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METAL POLLUTION AND MICROBIAL QUALITY ASSESSMENT OF SCRAPYARD SOIL IN PARTS OF BENIN CITY, NIGERIA.

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ABSTRACT

The proliferation of scrapyards is an environmental threat and constitutes a possible health hazard to nearby residents. This study is aimed at assessing some physicochemical properties, metal pollution, and microbial quality of scrapyard soil in Oluku, University of Benin Botanical Garden (reference) and Upper Iwehen Street, Benin City. Soil samples were gathered from three points between January to March 2024 to a depth range of 0-15cm using hand dug auger. Physicochemical and microbial analyses were conducted using established analytical techniques. The results indicated that all physicochemical parameters at the points fall within the acceptable limits except for conductivity (1107 µs/cm) in scrapyard point 3, which slightly exceeds the stipulated guideline. Metal analysis revealed that Cr, Fe, and Pb levels were within permissible limits, with Zn (300.1) exceeding limits at scrapyard point 1, and Cd (3.1) and Cu (106.8) surpassing permissible limits in scrapyard points. Also, four metals discriminated between the reference point and the scrapyard points ($P<0.05$). The contamination degree result reveals that the scrapyard points 1 and 3 (9.64 and 8.48) are moderately contaminated while the reference point (2.84) is slightly contaminated. The pollution load index indicated that the scrapyard points 1 and 3 (1.10 and 1.08) are polluted, while the reference point (0.94) is unpolluted. The geo-accumulation index (I_{geo}) results for Cd, Cu, and Zn distinguish between the scrapyards and reference points while Cr, Fe, and Pb did not. Cadmium in scrapyard points 1 and 3 (2.90 and 2.61) indicated moderately to heavily contaminated, contrasting with the slightly polluted in the reference point (0.90). Total bacteria count ranged from (3×10^3- 6×10^3) cfu/g in scrapyard points and (0×10^3-1×10^3) cfu/g at the reference point. The results reveal that scrapyard points 1 and 3 are contaminated when compared with the reference point.

Keywords: *Contamination* degree, *Geo-accumulation index, Metal pollution, Microbial quality, Scrapyard*.

INTRODUCTION

Development, increasing urbanization, and climate change are intricately connected to Municipal solid waste management (Oteng-Ababio, 2018). The rapid expansion of the global economy has intensified pressure on soil resources. The current pace of urbanization and industrialization in Nigeria has led to a rise in the generation of scrap waste usually deposited where metals and other constituents are leached into the earth resulting in impairment in sections of the city (Adedeji *et al*., 2014).

A metal scrapyard serves as a collection point primarily for metal scraps, which can be either new or old. New scraps originate from pre-consumer sources such as cuttings, trimmings, and materials that do not meet specifications, while old scraps come from post-consumer sources once a product reaches the end of its functional life. Examples include used vehicular car parts, iron, and steel (Hardy *et al.,* 2008). However, heavy metals can also be disposed of as waste during various stages of manufacturing, use, and recycling during storage at the scrapyard. These items are typically resold as scrap metal or usable parts, with additional services like vehicle disposal, part sales, and metal recycling often provided (Jones *et al*., 2021). Scrapyard operations, including vehicle and machinery dismantling, metal cleaning, sorting, and recovery, carry inherent risks due to the presence of toxic substances (Adedeji *et al.,* 2014). These substances can adversely affect human well-being, and the natural ecosystem (Khashman *et al.,* 2006). Soil acting as a complex porous medium, retains and transports pollutants like cadmium, cobalt, copper, nickel, lead, and zinc into nearby surface and groundwater, exposing residents to health hazards (Leung *et al*., 2010). Groundwater studies around scrapyards have shown elevated levels of metals (Momodu *et al.,* 2010*)*. The concern for metal contamination in soil is tied to its potential impact on the food chain, affecting plant uptake, which, in turn, influences animal and human well-being (Ekosse *et al*., 2005).

Due to heavy metals' non-biodegradable nature, they are not easily broken down by metabolic processes or detoxified. Consequently, they remain in the soil for extended periods, impacting its biological, chemical, and physical properties, and potentially affecting productivity (Jones *et al*., 2021). Metals exist in various forms that affect their mobility and availability to organisms. Therefore, the toxic property of metals in soil is strongly influenced by their chemical form, leading to increased attention to metal speciation (Hardy *et al*., 2008; Jones *et al*., 2021). The accumulation of discarded iron materials and associated activities pose significant environmental concerns, particularly regarding their impact on surrounding soil.

Urban topsoil and water contamination primarily stem from human activities like those found in scrapyards, which can endanger public health through the ingestion of toxic metals like lead and cadmium (Adamo *et al*., 2009). Despite well-documented heavy metal concentrations in advanced nations, there is a lack of data and statistics for many evolving nations, including Nigeria (Huu, *et al.,* 2010). Scrapyards in Nigeria, are situated haphazardly in urban areas, and various scrap materials from automobiles, machinery, and electrical appliances, are often laden with contaminants that can be harmful and cause environmental damage if not handled correctly (Matini *et al*., 2011). Such activities also emit hazardous gases and may even involve radioactive materials (Adedeji *et al*., 2014). The quality of surface water and groundwater may be influenced by runoff from scrapyards posing a significant risk to water pollution (Thompson *et al.,* 2019)

Reportedly, Scrapyards in Benin City contributes over a million naira in taxes to the Edo State Government annually, along with forty thousand naira to the community. Historically, the land at Upper Iwehen was a haven for criminals and nuisances due to its abandonment and proximity to a moat. However, with the establishment and growth of the scrapyard business, the area has transformed, putting an end to its previous misfortunes. Examples of scraps found in both scrapyards include automobile parts, papers, cartons, metal scraps, and aluminum scraps. With the proliferation of scrapyards in Benin City, there is an increased likelihood of soil contamination with these substances, especially in areas surrounded by these scrapyards. Therefore, this study serves as additional data for researchers and government agencies engaged in the management of soil in urban areas to ascertain the effect of scrapyards on soil quality. Also, the study included in its assessment microbial analysis, geo-accumulation index, and contamination degree, while monitoring other parts of Benin not previously evaluated in earlier studies.

MATERIALS AND METHODS

DESCRIPTION OF STUDY AREA

Benin City, situated in Edo State, Nigeria, serves as a pivotal location for studying scrapyard soils. Positioned approximately at 6.3350° N latitude and 5.6037° E longitude, it resides in the southern region of Nigeria. The city's significance lies in its role as a hub for various industrial and commercial activities, including scrapyard operations. Three sample locations comprising two scrapyards close to residential houses and one reference point were selected for this study. The first scrapyard which lies between latitude N6˚26ˈ58.854ˈˈ and longitude E5˚35ˈ46.752 is located in Oluku community in Ovia North East Local Government. This scrapyard is said to have been in existence for over seven years. The Second scrapyard lies between the latitude N 6°20ˈ28.68” and longitude E 5º37’15.396” and it is located on Upper Iwehen Street, within the Oredo Local Government Area. With a history spanning over 20 years, it functions as a crucial source of livelihood for both its workers and the community. The reference point lies between latitude N6°23ˈ50.91 and longitude E5˚36ˈ57.534 and it is located on the premises of the University of Benin, Ugbowo campus. The University of Benin Botanical Garden has two main roles: it helps students learn about plants and it's a place for researchers to study plant life and how to protect it. Moreover, it assumes a crucial role as the designated reference point for our ongoing study. This choice is informed by the discernible disparity in soil contamination levels between the garden and the scrapyards.

Sample collection and processing

Twelve soil samples (Eight from two scrapyards), (Four from the reference point) were collected at least once in two weeks for a period of two months from January 2024 to February 2024. Samples were collected from sample point one to sample point three at every sampling event. The samples were immediately taken to the laboratory for the analysis of physicochemical parameters, heavy metals analysis, and microbiological analysis. Soil samples were collected at a depth of 15cm using a hand-dug auger (Akinnusotu and Arawande, 2016). Upon extraction using the hand-dug auger, any surface debris present on the soil was carefully removed before sampling. The collected samples were then processed according to the standard method described by Jones *et al*., (2021) and placed into a sterile container, and appropriately labelled for analysis.

Analysis of soil physicochemical parameters

Soil physicochemical parameters namely, electrical conductivity (EC) and pH were determined using pH meter and conductivity (HANNA Instrument) (Okeke *et al*.,2020). Nitrate was measured by using a measuring cylinder, and 10ml of the soil extract was measured and transferred into a conical flask. Following this, 1 ml of bromocresol was introduced using a syringe, and 10 ml of sulfuric acid was added with a measuring cylinder. After allowing the solution to stand for 10 minutes, the visible spectrophotometer VS721G was adjusted to a wavelength of 460nm to 570nm. Calibration was performed using 3ml of distilled water before proceeding with the experiment, which involved analyzing 3ml of the soil sample.

Phosphate was determined by the ascorbic acid method outlined in APHA (1998). In the analysis, 5ml of the sample was earlier measured into a 50ml flask, thereafter 1ml of ascorbic acid was added. The sample volume was adjusted to 25ml by adding distilled water. After 30 minutes, the blue-colored sample was analyzed using the visible spectrophotometer VS721G, specifically set at a wavelength of 660nm.

Heavy metals determination

The heavy metals analyzed included chromium, cadmium, copper, iron, zinc, and lead. Soil samples were processed and tested for metals using an Atomic Absorption Spectrophotometer (Model Buck Scientific 210 VGP) (Adedeji *et al*., 2014).

Microbiological analysis

One gramme (1g) of soil sample was put into a test tube of sterile water for dilution, then we homogenized properly, thereafter serial dilution of the soil samples was prepared to reduce the microbial concentration to a countable range, and 1ml of the 4^{th} serial dilution was put in a Petri dish and a media was added to each sample. For bacteria count, the media used was the nutrient agar which was made ready by dissolving 28g of the agar powder in 1L of deionized water and then autoclaved at 121˚C for 15 minutes to sterilize and the sterilized agar was allowed to cool to molten state at about 45ºC. This media is used to identify and isolate the bacteria. For *Escherichia coli* count, the media used was the Mackonkey agar which was prepared by dissolving 52g of the agar powder in 1L of deionized water and then autoclaved at 121˚C for 15 minutes to sterilize it, and after sterilizing the agar was allowed to cool to at molten state at about 45˚C. For coliform count, the media used was Eosin Methylene blue agar (EMB) which was made by dissolving 40g of the powder in 1L of deionized water then autoclaved at 121˚C for 15 minutes to sterilize it, and after sterilizing the agar was allowed to cool to at molten state at about 45˚C. After adding the media to the plates, we shake them for even distribution and then place the plates in an incubator set to a suitable temperature of 37°C for 24 to 48 hours. Then we counted the visible colony and calculated the colony forming units (CFU) per gram of soil sample.

Quality Assurance and Control

Laboratory techniques strictly followed Standard Operating Procedures (SOPs), and sampling procedures adhered to established protocols at both the metal scrapyard points and the reference point. Measures were taken to prevent contamination during the sampling process, and samples were air-dried and stored in sterilized containers before analysis. Equipment calibration and management were conducted by regulations set forth by the National Chemical Laboratories (NCLs).

Data analysis

Data analysis was done to determine the basic descriptive statistics, while the Pearson correlation coefficient was used in the determination of the connection between metals and the physicochemical properties of the soil. Soil parameters were compared to guidelines and depicted using tables. Analysis of variance was employed to determine if there were significant distinctions in soil physicochemical properties and metals among the investigated points and when there was a significant difference a Bonferroni post hoc test was carried out to determine the source of the difference. All the statistical analyses were carried out using Microsoft Excel (2019).

Pollution indices evaluation

Contamination factor (CF)

It is expressed as the ratio of the contaminant's pseudo-total level in the tested soil sample compared to that in the background sample is depicted on a contamination scale ranging from 1 to 6 (Hakanson, 19080; Anegbe *et al.*, 2017):

CF < 1, low level of contamination

3 < CF < 6, considerable level of contamination

1≤ CF < 3, moderate level of contamination

and CF > 6, a very high level of contamination

$$CF = \frac{\text{metal concentration in sample}}{\text{metal concentration in the background}} \quad (1)$$

Contamination degree (CD)

It is described as the aggregate of the whole contamination factors. It shows a sign of the degree of comprehensive contamination in soil from the collection point (Håkanson 1980; Enuneku et *al.*, 2018). It is represented as:

$$CD = \sum_{i=1}^{n} CF \quad (2)$$

CD < 6 is a low degree of contamination

12 ≤ CD < 24 considerable degrees of contamination

6 ≤ CD < 12 is a moderate degree of contamination

CD ≥ 24 very high degree of contamination

Pollution load index (PLI)

It stands for the factor by which the metal content in the soil surpasses the background concentration. It provides all-inclusive knowledge regarding the excessive levels of metal in a specific sample (Yang *et al.*, 2011; Enuneku *et al.*, 2018). PLI is defined as the nth root of the multiplications of the concentrations (Madugu *et al.*, 2020). Overall, PLI

$$PLI = (CF_1 \times CF_2 \times CF_3 \cdots \times CF_n)^{1/n} \quad (3)$$

Where, CF = contamination factor, n = number of metals

The PLI value of > 1 connotes polluted whereas < 1 connotes no pollution.

Geo-accumulation index (***I_{geo}***)

This index serves as a tool to appraise the presence and concentration of human-made contaminants deposited on the surface of soil. Initially proposed by Muller (1969) in the late 1960s, this index has become a standard tool in studies focusing on trace metal analysis. It effectively evaluates contamination levels by comparing the concentrations observed in the study with those from pre-industrial times. It is represented as

$$\boldsymbol{I_{geo}} = \mathrm{Log}_2 \frac{Cn}{1.5Bn} \quad (4)$$

Where C= concentration of element "n", B= geochemical background of the metal (n)

Factor 1.5= possible variation of the background data due to lithogenic effect

$I_{geo} < 0$ denotes uncontaminated soil

$3 < I_{geo} < 4$ connote heavily contaminated soil

$0 < I_{geo} < 1$ indicates uncontaminated to moderately uncontaminated soil

$4 < I_{geo} < 5$ show heavy to extremely contaminated soil

$1 < I_{geo} < 2$ signify moderately contaminated soil

$5 < I_{geo} < 6$ connote extremely contaminated soil

$2 < I_{geo} < 3$ depicts moderately to heavily contaminated soil

RESULTS AND DISCUSSION

A result summary of the physicochemical variables of the scrapyard soil and reference points obtained from the different sampling points is shown in Table 4.1. The mean pH values in this study were 7.31, 7.44, and 7.35 for sample points 1, 2, and 3 respectively. The maximum value recorded for sample points 1, 2, and 3 were 8.1, 8.23, and 7.6 respectively, while the minimum value was 6.73 for both sample points 1 and 2, and 7.2 for sample point 3 (scrapyard point). The mean pH concentration of the scrapyard soil samples in this study varied from 7.3 to 7.44. This range value is similar to the findings of Eghomwanre *et al.* (2019) who recorded a pH range of 6.17 to 7.81 indicating neutrality to slight alkalinity of the soils. The pH value recorded in this study is between 6.0 and 9.0. This result showed that the pH of the scrapyard soil was all within the permissible limit of 6.5 - 8.5 (WHO, 2006).

The electrical conductivity (EC) recorded in this study ranged from 81.5 to 1107µS/cm. The recorded EC value for scrapyard sample points 1 and 3 was above the permissible limit of WHO, while sample point 2 (reference) was within the permissible limit. Eghomwanre *et al.* (2019) recorded an elevated average range of 870.00 - 1480.00 µS/cm for EC in soil samples in metal scrapyards in Benin City, this value was higher compared to the values reported in soil samples from the scrapyards in the present study. Okeke *et al.,* (2020) recorded an EC range of 77.71 to 70.84µS/cm for metal scrap dumps, this value was lesser than the result obtained from this study. The higher EC values noticed for scrapyards soil samples in Benin City could be attributed to certain metals derived from scrap materials contributing to the creation of soluble and ionizable inorganic salts within the soil (Osakwe, 2014). The mean total organic carbon recorded in this study was 1.47% and 2.53% in sample points 1 and 3 (scrapyards) and 1.95% for sample point 2 (reference). The soil organic carbon of this study ranged from 1.47 % to 2.53 % across the sampling points. These results were within the WHO permissible limit but less than the soil organic carbon values of 9.24 and 8.57% recorded by Okeke *et al.* (2020), and higher than 0.38 to 0.54% recorded by Akpoveta *et al.,* (2010). The mean concentration of organic matter recorded in this study ranged from 2.52 to 3.78% which was below the WHO permissible limit. The minimal biodegradable wastes found in soil samples from metal scrapyards, resulting from activities at these locations, may have contributed to their low levels of organic matter (Okeke *et al*., 2020). Okeke *et al.* (2020), had similar results of 4.12 to 3.38% for metal scrapyards in Enugu State, Nigeria.

The average concentration of nitrates ranges from 0.47 to 1.56 mg/kg, which is slightly higher than the nitrate value of 0.04 – 0.62% recorded in the study by Obianefo *et al.,* (2017) on a dumpsite in River State, but lower than 2.18 to 44.27 mg/kg recorded by Eghomwanre, *et al.,* (2019). Higher nitrate levels of 4.17 to 11.33 mg/kg and 3.476 to 4.522 mg/kg have been reported by previous authors (Uba *et al.,* 2008; Osazee *et al*., 2013). The mean concentration of phosphate ranged from 3.05 to 4.64 mg/kg with the highest value recorded in sample point 1 which could be due to the proximity it has to a market, a primary school, and the activities in that scrapyard. This result is similar to the phosphate value 0.041 –4.07 mg/kg recorded by Obianefo *et al.,* (2017). The values of nitrate and phosphate recorded in this study were within the acceptable limit of WHO 2006. Some soil physicochemical parameters strongly correlated with some heavy metals (Table 2).

Table 1: Physicochemical properties of scrapyard soil and the reference sample point

	pH	**EC (µs/cm)**	**TOC %**	**TOM %**	**NO_3 mg/kg**	**PO_4 mg/kg**
Sample point 1						
Mean ±SD	7.31±0.57	662±37.63	1.47 ± 0.16^{AA}	2.52 ± 0.27^{AA}	1.08±0.63	4.64±1.23
Minimum	6.73	606	1.34	2.31	0.17	3.42
Maximum	8.1	684	1.7	2.93	1.51	6.36
Sample point 2 (Reference)						
Mean ±SD	7.44± 0.63	81.5± 16.68	1.95 ± 0.33^{AA}	3.36 ± 0.56^{AA}	0.47±0.22	3.05±1.20
Minimum	6.73	70	1.58	2.73	0.15	2.13
Maximum	8.23	106	2.22	3.83	0.62	4.81
Sample point 3						
Mean ±SD	7.35± 0.19	1107± 1085.92	2.53 ± 0.55^{AB}	3.78 ± 0.65^{AB}	1.56± 0.94	3.88± 1.82
Minimum	7.2	204	1.895	3.22	0.38	2.32
Maximum	7.6	2686	3.23	4.35	2.32	5.8
P-value	0.94	0.12	0.01	0.02	0.12	0.34
WHO Permissible limits	6.5-8.5	100	50	50	-	-

EC: Electrical conductivity; TOC: Total organic carbon; TOM: Total organic matter, ANOVA-derived P-values are denoted, with different superscript letters per variable indicating significant differences ($P < 0.05$) identified by posthoc testing. The same superscript letter between points per variable indicates no significant differences ($P > 0.05$)

Table 2: Correlation coefficient of soil physicochemical parameters in Scrapyards

	pH	*EC*	*TOC*	*TOM*	*NO_3*	*PO_4*	*Cd*	*Cr*	*Cu*	*Fe*	*Pb*	*Zn*
pH	1											
EC	-0.73	1										
TOC	0.25	0.48	1									
TOM	0.48	0.25	**0.97**	1								
NO_3	-0.72	**1.00**	0.49	0.26	1							
PO_4	-0.98	0.59	-0.43	-0.64	0.58	1						
Cd	-1.00	**0.78**	-0.18	-0.41	**0.77**	**0.96**	1					
Cr	-0.98	0.56	-0.45	-0.65	0.56	**1.00**	**0.96**	1				
Cu	-0.96	**0.89**	0.04	-0.21	**0.89**	**0.89**	**0.98**	**0.88**	1			
Fe	-0.96	**0.89**	0.03	-0.22	**0.89**	**0.89**	**0.98**	**0.88**	**1.00**	1		
Pb	-1.00	0.71	-0.28	-0.50	**0.71**	**0.99**	**0.99**	**0.98**	**0.95**	**0.95**	1	
Zn	-0.99	**0.81**	-0.12	-0.36	**0.81**	**0.95**	**1.00**	**0.94**	**0.99**	**0.99**	**0.99**	1

EC: Electrical conductivity; TOC: Total organic carbon; TOM: Total organic matter, bold values represent significant correlation at $P<0.05$

All metals in the course of this study had their highest concentration in sample point 1, followed by sample point 3, and the least in sample 2 (reference point) and this was probably due to the high level of scrapyard activities present in sample points 1 and 3 Table 3. In addition, four metals namely, Cu, Fe, Pb, and Zn discriminated between the reference point and the scrapyard points as the metal values significantly differ ($P < 0.05$) between the reference point and the scrapyard points. The mean concentration of cadmium recorded from this study ranged from 0.84 to 3.35 mg/kg across the sampling points. When these values were compared with the World Health Organization's permissible limit, DPR intervention target value, and DPR value, sample point 1(scrapyard) exceeded the WHO permissible limit.

The value of Cd recorded is similar to 0.75 to 2.15 mg/kg reported by Qasem *et al.,* (2005). Chromium is usually regarded as being hazardous to both plants and people. The buildup of chromium in the soil has the potential to limit its ability to perform its job, harm plants, and poison the food chain (Ivezic *et al.,* 2012). The mean level of chromium recorded from this study ranged from 10.29 to 20.22mg/kg across the sampling points which is less than the value of Cr 1.57 to 40.7 recorded by Eigbike *et al.,* (2024). Chromium values were within the stipulated guideline.

Copper is a significant component of machinery and electrical devices, leading to elevated concentrations being detected in the vicinity of scrapyards (Adedeji *et al.,* 2014). However, such high levels of copper pollution in the soil can pose considerable health hazards to both humans and the environment. Particularly, children residing near scrapyards face significant risks (Hogan, 2010). The results reveal that scrapyard soil in sample points 1 and 3 exceeded the WHO limit, while sample point 2 (reference) was within the WHO permissible limit. This is similar to the result of Cu concentration obtained from a study conducted by Jaradat *et al.,* (2005).

The mean concentration of iron recorded from this study ranged from 290.88 to 679.22mg/kg across the sampling points. Lower values were recorded in the reference point compared to the scrapyard points. The values recorded in this study are lower than the Fe level of 126.00 to 1267.50mg/kg recorded by Eigbike *et al.,* (2024).

Table 3: Heavy metal concentration (mg/kg) of soil samples from scrapyards in Benin City

	Cd	Cr	Cu	Fe	Pb	Zn
				mg/kg		
Sample point 1						
Mean ±SD	3.35±1.61	20.22±6.39	107.55±11.94^{AA}	679.22±58.99^{AA}	8.21±3.13^{AA}	300.05±69.73^{AA}
Minimum	0.94	11.49	89.67	597.51	3.87	211.67
Maximum	4.3	25.47	114.43	723.94	11.263	365.23
Sample point 2 (Reference)						
Mean ±SD	0.84±0.46	10.29±2.00	37.73±13.18^{AB}	290.88±66.09^{BB}	1.85±0.33^{BB}	85.77±12.29^{BB}
Minimum	0.58	7.56	29.28	246.83	1.38	78.33
Maximum	1.55	12.37	57.39	386.62	2.09	103.97
Sample point 3						
Mean ±SD	2.75± 2.26	15.26± 2.69	106.03± 41.72^{AA}	666.98±143.88^{AA}	6.09± 4.24^{AA}	260.22± 97.37^{AA}
Minimum	0.79	12.97	53.82	486.98	1.47	132.74
Maximum	5.21	18.93	152.93	822.54	10.57	347.65
P-value	0.13	0.03	0.006	0.0004	0.04	0.004
DPR Target Value	0.8	100		-	85	
DPR Intervention Value	12	380		-	530	
WHO MPL	3	100	100	50000	100	300

ANOVA-derived P-values are denoted, with different superscript letters per variable indicating significant differences ($P < 0.05$) identified by post-hoc testing. The same superscript letter between points per variable indicates no significant differences ($P > 0.05$). Source: FAO/WHO, (2011); DPR, 2002

The mean concentration of lead recorded from this study ranged from 1.85 to 8.21 mg/kg across the sample points. Lower Pb levels were recorded in the reference point. This value range recorded is less than 79 to 307 mg/kg recorded by Qasem *et al.,* (2005). The average Zinc concentrations observed in this study varied from 85.77 to 300.05mg/kg across the sampled points. Higher zinc levels were recorded in scrapyards sample points and sample point 1 slightly exceeded the WHO's limit.

The contamination factor, contamination degree, and pollution load index were calculated summarized, and presented in Table 4 and Figures 2 and 3. The contamination degree for scrapyard points 1 and 3 (were above 1) indicates a moderate degree of contamination, while sample point 2 (reference) shows a low contamination degree (0.94) which is less than 1 (Table 4). The Pollution load index (PLI) values of sample points 1, 2, and 3 were 1.10, 0.94, and 1.08 respectively (Table 4). The result showed that scrapyard sampling points 1 and 3 were polluted because soils in the scrapyards exceeded the critical value of 1.0. These soils were probably contaminated by scrapyard activities such as improper waste disposal, negligent handling of chemicals, inadequate containment measures, and lack of maintenance while sampling point 2 (reference) with a PLI value of less than 1 which is indicative of non–pollution. Elevated levels of metals beyond the Maximum Permissible Level (MPL) can result in various health issues including nervous, cardiovascular, renal, and neurological impairments, as well as bone diseases and other disorders (Adedeji *et al.*, 2014).

Table 4: Calculated contamination factor (CF), contamination degree (CD), and Pollution Load Index (PLI) of soil samples from Scrapyards in Benin City

Metals	Sp 1	Sp 2 (Reference)	Sp 3
Cd	4.19	1.050	3.438
Cr	0.20	0.103	0.153
Cu	2.99	1.048	2.945
Fe	0.018	0.008	0.018
Pb	0.10	0.022	0.072
Zn	2.14	0.613	1.859
CD	9.635	2.843	8.483
PLI	1.10	0.94	1.08

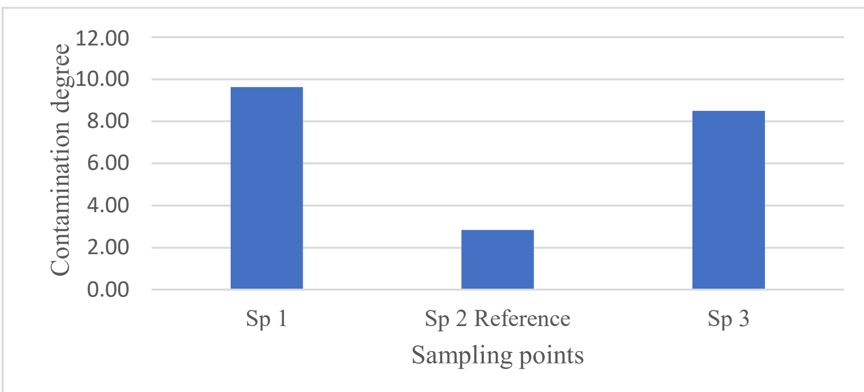

Figure 2: Contamination degree for the three sample points in the study area

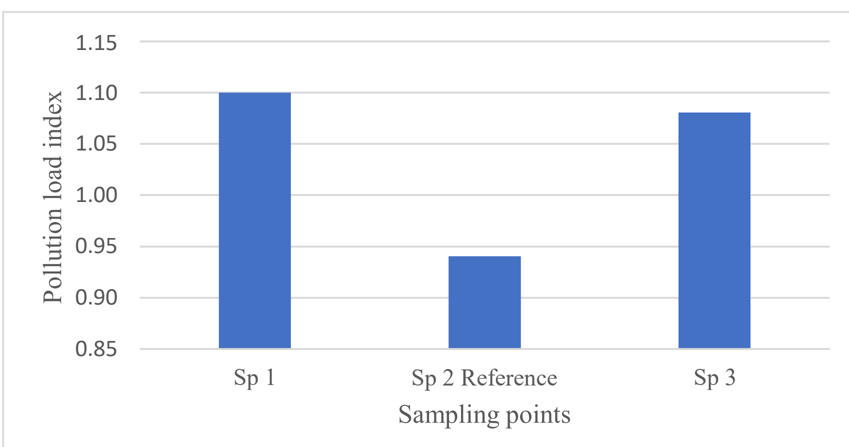

Figure 3: Pollution load index for the three sample points in the study area

The geo-accumulation index (I_{geo}) level of the various heavy metals is shown in Figure Table 5. The I_{geo} levels of cadmium in sample points 1 and 3 were found to have a value greater than 2 which denotes moderately to severely polluted with sample point 2 (0.9) denoting it to be uncontaminated to moderately uncontaminated. The I_{geo} of chromium in all sample points was less than 1 which is interpreted as unpolluted. This result is indistinguishable from the result of I_{geo} of Cr from Jones *et al.,* (2021). The I_{geo} of copper in scrapyard sample points 1 and 3 were found to be less than 1 which denotes slightly polluted and sample point 2 (reference point) with a value of less than 0 denoting it to be unpolluted. The I_{geo} of iron in all sample points had a mean value of less than 0 which is interpreted as unpolluted. The I_{geo} of lead in all sample points had a mean value of less than 0 which is denoted as unpolluted. This result is different from the result on I_{geo} of Cu in Jones *et al.,* (2021). The I_{geo} of zinc in sample points 1 and 3 has a value of less than 1 which denotes that the soil is slightly polluted and sampling point 2 has a mean value of less than 0 which is interpreted as unpolluted.

Table 5: Geo-accumulation index of metals at the sample points (Sp) in Benin City

Metal	Sp 1	Sp 2	Sp 3
Cd	2.90	0.90	2.61
Cr	-2.74	-3.71	-3.15
Cu	0.67	-0.84	0.65
Fe	-6.67	-7.89	-6.69
Pb	-1.87	-4.02	-2.30
Zn	1.07	-3.71	0.87

Table 6: Bacteriological qualities of soil samples from sample points in Benin City, Nigeria

Soil Samples	Total Bacteria Count (CFU/g)	Total Coliform Count (CFU/g)	*E. coli* Count (CFU/g)
1st sample in point 1 (Sp 1a)	$2×10^3$	$3×10^3$	$1×10^3$
2nd sample in point 1 (Sp 1b)	$2×10^3$	$1×10^3$	$0 ×10^3$
3rd sample in point 1 (Sp 1c)	$2×10^3$	$3×10^3$	$1×10^3$
4th sample in point 1 (Sp 1d)	$2×10^3$	$1×10^3$	$0 ×10^3$
1st sample in point 2 (Sp 2a)	$0 ×10^3$	$3×10^3$	$0 ×10^3$
2nd sample in point 2 (Sp 2b)	$1×10^3$	$0 ×10^3$	$1×10^3$
3rd sample in point 2 (Sp 2c)	$0 ×10^3$	$3×10^3$	$0 ×10^3$
4th sample in point 2 (Sp 2d)	$1×10^3$	$0 ×10^3$	$1×10^3$
1st sample in point 3 (Sp 3a)	$3×10^3$	$4 ×10^3$	$1×10^3$
2nd sample in point 3 (Sp 3b)	$6×10^3$	$4 ×10^3$	$2×10^3$
3rd sample in point 3 (Sp 3c)	$3×10^3$	$4 ×10^3$	$1×10^3$
4th sample in point 3 (Sp 3d)	$6×10^3$	$4 ×10^3$	$2×10^3$

The condition of the soil is primarily influenced by its natural composition, human-induced alterations, and its physical and chemical properties (Akpoveta *et al.,* 2010). Despite instances where individuals have dumped scrap metal onto surface soils, there have been variations in the microbial content of the affected soil. This suggests that the waste materials did not negatively impact the growth and spread of soil microorganisms (Osazee *et al.,* 2013). However, this study revealed that the scrapyard at Upper Iwehen Street (point 3) exhibited the highest total bacteria count (TBC), ranging from (2×10^3 - 6×10^3) cfu/g, likely due to intense scrapyard activities in that area, while the lowest TBC was found in the reference point, ranging from (0×10^3 - 1×0^3) cfu/g. Total coliform count (TCC) in the scrapyard sample points ranges from (1×10^3-4×10^3) cfu/g. This result is similar to the findings of Oluseyi *et al.,* (2014). The bacterial count obtained from the reference soil was notably lower compared to soils collected from the scrapyards. This difference may be attributed to the increased presence of biodegradable organic and inorganic materials from various scraps continually deposited at these locations (Oluseyi *et al.,* 2014).

CONCLUSION

The results from the current study reveal that the scrapyard points compared to the reference point are contaminated. We recommend further studies on soil quality assessment in scrapyards, given the proliferation of such activities. Additionally, regular monitoring of scrapyards in Benin City is advised while agencies concerned with soil management especially in urban areas should ensure that scrapyards are located only on the outskirts of the city far from residential areas.

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CONFLICT-OF-INTEREST DISCLOSURE

No conflict of interest was declared.

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