and avians) that consume them. Despite a wealth of literature, there are still many unsolved questions regarding how soil characteristics (pH, organic matter, metal concentration), earthworm general and Eco-physiological groups affect earthworms' ability to bioaccumulate metals. To this end, a universal quantitative relationship between soil metal concentration and tissue metal concentration is lacking. Hence the need to assess the potentials before adoption as tool for biomonitoring in a given setting.

Due to the rising demand for personal and commercial vehicles, the majority of which are second hand "Tokunbo" cars, auto mechanic workshop activities have expanded greatly in Nigeria (Ololade, 2014). Mechanics, panel beaters, auto electricians, spray painters, vulcanizers, and occasionally car wash attendants make up the majority of the workforce in auto workshops. Metal scraps, used batteries, packing materials, used lubricants (which contain oxidation products), worn-out parts (containing metal particles and other pollutants brought on by machinery wear) and hydrocarbons (with chemicals both organic and inorganic used as oil additives) are among the waste products generated by artisan operations in the environment of the auto mobile workshop (Ololade, 2014). Groundwater water is put at risk by the leachates from these materials that infiltrate the soil. Auto mechanic workshop in the country faces serious environmental concerns and sustainability issues due to poor waste management. In the cities of developed nations and in some Nigerian cities, automobile mechanic workshops are located or concentrated in "mechanic village". These are facilities and places that were formally planned and constructed to accommodate the activities involved in maintaining and repairing automobiles (Nwachuku, Feng & Alinnor, 2011). Due to the lack of this crucial infrastructure, small and medium-sized clusters of car mechanic workshops have spread across Calabar, filling every available space. This is being done with disregard for the environmental effects of the operations. Sadly, information on the impact of the activities of these workshops on the Calabar ecological geochemical environment is currently relatively scarce. Monitoring lead, cadmium, chromium, nickel and copper in soils around auto mechanic workshop in Calabar metropolis is essential for ecological and health concerns. It could act as early warning signal on the pollution status of soils.

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 (Udofia, Udiba, Udofia, Ezike & Udiba, 2016). Small and medium-sized clusters of car mechanic workshops, therefore adorn the city, filling every available space.

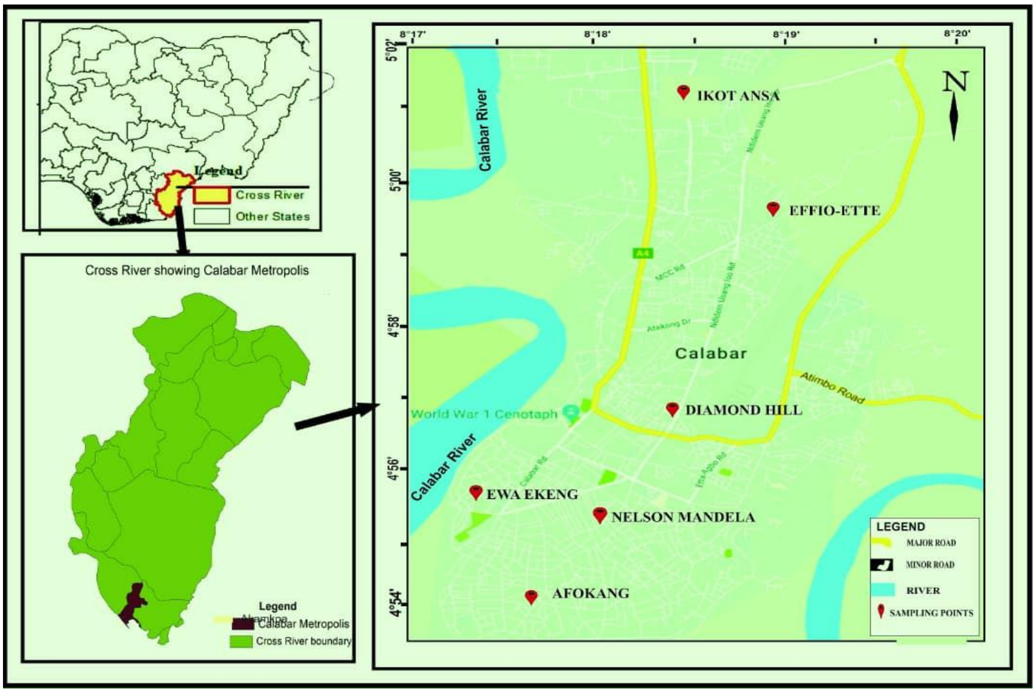

FIG. 1: Map of Calabar metropolis showing sampling points

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, three months in the dry season and three months in the wet season. Earthworms were also collected from each of the sampling points Soil samples were stored in black poly ethylene bags and earth worms in transparent sample bottles, labelled, placed in ice-chest and transported to Lab 249, Department of Zoology and Environmental Biology, University of Calabar, Nigeria

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: To prepare the soil samples for analysis, a standardized procedure (Abida, Ramaiah, Khan & Veena, 2009). The soil samples obtained from the three sampling points at each auto mechanic workshop were mixed together. Similarly, earthworm samples obtained from the three sampling points at each mechanic workshop were mixed together. Soil sample were air dried in the laboratory for five days, then crushed into fine powder using laboratory mortar and pestle. 1g was digested using 20ml of hydrofluoric acid, nitric acid and perchloric acid, ratio 1:3:1. 5g of thawed earthworm were digested using nitric acid and perchloric acid, ratio 3:1 (Baker & Amacher, 1982; Udiba, Ogabiela, Hammuel, Magomya, Yebpella, Ade-Ajayi, Odey, & Gauje, 2012).

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 batch 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.

Bioaccumulation Factor (BAF): Bioaccumulation factor was calculated using equation 1

$$BAF = \frac{Ce}{Cs} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where Ce is the metal concentration per kilogram earthworm and Cs is the concentration metals per kilogram soil.

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 analyzed certified 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: The ranges of metals concentration in soils across auto mechanic workshop in Calabar metropolis during dry and wet seasons are presented in Table 3. Table 3 shows that metals concentration (mg/kg) in soil were of the ranges 45.6-102 and 36.74-101.72, 2.38-9.97 and 2.13-9.56, 6.58-19.45 and 6.21-17.83, 12.09-36.32 and 10.38-29.89 and 21.26-48.98 and 19.23-48.32 during dry and wet season for lead, cadmium, chromium, nickel and copper respectively. The highest concentration of each metal was recorded at Afokang during both dry and wet season. 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:

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 mechanic auto workshops and the control was also significant (ANOVA, $p < 0.05$, Figure 2). The difference in soil metals concentrations between the 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.

Table 3: 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	74.25-91.65	64.87-79.54	43.87-45.67	91.87-102.46	68.37-69.76	45.62-46.83	23.12-23.45
	Cadmium	8.38-8.48	5.73-5.99	2.38-3.67	9.67-9.97	3.65-4.12	2.47-3.83	0.56-0.77
	Chromium	12.34-15.24	11.67-12.79	6.58-7.78	16.09-19.45	8.34-10.23	6.59-6.96	1.34-1.87
	Nickel	24.37-29.84	18.56-22.74	12.34-14.67	31.47-36.32	15.26-16.54	12.09-12.85	4.98-5.87
	Copper	39.37-43.77	29.45-34.87	24.53-25.86	45.46-48.98	25.71-26.86	21.26-23.87	10.45-11.93
Wet Season	Lead	62.48-92.75	54.76-77.76	36.79-45.21	92.49-101.72	54.75-68.34	36.74-45.48	12.35-23.07
	Cadmium	7.98-8.45	3.78-5.87	2.87-3.56	8.23-9.56	2.84-3.87	2.13-3.21	0.42-0.72
	Chromium	10.35-14.24	9.32-11.98	6.21-6.47	12.96-17.83	6.28-9.21	5.01-6.43	1.04-1.65
	Nickel	23.08-24.45	18.46-20.19	12.54-13.35	27.09-29.89	15.23-16.42	10.38-11.98	4.12-5.21
	Copper	39.72-42.17	30.09-32.91	23.41-24.16	45.34-48.32	23.17-25.41	19.23-20.16	10.45-11.09

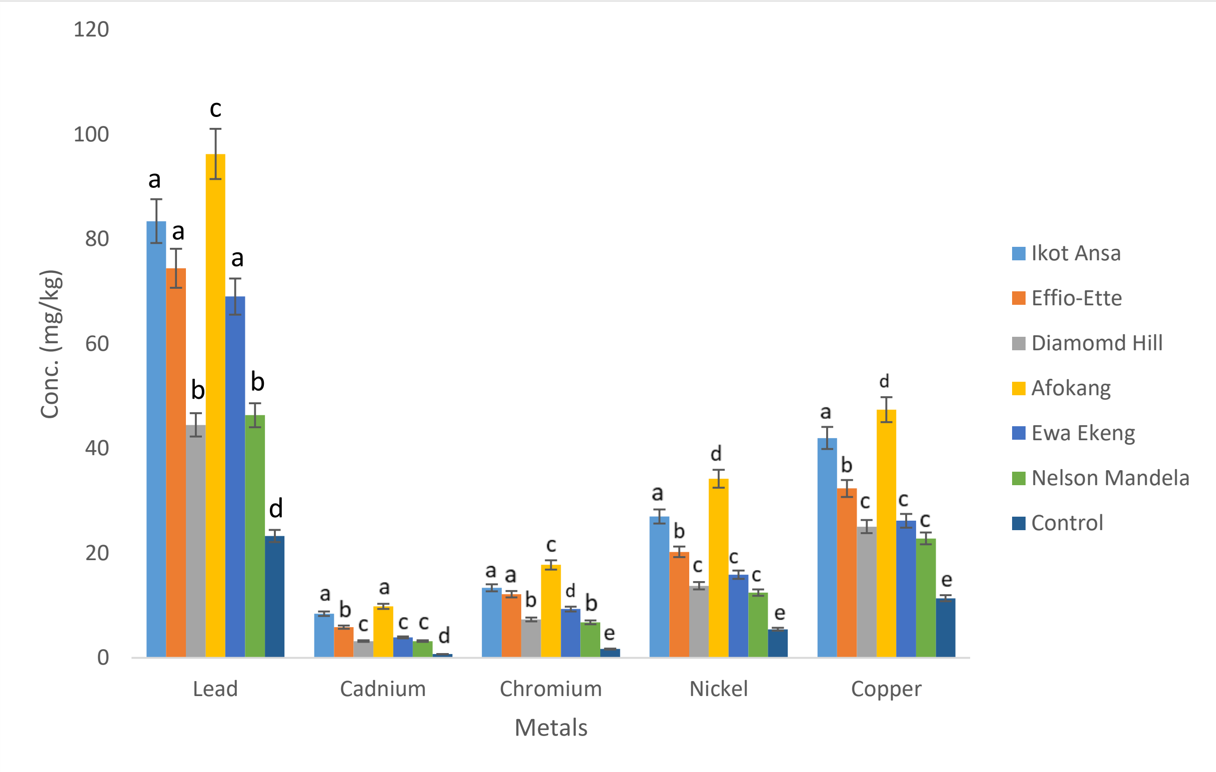

Figure 2: Comparison of metals concentrations between auto-mechanic workshops

3.3: Total Heavy Metal Concentration in Earthworm around Auto Mechanic Workshops in Calabar Metropolis

Table 4 shows that metals concentration (mg/kg) in earthworm across auto mechanic workshops were of ranges 14.47-52.19 and 14.02-57.42, 1.82-6.99 and 0.74-6.82, 1.23-12.56 and 1.94-10.34, 7.98-26.61 and 7.21-15.97 and 9.81-32.19 and 11.42-32.14 during dry and wet season for lead, cadmium, chromium, nickel and copper respectively. Metals content displayed the following sequence:

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

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

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

Statistical analysis revealed that the average concentrations of all the metals in earthworm across the mechanic workshops were found to be significantly higher than the control at 95% confidence level. The difference in metals content of earthworm between auto mechanic workshops was also significant (ANOVA, $p < 0.05$). The difference in metals content of earthworm between dry and wet seasons across mechanic workshops were not significant ($p > 0.05$) except for chromium and copper.

Table 4: Total Heavy Metal Contents of Earthworm within Auto Mechanic Workshops in Calabar Metropolis

Season	Metal	Ikot Ansa	Effio-Ette	Diamond hill	Afokang	Ewa Ekeng	Nelson Mandela	Control
Dry Season	Lead	34.75-39.04	24.52-32.61	14.47-22.29	41.56-52.19	25.28-34.07	16.35-25.82	6.48-13.98
	Cadmium	5.34-6.01	3.57-4.05	1.82-2.54	6.42-6.99	2.47-3.03	1.89-2.43	0.36-0.59
	Chromium	7.01-10.23	4.36-10.03	1.97-4.87	8.79-12.56	3.86-7.38	1.23-4.94	0.43-1.04
	Nickel	19.19-20.98	13.76-14.73	10.62-12.94	24.28-26.61	11.43-12.09	7.98-9.18	3.21-3.96
	Copper	27.54-28.97	18.92-29.53	11.34-16.09	25.81-32.19	19.38-19.87	9.81-14.67	6.78-8.41
Wet Season	Lead	24.07-42.87	24.82-32.73	14.02-18.93	35.85-57.42	15.04-26.71	14.38-19.99	7.15-10.62
	Cadmium	4.62-5.67	3.12-3.86	1.23-1.89	4.74-6.82	1.08-1.74	0.74-1.98	0.51-0.67
	Chromium	7.36-9.36	6.98-9.14	4.02-5.29	5.67-10.34	2.16-5.98	1.94-4.74	0.09-0.21
	Nickel	13.07-13.92	11.41-12.18	8.27-8.86	15.05-15.97	11.33-12.12	7.21-7.54	2.64-3.98
	Copper	21.43-25.62	19.52-21.32	14.17-15.78	24.91-32.14	11.42-16.64	12.43-17.95	5.22-7.24

Bioaccumulation Factor (BAF): Table 5 revealed that the average bioaccumulation factors for both dry and wet seasons were 0.44, 0.42 for lead, 0.69, 0.56 for cadmium, 0.54, 0.31 for chromium, 0.74, 0.63 for nickel and 0.63, 0.88 for copper. The highest bioaccumulation factor (1.08) was recorded by copper at Nelson Mandela during dry season and the lowest contamination factor (0.17) by chromium at Ewa Ekeng during wet season. The average bioaccumulation factor of the metals followed the trend Cu > Ni > Cd > Pb > Cr.

Table 5: Bioaccumulation Factor (BAF)

Auto mechanic workshop	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	0.44	0.44	0.67	0.63	0.61	0.69	0.75	0.57	0.67	0.82
Effio-Ette	0.38	0.44	0.66	0.70	0.58	0.32	0.70	0.61	0.70	0.88
Diamond hill	0.43	0.38	0.69	0.48	0.43	0.28	0.84	0.65	0.53	1.00
Afokang	0.49	0.49	0.69	0.64	0.60	0.22	0.74	0.55	0.60	0.83
Ewa Ekeng	0.43	0.35	0.72	0.40	0.58	0.17	0.74	0.74	0.75	0.67
Nelson Mandela	0.48	0.43	0.68	0.49	0.43	0.20	0.67	0.66	0.51	1.08
Average	0.44	0.42	0.69	0.56	0.54	0.31	0.74	0.63	0.63	0.88

Relationship between heavy metal concentrations in soil and earthworm (*L. terrestris*) from mechanic workshops in Calabar: The relationship between heavy metal concentrations in soil and earthworm (*L. terrestris*) from mechanic workshops in Calabar presented in Table 6 The summary of the relationship between the concentration of heavy metals in soil and (earthworm) from mechanic workshops in Calabar is. shown in

Table 7. A strong positive correlation was observed between lead in soil and lead in earthworm (r = 0.95), cadmium in soil and cadmium in earthworm (r = 0.98), chromium in soil and chromium in earthworm (r = 0.92), nickel in soil and nickel in earthworm (r = 0.96) and between copper in soil and copper in earthworm (r = 0.93). All the correlations were significant at 99% confidence level.

TABLE 6: Relationship between heavy metal concentrations in soil and earthworm (*L. terrestris*) from mechanic workshops in Calabar

Metals	Soil against earthworm (r)	Inference
Pb	0.95	strong positive relationship
Cd	0.98	strong positive relationship
Cr	0.92	strong positive relationship
Ni	0.96	strong positive relationship
Cu	0.93	strong positive relationship

Discussion: Total Heavy Metal Concentration in soil within Auto Mechanic Workshops in Calabar Metropolis: The heavy metals under consideration (Lead, cadmium, chromium, nickel and copper) are classified as potentially toxic elements (PTEs) (Nicholson, Williams & Hill, 2020). The concentrations of Lead, cadmium, chromium, nickel and copper across auto mechanic workshops studied were lower than the United Kingdom soil guideline values for residential with home grown plants of 200 mg/kg, 10 mg/kg, 21 mg/kg and 130 mg/kg respectively. Soil lead, nickel and copper concentrations were also below United State Environmental protection Agency (US-EPA) maximum permissible limit (MPL) of 400 mg/kg, 50mg/kg and 50 mg/kg respectively. Soil cadmium concentration was however above US-EPA MPL of 3 mg/kg. Chromium concentration was below WHO and FAO guidelines for soil chromium levels of 300 mg/kg and 100 mg/kg respectively. The ranges of lead concentrations measured across auto mechanic workshops in this study were higher than that reported by Adebayo *et al*., 2017 but lower than 1162 mg/kg reported for mechanic workshops in Owerri, Nigeria (Nwachukwu *et al*., 2011). Higher mean soil cadmium, nickel and copper levels of 12.7 mg/kg, 40.6 mg/kg and 1348 mg/kg, and 17.9, 18.0 mg/kg and 254.1 mg/kg were reported for mechanic workshops at Gboko and Makurdi, Nigeria (Pam, Sha'Ato & Offem, 2023).

The significant variation in heavy metals concentrations observed between the different auto mechanic workshops suggest that, anthropogenic influence and not geogenic sources are responsible for the presence of these metals at the concentration determined. 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). The significant difference in soil metals levels between the workshops and the control, point to the fact that, activities of the mechanic workshops may be responsible for the elevated metals concentrations. The mechanic workshop at Afokang which recorded the highest concentration all the metals under consideration is located in the suburb and had the highest population of artisans. The workshop was observed to be the largest, most busy, most unorganized with carcases of abandoned vehicle littered around and reported as the oldest of the workshop studied. On the other hand, Diamond Hill and Nelson Mandela which were relatively smaller, well organized and most recent, recorded the lowest soil metals concentration. This suggests that, the length of time the workshop has been in used (age), level of activities, approach to waste management and population of artisans play significant role in determining soil metal levels. This observation is in agreement with Adebayo, Jayoye, Ilemobayo & Labunmi, (2017).

Total Heavy Metals Concentration in Earthworm around Auto Mechanic Workshops in Calabar Metropolis: Mean earthworm cadmium, chromium, nickel and copper contents were below concentrations (10 mg, 100mg/kg, 50mg/kg and 250 mg/kg respectively) known to be hazardous to fowls and rodents (NRC, 2006). Mean lead content of earthworm on the other hand, was above 10 mg/kg which according to United State National Research council, is hazardous to small mammals and avian (NRC, 2006). Lead, cadmium, nickel and copper contents of earthworm across the auto mechanic workshops followed the same pattern as the soil metals concentration, suggesting that soil metal concentration has significant influence on the earthworm tissues content. Similar finding was reported by Richardson, Gorres, &

Sizmur, 2020, who investigated the influence of soil metal concentration on the earthworm tissue concentration using 'generalized linear mixed effects model'. In regional inventories of soil contamination, the concentration in the bioindicator species indicates the bioavailable portion of the contamination (Tischer, 2009). Assessment of chemical concentrations in a bioindicator species on a regular basis might be used to monitor trends

Bioaccumulation Factor (BAF): Bioaccumulation of metals into earthworm in soil is a complex process determined by such factors as concentration, chemical speciation and spatial distribution. Chemical speciation and solubility of metals are significantly influenced by pH and Redox potentials of the soil. There is therefore no universal bioaccumulation rate of metals by the organism. Bioaccumulation factor (BAF) values > 1 indicates that accumulation in the organism is greater than the accumulation in the medium. The BAF in this study was less unity for all the metals except or copper at Diamond Hill and nelson Mandela during wet season suggesting that, the metals are not actively bioaccumulated by the *Lumbricus terrestris* physiologically. The extent to which earthworm uptake and retain metals and other contaminants is greatly influenced by its ability to regulation internal tissue concentrations and bioavailability of the metal in soil (Richardson *et al*., 2020). The limited bioaccumulation of Pb, Cd, Cr and Ni may be driven by specific conditions such as very low soil metal concentrations with low earthworm uptake and elevated soil metal concentrations with low earthworm uptake due to low chemical bioavailability, increased excretion and regulations to maintain homeostasis.

Relationship between heavy metal concentrations in soil and earthworm (*L. terrestris*) from mechanic workshops in Calabar: The significant positive correlations observed between soil concentration of metals and metals contents of earthworm at 99% confidence level indicates clearly that increase in the concentration of each the metals in soil is associated with a corresponding increase in the concentrations of the metals in earthworm suggesting that same source may be responsible for the presence of the metal at the concentrations determined and that earthworm could be a good bio-indicator of the metals under study in soil within mechanic workshops in Calabar. This result is in agreement with Neuhauser, Cukic, Malecki, Loehr & Durkin, (1995) who also reported strong positive correlations between cadmium, zinc, lead and copper in contaminated soil and earthworm. Ezemonye & Enete, (2004) also reported positive correlations between heavy metals in soil and earthworm. In regional inventories of soil contamination, the concentration in the bioindicator species indicates the bioavailable portion of the contamination (Tischer, 2009). Assessment of chemical concentrations in a bio-indicator species on a regular basis might be used to monitor trends

Conclusion: Soil lead, chromium, nickel and copper concentrations across auto mechanic workshops were lower than the United Kingdom soil guideline values, United State Environmental protection Agency (US-EPA) maximum permissible limit (MPL) and WHO/FAO soil guidelines. However, cadmium concentration was above US-EPA MPL. The significant variation in heavy metals concentrations observed between the different auto mechanic workshops suggests anthropogenic influence. Hence auto mechanic activities may have contributed significantly to the presence of these metals at the concentration determined. 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 findings of this study also suggests that, age of the workshop, level of activities, approach to waste management, population of artisans play significant role in determining soil metal levels. Mean earthworm metals contents were below concentrations known to be hazardous to fowls and rodents except for lead. Earthworm metals contents followed same pattern as the soil metals concentration, thus, insinuating soil metal concentration has significant influence on the earthworm tissues content. The significant positive correlations observed between soil concentration of metals and metals contents of earthworm at 99% confidence clearly point to the fact that, same source may be responsible for the presence of these metal at the concentrations determined in both soil and earthworm, and that earthworm could be a good bio-indicator of the metals under study in soil within mechanic workshops in Calabar. Heavy metal bioaccumulation in earthworms can be used as an ecological indicator for heavy metal contamination in soil. Further studies to identify species of earthworms, whose abundance/absence, behaviour (preference, avoidance, activity) when in contact with a soil substrate and ability to bio-accumulate could be used as ecological indicators and monitors for specific heavy metal in soil is hereby recommended

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