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Pollution Indices and Microbiological Assessment of Soil Samples from Motor Parks Around New Benin Market, Benin City, Nigeria

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Abstract

This study was designed to assess the physicochemical, pollution level and microbiological quality of soil samples collected from motor parks around the busy New Benin Market. Four different motor parks were selected for the study including a control location. Atomic Absorbance Spectrophotometry, pour plate method were adopted in analyzing the physico-chemical, heavy metals and microbial flora of the top soils Result obtained for physiochemical analysis revealed pH and electrical conductivity of the soils ranged from 6.68±0.09 - 7.39±0.12 and 314.5±34.50 – 1598.5±157.50µS/cm respectively. Soil particle analysis revealed percentage composition of sand and silt ranged from 92.92±0.91 – 95.585±0.12 %. And 2.32±0.17 – 4.33±0.05 % respectively. The levels of Lead, Cadmium and Chromium 0.01±0.01 – 0.06±0.04 mg/g, 0.02±0.02 – 0.14±0.11 mg/g and 0.02±0.01 – 0.14±0.11 mg/g respectively. The ecological risk index in soil samples revealed that lead, cadmium and chromium concentrations in soil samples had no ecological risk (ERI<40). Pollution Load Index of soils ranged from 0.00229-0.00607. Potential ecological risk index (PERI) of soils ranged from 0.007-2.41. The Total heterotrophic bacterial counts and Total fungal counts of the soil samples ranged from 60.50±2.50 – 114.00±3.00 (×10^4 cfu/g) and 50.50±5.50 – 70.50±4.50 (×10^4 cfu/g) respectively. Identified bacteria were Klebsiella sp., E. coli, Enterobacter aerogenes, Aerobacter sp., P. mirabilis, Serratia sp., Bacillus sp. And Micrococcus sp. Predominant fungal isolates were species of Aspergillus, Trichoderma, Mucor and Penicillium. The contamination levels from the studied soil samples indicate relative low pollution; however, there is a call for environmental attention to avoid any possible escalation of pollution levels.

Keywords: Ecological Risk Index, Microbiological quality, Motor parks, Physicochemical, Pollution level

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INTRODUCTION

Several pernicious chemical compounds from various sources have been observed to be constantly released into the environment with an associated ecological involvement (Adesuyi et al., 2016; Adesuyi et al., 2018). Heavy metal accumulation in soil are due to uncontrolled human activities which include the fast expanding industrial zones, indiscriminate disposal of sewage sludge, organic and inorganic wastes, agricultural activities (such as application of pesticides, fertilizers, manures etc) and exposure to petrochemicals (Aloysius et al., 2013).

According to Arévalo-Gardini et al. (2015), physicochemical properties with a correlative relationship with microbial qualities are a veritable tool in evaluating soil health. Changes in soil microbial diversity has been shown along soil depths with substantial influence in soil properties (Steven et al., 2013; Dong et al., 2017).

At limited levels, some heavy metals are essential elements for living things however high levels of these metals are usually associated with health challenges with morbidity and mortality consequences (Ibrahim et al., 2019). Uncontrolled and unmonitored anthropogenic activities have been observed to significantly influence these chemical and non-chemical contaminants to elevated levels when compared to influence due to geogenic or natural processes (Dasaram et al., 2011). Their impacts are heightened by their persistence and tendency to bioaccumulate in the environment, as well as to migrate along the food chain (Udousoro et al., 2010).

Motor Parks are designated and reserved locations within a city to coordinate inter and intra-transport systems for commuters (Ahmed, 2016). Therefore, makes it an essential part of the transport system with its crucial role in the management of traffic decongestion (Imarhiagbe and Ovie, 2022). Occasionally, urgent repairs of faulty vehicles may also be carried out at motor parks resulting in oil, grease and other chemicals being indiscriminately discharged into the receiving soil environment (FEPA, 1991). This study was to assess the pollution level and soil qualities of the different Motor Parks around the bustling New Benin Market.

MATERIALS AND METHODS

Study area and Samples collection

Soil samples were collected at four motor parks located around New Benin Market, Benin City, Edo State. The sampling Motor Parks (Fig 1) were Third-East Circular Road Motor Park (Lat. 6° 20' 54'' N; Long. 5° 37' 56'' E), Ikpoba Hill Motor Park (Lat. 6° 21' 4'' N; Long. 5° 37' 57'' E), Upper Mission extension Motor Park (Lat. 6° 21' 7'' N; Long. 5° 37' 57'' E), Aduwawa-Eyan Motor Park (Lat. 6° 21' 4'' N; Long. 5° 37' 56'' E) and control location (approximately 100 metres away from New Benin Market. Top soils were collected using soil auger and dispensed into a labeled sterile polythene bags. The samples were immediately conveyed to the laboratory for analysis.

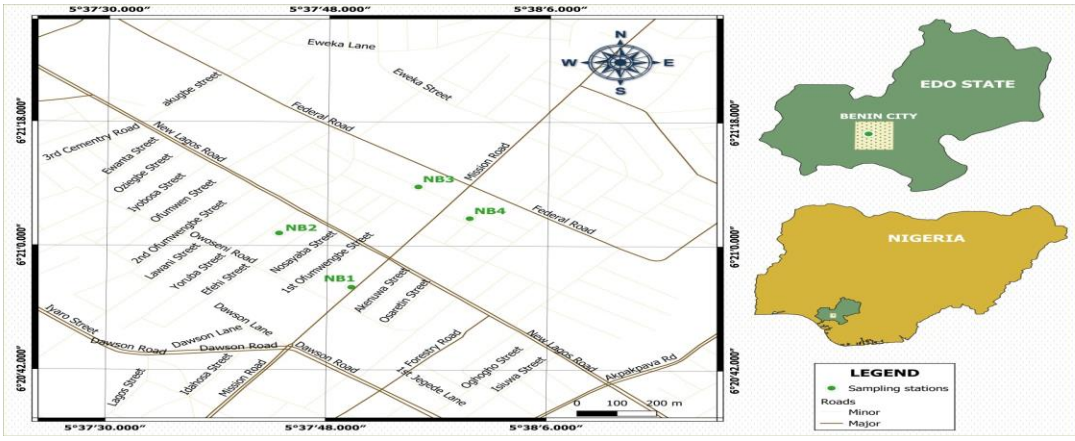

Fig 1: Map of Benin City showing sampling location

Physiochemical parameters: Selected parameters were investigated according to protocols described by Sioutas (2010) and Onyele and Anyanwu (2018).

The pH: Twenty (20g) grams of the air dried soil samples were weighed into a grease-free beaker with 20ml of distilled water added and stirred intermittently for 30 mins with a glass stirrer. The pH meter was standardized using a buffer pH 4.00 and 9.00 before the pH of the soil suspension was taken. The electrode was dipped into the liquid part of the mixture and the reading was recorded.

Electrical conductivity: The electrical conductivity (EC) of the soil samples was determined using a calibrated and standardized conductivity meter. The meter probe containing the electrode was dipped into the liquid part of the mixture and the reading was taken.

Particle size: One hundred gram (100g) of the soil samples were transferred into a weighing bottle and poured into the arranged mesh, arranged in descending order of mesh size from 425nm to 38nm. This was shaken manually to allow for the proper distribution of the soil particles in the various meshes. Each soil sample in the mesh was weighed and recorded.

Heavy metal analysis: The soil samples were digested using freshly prepared solution of HNO_3: HCL (3:1) and The digested solutions were allowed to cool and then filtered using a 110 mm Whatman filter paper into 100 ml standard flasks. The bottles were thereafter filled up to mark with distilled water. Samples were subsequently analyzed for levels of lead, cadmium and chromium using atomic absorption Spectrophotometer (Buck Scientific, 210 VGP) (Massadeh et al., 2017).

Pollution assessment model: The adopted assessment model was according to Xue et al. (2015) and Elnazer et al. (2015). The grades and classes of pollution indices are stated in Table 1.

Index of geoaccumulation: The index of geo-accumulation (I_{geo}) was determined according to the mathematical equation:

$$I_{geo} = \log_2 \left[\frac{C_m}{1.5 \times B_m} \right] \quad [1]$$

Where C_m is the concentration of the studied heavy metal in the soil sample and Bm is the geochemical background value of the same metal. The background reference used in this study is based on the world soil average abundance of metals [Pb = 22, Cd = 0.5, Cr = 50] and the constant [1.5] is used for possible variations of the background data due to lithogenic effect (Kabata-Pendias & Pendias, 2001).

Potential Ecological risk index: The ecological risk factor (E_i) expresses the potential ecological risk of a given contaminant and was estimated by the mathematical equation:

$$PERI = \sum E_i$$
$$E_i = T_i \cdot CF_i \qquad [2]$$
$$CFi = C_m / B_m$$

Where T_i is the toxic-response factor for a given substance, and CF_i is the contamination factor. The T_i values of heavy metals are; Pb = 5, Cd = 30, Cr = 2 (Xue et al., 2015).
Pollution load index and contamination factor: Pollution load index (PLI) for a set of 'n' polluting elements was calculated by the equation;

$$PLI = (CF1 \times CF2 \times CF3 \times \ldots \times CFn)^{1/n}.$$
$$CF = C_m / B_m \qquad [3]$$

Where n is the number of metals studied, CF1 is the contamination factor of metal 1 in the study area. The PLI gives simple comparative means for assessing a site quality.
Isolation and Enumeration of total heterotrophic bacteria and fungi: The microbiological parameters studied were total heterotrophic bacterial and total fungal counts adopting pour plate technique (Cheesebrough, 2000); Harley & Prescott, 2002; Sharma, 2009). The identification of isolated bacteria was done using the taxonomic scheme of Bergey's manual of determinative bacteriology while the fungal isolates were identified adopting wet mount Macroscopic and microscopic examination (Banette & Hunter, 1975).

RESULTS AND DISCUSSION

Results of physiochemical quality of soil samples from the Motor Parks are stated in Table 2. The pH of samples ranged from 6.68 ± 0.09 - 7.39±0.12. Electrical conductivity values ranged from 314.5±34.50 – 1598.5±157.50µS/cm. Particle size analysis revealed that the soil samples were basically sandy, with a percentage range of 92.92±0.91 – 95.585±0.12 %. Percentage silt composition of the soil samples was from 2.32±0.17 – 4.33±0.05 %. The pH of the soil may have been greatly influenced by the vehicular activities such as exhaust releases, oil and fuel discharge into the soil environment occurring on daily basis (Dauda & Odoh, 2012). The range of lead concentration was from 0.01±0.01 – 0.06±0.04 mg/g; cadmium concentration ranged from 0.02±0.02 – 0.14±0.11 mg/g and chromium concentrations ranged from 0.02±0.01 – 0.14±0.11 mg/g. Cadmium had been implicated with kidney lesions, hypertension, mutagenesis, and carcinogenesis (Mohammed et al., 2020). Chromium compounds according to epidemiological study was shown to be carcinogenic (Otte, 2017), and able to cause gastrointestinal hemorrhage, hemolysis and acute renal failure (Adedeji et al., 2013). The physiochemical quality and concentration of heavy metals of the soil samples are expected to be influence by factors which include anthropogenic activities (population size, fumes from vehicle exhaust, indiscriminate waste disposal, fossil-fuel combustion) and the natural environment of the motor parks, such as topography, climate, industrial production (Xue et al., 2015).

Tables 3A-B show the results obtained for pollution indices. The Index of Geoaccumulation (I_{geo}), indicated uncontaminated to moderate level ($0 < Igeo < 1$) of lead in soil samples from all motor parks. Same was observed for cadmium and chromium concentration in with value occurring below 1. The ecological risk index revealed that lead, cadmium and chromium concentrations in soil samples had no ecological risk (ERI<40). Values obtained for contamination factor in soil samples revealed that these heavy metals had no significant contamination level (Table 3A). Table 3B shows the results obtained for the Pollution Load index (PLI) and Potential Ecological Risk index (PERI) of top soil samples from New Benin motor parks. Results obtained for the Pollution Load index estimation showed values ranged from 0.00229-0.00607. All PLI estimates were less than one indicating low levels of heavy metals in the investigated soil samples. Also, the Potential Ecological Risk Index (PERI) of the studied soil samples revealed values ranging from 0.007-2.41, indicating that the heavy metals were of low ecological risk. Values obtained for the ecological risk index of soil from the various motor parks visited in this study suggested low ecological risk (Ei < 40 = low).

Microbiological quality of soil samples: Microbial population of soil collected from Motor parks in New Benin market is shown in Table 4. The total heterotrophic bacterial counts (THB) in the various soil samples ranged from 6.1±0.5 – 11.4±1.00 $\times 10^4$ cfu/g. The Total fungal counts ranged from 4.0±0.5 – 5.5±0.1 $\times 10^4$ cfu/g. The presumptive identified isolates were *Klebsiella* spp., *Serratia* sp., *Micrococcus* sp., *Bacillus* spp., *Enterobacter aerogenes, Aeromonas* sp. and *Proteus mirabilis* (Table 4); and the fungal isolates were species of *Aspergillus, Penicillium, Trichoderma* and *Mucor.* The isolation of these diverse organisms can be attributed to the ubiquitous nature of these microorganisms in soil habitat. Many microorganisms are known to grow in the soil and also play significant roles in sole formation. The diversity of these microorganisms enables this group of biological entity to thrive in harsh conditions, such as acidic or alkaline soils as they flourish and reproduce in these ecological niches (Madigan et al., 2019).

CONCLUSION

The contamination levels from the studied soil samples indicate relative low pollution (Igeo < 1); however there is an urgent call for attention to avoid any possible escalation of pollution levels and its associated health risk, based on the fact that the soil from these locations may continuously be exposed to increase and regular vehicular activities.

Table 1: Grades and classes of pollution indices

Index of Geoaccumulation (I_{geo})			Contamination Factor (CF)		Ecological risk index (ERI)		Pollution load index		Potential ecological risk index (PERI)	
Class	**Igeo**	**Interpretation**	**CF**	**Interpretation**	**ERI**	**Interpretation**	**PLI**	**Interpretation**	**PERI**	**Interpretation**
0	≤ 0	unpolluted	< 0.1	very slight contamination	ERI<40	low	< 1	no pollution	PERI < 300	moderate risk (MR)
1	0.1–1.0	unpolluted to moderately polluted	0.10 – 0.25	slight contamination	40≤ERI<80	moderate	1.0 < 2	moderate pollution	300 < PERI < 600	considerable risk (CR)
2	1.1–2.0	moderately polluted	0.26 –0.5	moderate contamination	80≤ERI< 160	considerable	2.0< 3	heavy pollution	PERI > 600	very high risk (VHR)
3	2.1–3.0	moderately to strongly polluted	0.51 – 0.75	severe contamination	160≤ERI< 320	high	≥3.0	extreme pollution		
4	3.1–4.0	strongly polluted	0.76 – 1.00	very severe contamination	ERI≥320	Very high				
5	4.1–5.0	strongly to extremely polluted	1.1–2.0	slight pollution						
6	> 5	extremely polluted	2.1–4.0	moderate pollution						
			4.1–8.0	severe pollution						
			8.1–16.0	very severe pollution						
			>16	excessive pollution						

Xue et al. (2015); Elnazer et al. (2015).

Table 2: Physiochemical quality of soil samples from Motor parks in New Benin market

Parameters	NB1 Mean	NB1 ±S.E	NB2 Mean	NB2 ±S.E	NB3 Mean	NB3 ±S.E	NB4 Mean	NB4 ±S.E	CTR Mean	CTR ±S.E
pH (°C)	6.94	±0.02	7.385	±0.12	7.135	±0.11	7.06	±0.01	6.68	±0.09
EC (µS/cm)	314.5	±34.50	417	±76.00	429	±165.00	949.5	±114.50	1598.5	±157.50
Sand (%)	95.31	±0.34	92.92	±0.91	95.58	±0.12	95.56	±0.24	95.47	±1.09
Silt (%)	2.32	±0.17	4.33	±0.05	3.99	±0.00	4.58	±0.58	2.92	±0.07
Clay (%)	0.01	±0.00	0.01	±0.00	0.01	±0.00	0.00	±0.00	0.00	±0.00
Pb (mg/g)	0.03	±0.01	0.06	±0.04	0.01	±0.01	0.01	±0.00	0.01	±0.01
Cd (mg/g)	0.00	±0.00	0.14	±0.11	0.04	±0.04	0.02	±0.01	0.02	±0.02
Cr (mg/g)	0.05	±0.01	0.05	±0.00	0.06	±0.00	0.04	±0.01	0.07	±0.00

Key: NB1 = New Benin Park, NB 2 = Ikpoba Hill Park, NB3 = Upper Mission extension park, NB4 = Aduwawa-Eyan Park, CTR =Control

Table 3A: Index of Geoaccumulation, Ecological risk index and Contamination factor of soil samples from Motor parks in New Benin market

		Motor Parks				
Parameters (Mg/g)	**Exposure**	**NB1**	**NB2**	**NB3**	**NB4**	**NB5**
Pb	I_{geo}	-10.37	0.86	-11.1	-8.37	-12.69
Cd		NIL	-4.68	-4.23	-5.64	-5.23
Cr		-10.7	-10.56	-10.29	-10.87	-10.07
Pb	E_i	0.0057	0.0125	0.0034	0.0023	0.001
Cd		NIL	1.65	2.4	0.9	1.2
Cr		0.002	0.002	0.0024	0.0016	0.0028
Pb	CF	0.00114	0.0025	0.0007	0.0005	0.004
Cd		NIL	0.055	0.08	0.03	0.04
Cr		0.0009	0.001	0.0012	0.0008	0.0014

Key: NB1 = New Benin Park, NB 2 = Ikpoba Hill Park, NB3 = Upper Mission extension park, NB4 = Aduwawa-Eyan Park, NB5 =Control, D_{ing} = Dose injection, D_{inh} = Dose inhalation, D_{dermal} = Dose of dermal contact, **Index** of Geoaccumulation (I_{geo}), Ecological risk index (E_i) and Contamination factor (CF)

Table 3B: Estimated Motor Parks Pollution Load index (PLI) and Potential ecological risk index (PERI)

Location Index	NB1	NB2	NB3	NB4	NB5
PLI	0	0.005161	0.004066	0.002289	0.006073
PERI	0.007	1.68	2.41	0.9	1.2

Key: NB1 = New Benin Park, NB 2 = Ikpoba Hill Park, NB3 = Upper Mission extension park, NB4 = Aduwawa-Eyan Park, NB5 =Control.

Table 4: Microbial population of soil collected from Motor parks in New Benin market

Motor Parks	THB ($x10^4$ cfu/g)	Predominant Bacterial isolates	TF ($x10^4$ cfu/g)	Predominant Fungal isolates
NB1	9.4±0.5	*Klebsiella* sp., *Micrococcus* sp., *Bacillus* spp., *Aerobacter* sp., *Proteus mirabilis,*	5.2±0.20	*Aspergillus* spp., *Penicillium* spp.
NB2	6.9±0.50	*Micrococcus* sp., *Bacillus* spp., *Klebsiella* sp., *Serratia* sp.	5.5±0.1	*Aspergillus* spp., *Penicillium* sp.
NB3	11.4±1.00	*Klebsiella* sp., *Micrococcus* sp., *Bacillus* spp., *Enterobacter aerogenes,*	4.7±1.0	*Aspergillus* spp., *Penicillium* sp., *Mucor* sp.
NB4	8.4±1.5	*Klebsiella* sp., *Enterobacter aerogenes, Proteus mirabilis, Micrococcus* sp., *Bacillus* spp.,	5.6±1.00	*Aspergillus* spp., *Penicillium* spp., *Trichoderma* sp.
CTR	6.1±0.50	*Micrococcus* sp., *Bacillus* spp., *Klebsiella* sp., *Escherichia coli,*	4.0±0.50	*Aspergillus* spp., *Penicillium* spp.

Key: NB1 = New Benin Park, NB 2 = Ikpoba Hill Park, NB3 = Upper Mission extension park, NB4 = Aduwawa-Eyan Park, CTR =Control, THB = Total heterotrophic bacteria count, THF = Total fungal count

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