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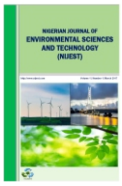

Assessment of Heavy Metal Contamination and Microbial Counts of Soils in Selected Auto-Mechanic Workshops within Benin Metropolis, Edo State, Nigeria

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ABSTRACT

This study carried out an assessment of heavy metal contamination and microbial counts of soils in selected auto-mechanic workshops within Benin metropolis, Edo State, Nigeria. The study assessed the distribution of some heavy metals and microbial counts across three soil depths of the auto-mechanic sites; determined the extent of contamination of heavy metals in the soils and; evaluated significant relationships among the selected heavy metals and microbial counts. A total of 27 soil samples were randomly collected from the three sites (Ugbowo and Uwelu auto-mechanic sites, and control site) at the 0-15, 15-30 and 30-45 cm soil depths. Each soil sample was analyzed for copper - Cu, iron - Fe, chromium - Cr, lead - Pb, cadmium - Cd, manganese - Mg, total heterotrophic bacteria count - THB and total heterotrophic fungi count - THF. Results revealed that Cu, Cr, Pb and Mn were within the permissible limits for heavy metals in soils established by World Health Organization and Department of Petroleum Resources. Concentrations of Cd exceeded the permissible limit with the contamination/pollution index indicating very severe contamination to slight pollution. Geogenic sources rather than anthropogenic sources accounted for the high Fe values. The study found that auto-mechanic activities had greater negative impact on bacteria counts than fungi counts. Significant positive and negative relationships were observed between the selected heavy metals and microbial counts. The study concluded that auto-mechanic activities increased the concentrations of Cd in all the soils and recommended phytoremediation to reclaim soils contaminated with Cd.

Keywords: Auto-mechanic, Benin metropolis, Contamination, Heavy metals, Microbial counts

1.0. Introduction

Heavy metals are ubiquitous elements in the environment with density greater than 5 g cm^{-3} and atomic mass of more than 20 that may have negative effects on the environment (Enete *et al*., 2021). Heavy metals result from both natural and anthropogenic sources and are found in air, water, sediment, soil and rock at various levels of concentrations. They are one of the most serious contaminants/pollutants in the natural environment because of their toxic, persistent and non-biodegradable properties (Ihejirika *et al*., 2016). The terms contamination and pollution are often used interchangeably, but a contaminant can be considered a pollutant when the concentration of the contaminant is high enough to cause harm. Heavy metal contamination/pollution in soils has become a challenging environmental concern in most cities of developing countries especially with the potential health and ecological risks associated with such contamination. These contaminants/pollutants may accumulate in the human body by direct transfer from the soil or from food chain through plants uptake (Sellami *et al*., 2020).

One of the major sources of anthropogenic heavy metals in urban soils in Nigerian cities is auto-mechanic servicing workshops. These auto-mechanic workshops are found in open plots of land within urban towns and cities. Within these urban locales are artisans who specialize in electrical and/or mechanical aspects of auto-vehicle repairs while others engage in metallurgical activities. Activities carried out within these auto-mechanic workshops involve working with and spilling of oil, grease, metal scrap, petrochemical, battery electrolyte, paint and other materials which contain heavy metals that are non-biodegradable and hazardous. These auto-mechanic wastes which comprise of complex mixture of hydrocarbons poured on the ground may increase the level of heavy metals in the soil. The heavy metals spread both horizontally and vertically, and contaminate/pollute the soil. It has been reported that absorption and bioaccumulation of heavy metals in humans may lead to liver and kidney problem, neurotoxic effect in children and damage circulatory and nerve tissues (Malik and Khan, 2016; Yu *et al*., 2017). Soil contamination/pollution has become a major concern in Nigeria's semi-industrialized sectors because it is considered as the ultimate sink for contaminants released into the ecosystem (Adelekan and Alawode, 2011). Unchecked industrial and anthropogenic activities have contributed significantly to elevated levels of heavy metals in soils when compared to contributions from natural processes. Increased concentrations of heavy metals above established permissible values for soils could alter its natural ability to perform ecosystem services; a change which may be irreversible.

Studies that have attempted to assess the effects of auto-mechanic activities on heavy metals concentrations in soils include impacts of automobile workshops on heavy metals concentrations of urban soils in Obio/Akpor Local Government Area, Rivers State, Nigeria (Utang *et al*., 2013); effects of selected heavy metals on topsoil at the vicinities of two automobile mechanic villages, Owerri municipal, Nigeria (Okoro *et al*., 2013); Impact of automobile repair activities on physicochemical and microbial properties of soils in selected automobile repair sites in Abuja, central Nigeria (Ekeocha *et al*., 2017); assessment of point-source pollution of anthropic soils in Benin City, Nigeria (Orobator *et al*., 2019); comparison of soil samples from selected anthropogenic sites within Enugu metropolis for physicochemical parameters and heavy metal levels determination (Okeke *et al*., 2020) and; assessment of heavy metal pollution in urban and peri-urban soil of Setif City eastern Algeria (Sellami *et al*., 2022). These studies reported different levels of heavy metals contamination/pollution in soils of the different auto-mechanic sites which they ascribed to various anthropogenic and geological influences. However, an assessment of contamination/pollution of heavy metals and microbial counts of soils with depths within selected auto-mechanic workshops in Benin metropolis has received limited attention even though the activities therein have been reported to produce harmful wastes which pose risks to the soil environment (Sellami *et al*., 2020; Okeke *et al*., 2020). Some of the heavy metals most frequently encountered in auto-mechanic waste include copper (Cu), iron (Fe), chromium (Cr), lead (Pb), cadmium (Cd), manganese (Mn) etc. Therefore, it is imperative to evaluate the extent of heavy metals contamination/pollution and microbial counts of soils in selected auto-mechanic workshops within Benin metropolis, Edo State, Nigeria.

This study combined analysis of heavy metals and microbial counts in soil samples as well as their statistical valuation and contamination/pollution indices. The main sources of the heavy metals and their environmental risk were discussed taking into account the natural and anthropogenic contexts. The specific objectives were to: (i) assess the distribution of selected heavy metals and microbial counts across three soil depths of the two auto-mechanic workshops; (ii) determine the extent of contamination/pollution of heavy metals in soils of the studied sites and; (iii) evaluate significant relationships among the selected heavy metals and microbial counts.

2.0. Methodology

2.1. Study area

Benin metropolis which is one of the fast expanding cities in Nigeria comprise of Oredo, Egor, Ikpoba-Okha and the urbanized parts of Ovia North-East and Uhunmwode Local Government Areas of Edo State (Balogun and Onokerhoraye, 2017). Benin metropolis lies within Latitude 6° 16' to 6° 33' N and Longitude 5° 31' to 5° 45' E (Figure 1). According to the Köppen's climate classification scheme, Benin metropolis has a humid tropical climate. It is characterized by a distinct dry and wet season with mean annual rainfall and temperature of 2,040 mm and 34°C respectively. The soils within the metropolis are deep, porous, non- mottled and non concretional with red colouration (Izevbigie *et al*., 2011).

Nine soil samples each were collected from three different sampling points at three depth levels; surface soil (0-15 cm), subsurface soil (15-30 cm) and deep soil (30-45 cm) in two auto-mechanic sites in Uwelu and Ugbowo areas of the Benin metropolis during the dry season. The control samples were collected at the same depth levels from a green uncontaminated site (arboretum) identified within the Faculty of Agriculture, University of Benin (Figure 1). The location of the control site was at the same geology with the two auto-mechanic workshops. A total of 27 soil samples were collected from the three sites for the purpose of this study.

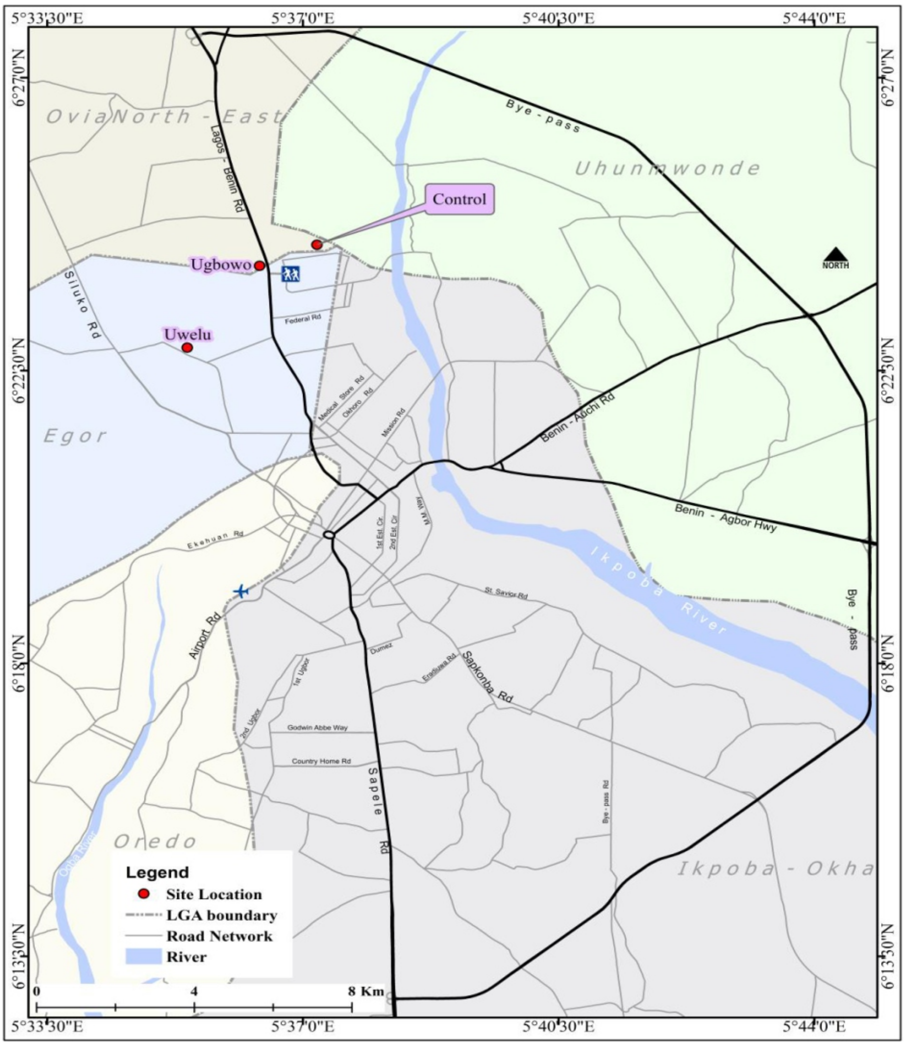

Figure 1: Benin Metropolis Showing Sites Location
Sources: Esri, Garmin, USGS and Geospatial Links Company (2022)

2.3. Soil laboratory analysis

Soil samples were air dried for 48 hours and homogenized to remove non-soil materials. Heavy metals; copper (Cu), iron (Fe), chromium (Cr), lead (Pb), cadmium (Cd) and manganese (Mn) in the soil samples were extracted by leaching into 0.1 M ethylenediaminetetraacetic acid (EDTA) and subsequently analyzed using atomic absorption spectrophotometer (AAS) (Ogbonna and Okeke, 2010). Enumeration of the viable bacteria and fungi population of the soil samples were carried out by pour-plating of 0.1 ml of the appropriate soil dilution (10^{-6}) on nutrient agar plates. Inoculated plates were incubated for 24 hours at 30°C and the microbial load was determined as a colony forming units (cfu g^{-1}) in each sample.

2.4. Statistical analysis

Descriptive statistics such as range, mean, standard deviation and coefficient of variation (CV) were computed for all the examined soil heavy metals and microbial counts. The distributions of heavy metals in soils across the examined sites and soil depths compared to World Health Organization (WHO, 1993; 1996) and Department of Petroleum Resources (DPR, 2002) standards were depicted using tables. Analysis of variance was used to test for significant differences in soil heavy metals and microbial properties among the examined sites. Pearson correlation analysis was tabulated to identify significant relationships between the selected heavy metals and microbial properties. The correlation coefficients between the heavy metals and microbial counts were computed using the entire raw data without taking into consideration the different soil depths. Thus, data for each of the three soil depths and for each site was summed and treated as one. This was aimed at reducing the possible bias that might result from the mean values at each soil depth. All the statistical analyses were carried out using Microsoft Excel (2010) and IBM SPSS statistics 16.0 softwares.

2.5. Contamination/pollution index (Ci/Pi) of the heavy metals

To assess the extent of heavy metal contamination/pollution in the soils, contamination/pollution index (Ci/Pi) of heavy metals in each soil sample was calculated using the Lacatusu (2000) formulation (1). The distinction between soil contamination and soil pollution range was established by means of the Ci/Pi (Table 2). Contamination/pollution index value less than 1 defined the contamination range and when it was greater than 1, it represented the pollution range.

$$\text{Ci/Pi} = \text{Mean concentration of heavy metal/Permissible value from reference table} \qquad (1)$$

Where: Ci/Pi = contamination/pollution index

Table 1: Maximum allowable limits for heavy metals (mg kg^{-1})

Heavy metal	Permissible value	Intervention value
Cu	36	190
Fe	48	-
Cr	100	380
Pb	85	530
Cd	0.8	12
Mn	12	-

Source: *Adapted from WHO (1993; 1996) and DPR (2002)*

Table 2: Significance of intervals of contamination/pollution index (Ci/Pi)

Ci/Pi	Significance
< 0.10	Very slight contamination
0.10 - 0.25	Slight contamination
0.26 - 0.50	Moderate contamination
0.51 - 0.75	Severe contamination
0.76 - 1.00	Very severe contamination
1.10 - 2.00	Slight pollution
2.10 - 4.00	Moderate pollution
4.10 - 8.00	Severe pollution
8.10 - 16.00	Very severe pollution
> 16.00	Excessive pollution

Source: *Adapted from Lacatusu (2000)*

3.0. Results and Discussion

3.1. Effects of auto-mechanic activities on soil heavy metals

Copper (Cu)

Table 3 presents the results of heavy metal in soils of the three studied sites. Results revealed that the concentrations of Cu declined with increasing soil depth in all the examined sites. This implies that Cu was more concentrated in the surface soil than in the subsurface and deep soil layers. There was insignificant interaction effect between the three sampled sites and soil depths on the concentrations of Cu in the soils ($p \geq 0.05$). However, the higher levels of Cu observed in surface soil of Ugbowo auto-mechanic site suggests the impact of auto-mechanic wastes in the surface soil. This may be traceable to high use of Cu conductors and wires, tubes, soders and other Cu containing rusted metals which are left exposed on the surface soil. Copper can be found in vehicle engines and some vehicle alloys contain copper (Adamiec *et al*., 2016). Alloway (1990) argued that Cu strongly attaches to organic matter and minerals, as a result it does not travel very far after release. This may be the reason why the highest values of Cu (1.21, 0.66 and 0.75 mg kg^{-1}) were found in the surface soils of the three sites. The concentrations of Cu recorded at all sites were within the maximum allowable limit set by WHO (1993; 1996) and DPR (2002) (Table 1). This implies that Cu toxicity is not a cause for concern in the studied locations especially as the Ci/Pi revealed very slight contamination (Table 3).

Iron (Fe)

The distributions of Fe across the sites were in no particular order (Table 3). However, the values of Fe increased as soil depths increased in both Ugbowo auto-mechanic workshop and control site. Comparatively, Fe was more concentrated in soils of the control site than in each of the two auto-mechanic workshops. Iron had the highest values among the six investigated heavy metals in all the soils. The concentrations of Fe in the control soils were 2 to 3 times greater than each of the two auto-mechanic soils and varied from 121.00 to 328.00 mg kg^{-1}. This may have accounted for significant variations ($p \leq 0.05$) in the concentrations of Fe across the three studied sites and soil depths. This result suggest geogenic sources rather than anthropogenic sources of Fe in the examined sites. Meanwhile, studies have shown elevated concentrations of Fe in soils compared to other metals, indicating that natural soils contain significant amounts of Fe (Adebayo *et al*., 2017; Ogunkolu *et al*., 2019). This implies that artisan activities at the auto-mechanic sites do not anthropogenically introduce Fe into the soil but may exist naturally in the soil. The concentrations of Fe in all the soils were observed to be very high especially when compared with WHO (1993; 1996) and DPR (2002) maximum limits of 48 mg kg^{-1} (Table 1), thus indicating Fe toxicity in the soils. The Ci/Pi for Fe concentrations in all the soils indicated slight to severe pollution (Table 3). Although Fe plays an important role in the human body as a vital component of proteins such as haemoglobin and cytochromes, excess ingestion of Fe may cause a condition known as hemocromatosis which causes damage to tissues.

Chromium (Cr)

Chromium values in all the examined sites declined with increasing soil depths (Table 3). Asamoaha *et al*. (2021) opined that Cr is a metal with low mobility. This may have accounted for the non-significantly higher Cr mean values (1.41, 1.09 and 1.10 mg kg^{-1}) recorded in the surface soil layer than in the subsurface and deep soil layers ($p \geq 0.05$). All the Cr mean values were significantly (70 times or more) lower than the WHO (1993; 1996) and DPR (2002) reference (Table 1). This outcome indicates natural levels of Cr in soils of the evaluated sites and not due to auto-mechanic activities. The Ci/Pi for Cr concentrations in all the soils indicated very slight contamination. Elsewhere, industrial activities such as tanning, ore refining and steel production as well as lack of proper disposal of wastes have been reported to increase the levels of Cr in soils (Xiao *et al*., 2013).

Lead (Pb)

Lead contamination/pollution in soils leads to decreased soil microbial activities and soil quality deterioration (Utang et al., 2013). An inspection of Table 3 revealed insignificant higher Pb mean values at each soil depths of Ugbowo auto-mechanic workshop than the values recorded at Uwelu auto-mechanic workshop and control site ($p \geq 0.05$). It was also observed that the surface soils, especially in Uwelu auto-mechanic workshop (14.96 mg kg^{-1}), had higher concentrations of Pb compared to the subsurface and deep soils of the other studied sites. This suggest that the dominant anthropogenic inputs such as auto-electrical and auto-mechanical operations of welding and soldering as well as improper disposal of lead batteries carried out at that particular location may have increased Pb concentrates in the surface soil. This may explain the high mean Pb level at Ugbowo auto-mechanic workshop. Nna Orji et al. (2018) in a similar study reported high levels of Pb at oil exchange points. Mean values of Pb recorded across the studied sites and soil depths were 5 to 65 times lower than the reference value (85 mg kg^{-1}) by WHO (1993; 1996) and DPR (2002) (Table 1). All the soils were slightly contaminated as their Ci/Pi values were < 0.25.

Cadmium (Cd)

The vertical pattern of Cd distribution along the soil depths in the study sites indicated a non-significant ($p \geq 0.05$) decline in Cd concentrations as soil depths decreased (Table 3). This infers higher concentrations of Cd in the surface soil layer than in the subsurface and deep soil layers. Cadmium was observed to be more concentrated in soils of Ugbowo auto-mechanic workshop (1.26, 1.03 and 0.84 mg kg^{-1}) than in the other sites indicating the negative impact auto-mechanic activities had on the soil. This outcome may be attributed to the large quantity of batteries being dumped in the auto-mechanic site. Batteries are good sources of several elements including Cd (Ogbonna and Okeke, 2010). The presence of additives consisting of metals in various proportions in lubricants used by auto-mechanic artisans may also be attributed to this outcome. It was observed that majority of the soil samples had Cd values greater than WHO (1993; 1996) and DPR (2002) critical limit (Table 1). Similar results were reported by Luter *et al*. (2011) and Orobator *et al*. (2019). Ci/Pi indicated very severe contamination to slight pollution of Cd in the soils. The elevated concentrations of Cd in the studied sites may have negative impact on the health of animals and humans through food poisoning as well as contaminate/pollute ground water quality considering the high water table in the southern parts of Nigeria and shallow bore-holes dug to get water for domestic use.

Table 3: Results of heavy metals

Heavy metals	Depth (cm)	Ugbowo auto-mechanic site				Uwelu auto-mechanic site				Control site				
		Range	Mean±SD	CV (%)	Ci/Pi	Range	Mean±SD	CV (%)	Ci/Pi	Range	Mean±SD	CV (%)	Ci/Pi	p-value
Cu (mg kg^{-1})	0-15	1.14-1.30	1.21±0.08	6.66	0.03	0.21-1.40	0.66±0.64	96.21	0.01	0.51-1.10	0.75±0.30	40.92	0.02	0.29
	15-30	0.57-1.24	0.94±0.34	36.21	0.02	0.19-1.20	0.57±0.54	96.39	0.01	0.29-1.20	0.69±0.46	66.40	0.02	0.62
	30-45	0.54-0.78	0.66±0.12	18.08	0.01	0.20-1.12	0.53±0.50	94.50	0.01	0.26-1.00	0.58±0.38	65.51	0.02	0.91
Fe (mg kg^{-1})	0-15	46.00-120.00	81.40±37.10	45.58	1.71	42.00-115.00	85.13±38.26	44.94	1.77	121.00-281.00	220.66±86.95	39.40	4.61	0.04*
	15-30	74.00-132.00	108.00±30.26	28.02	2.25	44.00-112.00	85.40±36.33	42.54	1.78	126.00-310.00	244.33±102.75	42.05	5.09	0.04*
	30-45	120.00-180.00	144.66±31.39	21.69	3.01	43.00-116.00	80.33±36.52	45.47	1.67	128.00-328.00	256.00±111.13	43.41	5.33	0.05*
Cr (mg kg^{-1})	0-15	1.30-1.62	1.41±0.18	12.90	0.01	0.45-2.30	1.09±1.04	96.19	0.01	0.80-1.52	1.10±0.37	34.06	0.01	0.79
	15-30	1.07-1.14	1.22±0.16	13.58	0.01	0.45-1.81	0.91±0.77	84.42	0.00	0.44-1.54	0.96±0.55	57.29	0.00	0.77
	30-45	0.94-1.06	1.00±0.06	6.00	0.01	0.48-1.80	0.92±0.76	82.83	0.00	0.42-1.28	0.81±0.43	53.44	0.00	0.90
Pb (mg kg^{-1})	0-15	2.00-39.00	14.96±20.83	138.21	0.18	1.10-4.00	2.10±1.64	78.39	0.02	0.10-9.30	3.20±5.28	165.09	0.04	0.42
	15-30	1.40-28.00	10.86±14.86	136.79	0.13	1.00-2.40	1.50±0.78	52.06	0.01	0.10-8.40	2.86±4.79	167.16	0.03	0.44
	30-45	1.20-10.20	4.86±4.72	97.10	0.06	0.80-2.10	1.30±0.70	53.84	0.02	0.10-8.50	2.90±4.84	167.23	0.03	0.56
Cd (mg kg^{-1})	0-15	1.10-1.50	1.26±0.20	16.43	1.61	0.00-1.90	0.76±1.00	130.65	0.95	0.70-1.40	1.03±0.35	33.98	1.31	0.63
	15-30	0.90-1.20	1.03±0.15	14.78	1.31	0.00-1.60	0.66±0.83	124.89	0.83	0.40-1.40	0.86±0.50	58.07	1.11	0.74
	30-45	0.80-0.90	0.84±0.05	5.94	1.05	0.00-1.60	0.66±0.83	124.89	0.83	0.20-1.10	0.70±0.45	65.46	0.91	0.91
Mn (mg kg^{-1})	0-15	11.20-12.20	11.66±0.50	4.31	0.97	2.80-18.30	8.56±8.47	98.95	0.71	6.50-13.10	9.06±3.53	39.00	0.76	0.75
	15-30	6.50-12.00	9.63±2.82	29.36	0.80	2.40-16.50	7.50±7.81	104.23	0.63	3.80-13.00	7.93±4.67	58.87	0.66	0.88
	30-45	6.40-8.10	7.20±0.85	11.86	0.60	2.40-15.20	6.93±7.17	103.41	0.61	3.20-10.40	6.50±3.63	55.95	0.54	0.98

*Cu - copper, Fe - iron, Cr - chromium, Pb - lead, Cd - cadmium, Mn - manganese, ±SD - standard deviation, CV - coefficient of variation, Ci/Pi - contamination/pollution index, * - significant at $p \leq 0.05$.*

Manganese (Mn)

Manganese as a ubiquitous element in the environment is widely distributed in rocks, sediments and soils (Shrivastava and Mishra, 2011). Table 3 revealed that there was an insignificant decrease in Mn concentrations as soil depths declined in all the examined sites ($p \geq 0.05$). Similar to Cu and Cd, Mn values were higher in the surface soil layer than in the subsurface and deep soil layers. Ugbowo auto-mechanic soils recorded the highest Mn values (11.66, 9.63 and 7.20 mg kg^{-1}) across the three soil depths than in the other two sites. This outcome maybe as a result of abandoned metal scraps, old batteries, equipment components and wastes from welding operations and vehicle spray painting that litter the surface soil. Chronic exposure to high levels of Mn in humans may result in central nervous system challenges. Also manganism which is characterized by feelings of weakness, lethargy and psychological disturbances may result from chronic exposure to higher Mn levels. However, the concentrations of Mn in all the soils indicated very slight contamination ($Ci/Pi < 0.10$) as they were below the critical value (12 mg kg^{-1}) established by WHO (1993; 1996) and DPR (2002).

3.2. Bacteria and fungi counts of soil

Results of microbial counts indicating the bacteria and fungi populations in all the soils of the examined sites are presented in Table 4. There was no regular pattern of distribution of total heterotrophic bacteria counts (THB) and total heterotrophic fungi counts (THF) in the two auto-mechanic sites. But, in the control site, both the THB and THF declined with increasing soil depths. It was observed that the fungi population was dominant over the bacteria population across all the soil layers and examined sites. This suggests that fungi maybe genetically resistant or tolerant to many of these contaminating heavy metals. There were no statistically significant variations among THB and THF counts across the soil depths and studied sites except for THF in the subsurface soil (15 - 30 cm).

Table 4: Results of microbial counts

Microbial counts	Depth (cm)	Ugbowo auto-mechanic site			Uwelu auto-mechanic site			Control			p - value
		Range	Mean±SD	CV (%)	Range	Mean±SD	CV (%)	Range	Mean±SD	CV (%)	
THB ($\times 10^6$ cfu g^{-1})	0-15	1.02-1.22	1.13±0.10	8.93	0.92-1.51	1.20±0.29	24.47	1.08-2.42	1.61±0.71	44.04	0.41
	15-30	1.18-2.34	1.69±0.59	34.92	0.65-1.49	1.08±0.42	38.92	1.01-1.28	1.18±0.14	12.54	0.24
	30 - 45	0.84-2.20	1.36±0.73	53.41	1.09-1.37	1.19±0.15	12.65	0.98-1.36	1.18±0.19	16.17	0.85
THF ($\times 10^4$ cfu g^{-1})	0 - 15	2.10-3.60	2.63±0.84	31.4	0.90-1.90	1.33±0.51	38.48	1.40-4.30	2.63±1.49	56.87	0.28
	15 - 30	2.40-4.20	3.50±0.96	27.55	0.80-1.70	1.13±0.49	43.52	1.20-1.90	1.66±0.40	24.24	0.01*
	30 - 45	1.10-3.00	2.00±0.95	47.69	0.80-1.80	1.36±0.51	37.54	1.10-2.40	1.63±0.68	41.67	0.60

*THB - total heterotrophic bacteria counts, THF - total heterotrophic fungi counts, ±SD - standard deviation, CV - coefficient of variation, * - significant at p ≤ 0.05.*

3.3. Correlation between the heavy metals and microbial counts

Correlation analysis has been widely used in environmental studies. It is an effective tool applied to understand the relationships between multiple variables. In this study, the inter-elemental association was assessed using Pearson product moment correlation to evaluate possible common sources of the heavy metals. The values of soil properties from each of the three soil depths were summed and treated as one for the purpose of this analysis. The correlation matrix for both the heavy metals and microbial counts in soil samples from the three sites are presented in Table 5. The results revealed that in soils of Ugbowo auto-mechanic site, significant positive correlations were observed between Cu/Cr, Cd and Mn; Cr/Cd and Mn; Cd/Mn; and THB/THF respectively. Significant negative correlations also existed between Cu/Fe; and Fe/Mn.

Results of Uwelu auto-mechanic site revealed significant positive correlations between Cu/Cr, Cd, Mn; Cr/Cd, Mn; Pb/THB; and Cd/Mn while significant negative associations were observed between Cu/Fe; Fe/Cr, Cd, Mn; Cd/THF; and Mn/THF respectively. In the control site, significant positive correlations were found between Cu/Cr, Pb, Cd; Cr/Pb, Cd, Mn; Pb/Cd, Mn; and THB/THF. Ekeocha *et al*. (2017) and Asamoaha *et al*. (2021) reported similar significant positive and negative correlations between some soil heavy metals. These results infer that majority of the investigated heavy metals show significant positive relationships between one another. This implies that the investigated elements have identical behaviour and are mutually dependent. It also suggests the possibility of the metals being released from similar origin.

Table 5: Pearson correlation matrix between heavy metals and microbial counts

	Cu	Fe	Cr	Pb	Cd	Mn	THB	THF
Ugbowo auto-mechanic site								
Cu	1							
Fe	-0.735*	1						
Cr	0.914**	-0.629	1					
Pb	-0.148	0.298	-0.071	1				
Cd	0.890**	-0.657	0.986**	-0.139	1			
Mn	0.993**	-0.695*	0.899**	-0.077	0.859**	1		
THB	0.054	0.084	0.135	-0.280	0.084	0.023	1	
THF	0.300	-0.180	0.522	-0.018	0.471	0.277	0.743*	1
Uwelu auto-mechanic site								
Cu	1							
Fe	-0.957**	1						
Cr	0.993**	-0.936**	1					
Pb	-0.324	0.267	-0.411	1				
Cd	0.940**	-0.856**	0.967**	-0.597	1			
Mn	0.999**	-0.954**	0.993**	-0.355	0.951**	1		
THB	0.032	-0.123	-0.050	0.736*	-0.276	-0.005	1	
THF	-0.657	0.633	-0.695*	0.711*	-0.792*	-0.682*	0.654	1
Control site								
Cu	1							
Fe	0.253	1						
Cr	0.993**	0.166	1					
Pb	0.919**	0.551	0.881**	1				
Cd	0.956**	0.007	0.976**	0.800**	1			
Mn	0.992**	0.219	0.996**	0.902**	0.970**	1		
THB	0.185	-0.605	0.244	-0.074	0.369	0.198	1	
THF	0.181	-0.691*	0.252	-0.095	0.397	0.210	0.980**	1

*Cu - copper, Fe - iron, Cr - chromium, Pb - lead, Cd - cadmium, Mn - manganese, * - correlation is significant at the 0.05 level (2-tailed), ** - correlation is significant at the 0.01 level (2-tailed)*

4.0. Conclusions

The soils of the examined locations were within range of the WHO (1993; 1996) and DPR (2002) permissible limits for Cu, Cr, Pb and Mn. The elevated concentrations of Fe in the soil samples were attributed to the parent material and not auto-mechanic activities. However, the soils were slightly polluted with Cd which may pose environmental risk. The bioaccumulations tendency of Cd and their non-biodegradable nature may render these soils a health risk to animals and man. This requires urgent attention. Significant positive and negative relationships were observed between some of the heavy metals and microbial counts indicating that the concentrations of some of these elements in the soil might have enhanced the abundance of others. The study recommended that people should be prohibited from growing edible crops within the confines of auto-mechanic workshops. Phytoremediation is required in order to remediate soils polluted with Cd.

Conflict of interest

The authors declare no conflict of interest, be it professional, financial and/or personal interests that might affect the acceptance of this manuscript.

References

Adamiec, E., Jarosz-Krzeminska, E. and Wieszala, R. (2016). Heavy metals from non-exhaust vehicle emissions in urban and motorway road dusts. *Environmental Monitoring and Assessment*, 188(6), pp. 1-11.

Adebayo, A.J., Jayoye, J.T., Adejoro, F., Ilemobayo, I.O. and Labunmi, L. (2017). Heavy metal pollution of auto-mechanic workshop soils within Okitipupa, Ondo State, Nigeria. *Academic Journal of Environmental Science*, 5(12), pp. 215-223.

Adelekan, B.A. and Alawode, A.O. (2011). Concentrations of muncipal refuse dumps to heavy metals concentrations in soil profile and ground water Ibadan, Nigeria. *Journal of Applied Biosciences*, 40, pp. 2727-2737.

Alloway, B.J. (1990). Soil processes and the behaviour of metals. In: Heavy metals in soils, B.J. Alloway, ed. Blackie and Son Ltd. Glasgow.

Asamoaha, B.D., Asare, A. Okpati, S.W., Aidoo, P. (2021). Heavy metal levels and their ecological risks in surface soils at Sunyani magazine in the bono region of Ghana. *Scientific African*, 13(1), pp. 1-10.

Balogun, T.F. and Onokerhoraye, A.G. (2017). Spatio-temporal growth of Benin City, Nigeria, and its implications for access to infrastructure. *Journal of Geography and Geology*, 9(2), pp. 11-23.

Ekeocha, C.I., Nwoko, C.I. and Onyeke, L.O. (2017). Impact of automobile repair activities on physicochemical and microbial properties of soils in selected automobile repair sites in Abuja, Central Nigeria. *Chemical Science International Journal*, 20(2), pp. 1-15.

Enete, U.O., Ekwuonu, A.M. and Osunwa, C.P. (2021). Heavy metal contamination of soils and vegetation around automobile workshops in Owerri metropolis. *World News of Natural Sciences* 40, 65-85.

Ihejirika, C.E., Njoku, R.F., Ede, T.E., Enwereuzoh, U.O., Izu nobi, L.C., Asiegbu, D. and Verla, N. (2016). Anthropogenic impact and geoaccumulation of heavy metal levels of soils in Owerri, Nigeria. *British Journal of Applied Science and Technology*, 12(1), pp. 1-9.

Izevbigie, F.C., Orimoloye, J.R. and Ogboghodo, I.A. (2011). Effect of petrol (PMS) fire on some soil properties, microbial populations, growth and yield of maize. *International Journal of ChemTech Research*, 7, pp. 47-56.

Lacatusu, R. (2000). Appraising levels of soil contamination and pollution with heavy metals. *European Soil Research Report*, 4, pp. 393 -402.

Luter, L. Akaahan, T.J. and Attah, S. (2011). Heavy metals in soils of automechanic shops and refuse dumpsites in Makurdi, Nigeria. *Journal of Applied Sciences and Environmental Management*, 15(1), pp. 207-210.

Malik, Q.A., Khan, M.S. (2016). Effect on human health due to drinking water contaminated with heavy metals. *Journal of Pollution Effects and Control*, 5, pp. 179.

Nna Orji, C., Abdulrahman, F.W., Isu, N.R. (2018). Pollution status of heavy metals in spent oil-contaminated soil in Gwagwalada. *Asian Journal of Applied Chemistry Research*, 1(2), pp. 1-10.

Ogbonna, P.C., Okeke, V.I. (2010). Metal content of soil and macronutrient of Gmelina leaves in Umuahia, Nigeria. *Journal of Applied Sciences and Environmental Sanitation* 6(1), pp. 15-22

Ogunkolu, A.B., Moses, O., Oyetunji, A.B. and Abudllahi, A. (2019). Assessment of heavy metal contamination of soil around auto mechanic workshops in Anyigba, Kogi State. *Journal of Environmental Studies*, 13(1), pp. 79-89.

Okeke, O., Ezeh, E., Okeke, H.C., Aniobi, C.C. and Akagha, C.I. (2020). Comparison of soil samples from selected anthropogenic sites within Enugu metropolis for physicochemical parameters and heavy metal levels determination. *Journal of Environmental Protection*, 11, pp. 848-861.

Okoro, A.C., Chukwuma, G.O., Chukwuma, E.C., Nwachukwu, P.C. and Ezeh, K.A. (2013). Investigating the effects of selected heavy metals on topsoil at the vicinities of two automobile mechanic villages, Owerri Municipal, Nigeria. *The International Journal Of Engineering and Science*, 2(11) pp. 19-26.

Orobator, P.O., Ekpenkhio, E. and Jideonwo, O. (2019). Assessment of point-source pollution of anthropic soils in Benin City, Nigeria. *The Nigerian Geographical Journal*, 13(2) pp. 51-64.

Sellami, S., Zeghouan, O., Dhahri, F., Mechi, L., Moussaoui, Y. and Kebabi, B. (2022). Assessment of heavy metal pollution in urban and peri-urban soil of Setif City (High Plains, eastern Algeria) *Environmental Monitoring and Assessment*, 194(2), pp. 126.

Sellami, S., Zeghouan, O., Lassaad, M., Moussaoui, Y., and Kebabi, B. (2020). Determination of lead concentrations in the soils of Setif City, Eastern Algeria. *Arabian Journal of Geosciences*, 13, pp. 1-9.

Shrivastava, K.B.L. and Mishra, S.P. (2011). Studies of various heavy metals in surface and ground water of Birsinghpur town and its surrounding rural area district Satna. *Current World Environment*, 6, pp. 271-274.

Utang, P.B., Eludoyin, O.S. and Ijekeye, C.L. (2013). Impacts of automobile workshops on heavy metals concentrations of urban soils in Obio/Akpor LGA, Rivers State, Nigeria. *African Journal of Agricultural Research*, 8(26), pp. 3476-3482.

Xiao, W., Rafiq, M.T., He, Z.L. and Li, T. (2013). Accumulation of chromium in Pak Choi (*Brassica chinensis* L.) grown on representative Chinese soils. *Journal of Environmental Quality*, 42, pp. 1-8.

Yu, F., Zhu, T., Li, M., He, J., Huang, R. (2017). Heavy metal contamination in soil and brown rice and human health risk assessment near three mining areas in Central China. *Journal of Healthcare Engineering*, 3, pp. 1-9.

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