



Research Article

Risk Assessment of Heavy Metals and Soil Qualities from Different Motor Parks Around Ekiosa Market in Benin City, Nigeria

<sup>1\*</sup>Imarhiagbe, Esosa Emmanuel and <sup>2</sup>Ovie, David Omokefe

<sup>1</sup>Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City

<sup>2</sup>Applied Environmental Bioscience and Public Health Research Group (AEBPH RG), University of Benin, Benin, Edo State, Nigeria

Corresponding author: [esosa.imarhiagbe@uniben.edu](mailto:esosa.imarhiagbe@uniben.edu)

Key Words:

Motor Park,  
Physicochemical,  
Microbiological qualities,  
Pollution and health risks

ABSTRACT

Soil samples from five motor parks around Ekiosa market in Benin City, Edo State were assessed for physicochemical, microbiological qualities, pollution and health risks due to heavy metals exposure. Standard analytical procedures; Atomic Absorbance Spectrophotometry, pour plate method were utilized in the determination of the physicochemical, heavy metals and heterotrophic microbial flora of the top soils. The pH range from  $7.28 \pm 5.14$  to  $7.48 \pm 5.14$ ; electrical conductivity ( $\mu\text{S}/\text{cm}$ ) of  $138.15 \pm 97.69$  to  $234 \pm 165.46$ . The particle size results were  $95.83 \pm 67.76$  to  $98.33 \pm 69.53$  % (sand),  $1.09 \pm 0.77$  to  $4.40 \pm 3.11$  % (silt) and  $0.002$  to  $0.9 \pm 0.26$  % (clay). The mean concentrations of metals recorded were found to be in the range (mg/g) of 0.025 to 1.05; 0.035 to 1.06; 0.05 to 0.15 and 24.05 to 31.10 for lead, cadmium, chromium and iron respectively,

which are higher than world soil average abundance of metals except for iron which was lower. Total heterotrophic bacterial and fungal enumeration yielded values that ranged from  $0.8$  to  $1.9 \times 10^5$  cfu/g and  $0.3$  to  $2.7 \times 10^5$  cfu/g respectively, which were lower than the control soil ( $2.3 \times 10^5$  cfu/g and  $2.7 \times 10^5$  cfu/g) for THB and THF respectively. The pollution assessment indices results indicated low ecological risk and moderate contamination for all metals except cadmium, which showed high ecological risk. Pollution assessment indices results indicated a polluted soil, the current safety of this site would be jeopardized over time due to continuous vehicular activities, therefore it should be suggested that motor parks be kept away from market environment.

Corresponding author: [esosa.imarhiagbe@uniben.edu](mailto:esosa.imarhiagbe@uniben.edu)

Department of Environmental Management and Toxicology, University of Benin, Benin City

## INTRODUCTION

Soil as an environmental component had been seen as a major sink of heavy metals from both natural and anthropogenic sources (Liang *et al.*, 2014). It may be contaminated by the accumulation of heavy metals through emissions from fertilizer and pesticides application, industrial activities (metallurgy, auto repair shop, coal combustion etc), road construction (asphalt, concrete and road paints), traffic (vehicular emissions, wear and tear of tyres and brakes linings, leakage of oil etc), spillage of petrochemicals, mining among others (Velea *et al.*, 2008). According to Akbar (2006) and Olukanni and Adebisi (2012) vehicular emissions and other traffic related phenomena constitute the major source of soil heavy metal pollution. Hence roadside and motor park soils have higher concentrations of heavy metals contamination, being the major areas of traffic activities. Vehicle exhaust is considered as a first-line source of heavy metal pollutants (Elnazer *et al.*, 2015).

Motor parks around market areas can pose significant environmental and health risks to living biota both within the soil and around the motor park environment. This is because heavy metals inhibit microbial growth in many biochemical ways and can be carried into the atmosphere through the action of wind (Hu, *et al.*, 2011), which can be inhaled, or deposited in food products displayed for sales. During dry the season, especially the harmattan, the action of wind can carry soil particles (dust) into the atmosphere. Heavy metals are known to attach themselves to these particles (Elnazer *et al.*, 2015) and are carried about into the atmosphere. The most common heavy metals found at contaminated sites, in order of abundance are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), and mercury (Hg) (USEPA, 1996). However, studies on roadside and motor park soil had indicated levels of lead (Pb), copper, (Cu), iron(Fe) cadmium (Cd), zinc

(Zn) and nickel (Ni) as the most pollutant metal owing to their presence in fuel as anti-knock agents, lubricating oil and metal parts that wear away (Elnazer *et al.*, 2015 and Xue *et al.*, 2015). Metals in dust can enter the human system through inhalation, ingestion and dermal contact (Xue *et al.*, 2015). These metals can accumulate in adipose tissue or deposit in the circulatory system causing respiratory and cardiovascular diseases, and even mortality (Suzuki *et al.*, 2009). They can also affect the normal function of organs and undermine the nervous and/or endocrine system (Chen *et al.*, 2018).

Specific metals widely associated with traffic or vehicular emissions (hence found around roadside and motor park soil) include copper (Cu), lead (Pb), chromium (Cr), cadmium (Cd), iron (Fe), and nickel (Ni) (Simon *et al.*, 2013). This is owed to the fact that they are present in the fuel as anti-knock agents, used as material in producing tires, metal bodies of vehicles and car batteries (Suzuki *et al.*, 2009). Metals increase the acidity of the soil (Palov *et al.*, 2020), this denatures and destroys important species of the microbial population living in the soil (Palov *et al.*, 2020). The loss of microbial diversity through heavy metal contamination has been an issue that has undergone many investigations and studies. The number of dust particles inhaled, ingested and absorbed through dermal contact by humans is dependent on the grain size of the particle, hence with the knowledge of the particle size of the soil determines their distribution atmospherically and their fate as dust in the environment (Xue *et al.*, 2015). Microorganisms in soil, such as protozoa, fungus, bacteria, and archaea, play an essential role in the biogeochemical cycle, notably in nutrient cycling, system stability, (Van Der Heijden *et al.*, 2008), anti-jamming capability, and sustainable development of soil (Gyaneshwar *et al.*, 2002). Elevated levels of heavy metals in soils decrease microbial population, diversity and

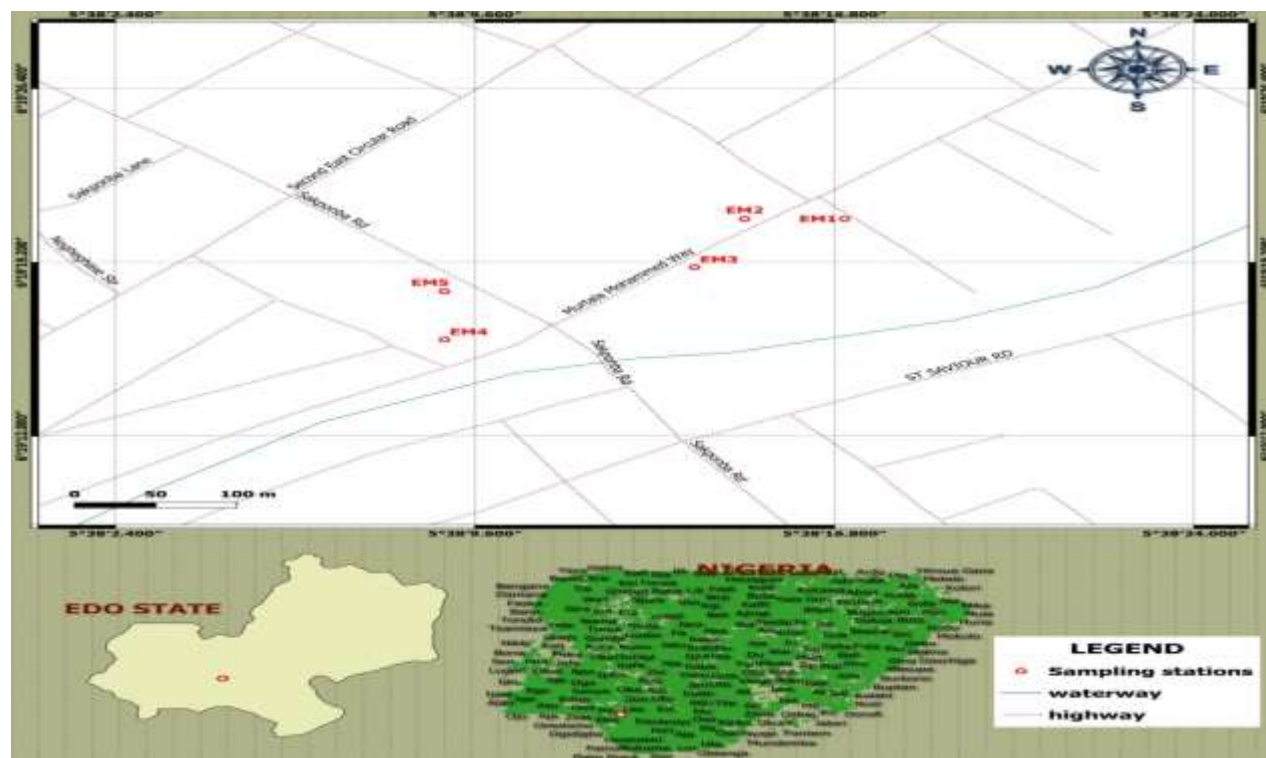
activities. Nonetheless, certain soil microbes tolerate and use heavy metals in their systems; as such they are used for bioremediation of polluted soils (Abdu *et al.*, 2016).

This study aimed to assess the risk of heavy metals and qualities of soil from motor parks located around Ekiosa market in Benin City, Nigeria.

## MATERIALS AND METHODS

### Study area

The studied locations are situated around the busy Ekiosa Market in Benin Metropolis. The market is one of the major markets in Benin City, Edo State with a geographic position system of 6° 19'24''N 5° 38'11''E (Figure 1, Plates 1A-B). The weather condition of the location is of tropical Savanna climate with average rainfall 2025mm/79.7 inches; rainy season runs from March/April to October/November, an average annual temperature of 26.1°C. It has ferruginized or literalized clay sand. Ekiosa market is known as a bustling market where foodstuffs, vegetables and other edible items are sold openly.



**Figure 1:** Map of Ekiosa market showing sampling points



**Plate 1A:** Pictorial view of the motor park with hawkers



**Plate 1B:** Pictorial view of the motor park with hawkers



**Plate 1C:** Pictorial view of the motor park with sellers with edible items sold at Ekiosa markets

### Sample collection and preparation

Top soil samples were collected from five (5) different motor parks within the Ekiosa market, except the control soil which was collected 100 meters away from the market location between Februarys to March 2021. These samples were collected in triplicates in labeled polythene bags and transported to the laboratory for physicochemical and microbiological qualities.

Soil samples were initially subjected to air drying on racks for five days and then lightly crushed to

remove large lumps and passed through a 2mm sieve, roots were removed to ensure homogeneity. Dried soil samples were placed in a head pan and thoroughly stirred and the final soil was stored in a cool dry and well-ventilated cupboard for future reference.

### Physicochemical parameters

The parameters investigated were pH, electrical conductivity and particle size according to protocols described previously Sioutas (2010) and Onyele and Anyanwu (2018).

### Heavy metal analysis

The soil samples were digested using the method of Likuku *et al.* (2013) and Massadeh *et al.* (2017). One gram (1g) of the sample was weighed into a 25ml conical flask and 10ml of freshly prepared aqua regia (3:1, HNO<sub>3</sub>: HCL) was added to it and heated on a hot plate for 45 minutes. It was allowed to cool, and then 20 ml of distilled water was added. This was then filtered using a 110 mm Whatman filter paper into a 100 ml standard flask. The bottle was then filled up to mark with distilled water. Samples were thereafter analyzed for heavy metals using atomic absorption Spectrophotometer (Buck Scientific, 210 VGP).

### Isolation and Enumeration of total heterotrophic bacteria and total fungi

One gram of respective soil samples was each suspended in nine (9) ml of sterilized nutrient broth in a conical flask. The soil suspension was thoroughly mixed and serial diluted to 10<sup>-3</sup> using tenfold dilution. Using the pour plate technique, aliquots (1ml) from each dilution were plated in duplicates sterile nutrient agar for total heterotrophic bacterial counts and potato dextrose agar for total heterotrophic fungal counts. The PDA agar plates were made selective for fungal growth by the addition of 1 ml of the antibiotic solution before the addition of the molten medium. The solution comprised of ampicillin (2.5g) and streptomycin (1.0 g) dissolved in 30.0ml sterile distilled water (Omonigho and Ugboh, 1998). The nutrient agar plates were incubated aerobically at 35°C for 48 hours. The potato dextrose agar plates were incubated at room temperature (28°C ± 5°C) for 5 days. After incubation, counts obtained from culture plates were recorded. The average counts observed at a particular dilution was multiplied by the dilution factor and expressed as the cell forming unit (cfu) per gram of the dried sample (Harley and Prescott, 2002).

### Characterization and identification of bacterial isolates

Pure bacteria isolates were stored at 4°C on agar slants which were re-inoculated for growth of individual colonies which were identified using morphological and biochemical techniques according to the taxonomic scheme of Bergey's manual of determinative bacteriology (Govindasamy *et al.*, 2011).

### Identification of fungal isolates

Pure fully grown fungal cultures were characterized and identified by noting their macroscopic and microscopic attributes. The microscopic portions of the fungal mycelium were observed using the wet mount technique with distilled water and lactophenol cotton blue utilized as mountants (Sharma, 2009). The mycelia structures visualized were recorded and compared with the information stated by Barnett and Hunter (2006).

### Pollution assessment model

To assess the level of motor park soil pollution with lead (Pb), cadmium (Cd), and chromium (Cr), the index of geoaccumulation ( $I_{geo}$ ), contamination factor (CF), the pollution load index (PLI), and the potential ecological risk index were determined. The classes of  $I_{geo}$ , CF, Ei, PERI and PLI are stated in Table 4 (Xue *et al.*, 2015 and Elnazer *et al.*, 2015).

### Index of geoaccumulation ( $I_{geo}$ )

The index of geo-accumulation ( $I_{geo}$ ) was determined according to Xue *et al.* (2015) with 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 examined metal in the soil sample and  $B_m$  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 and Pendias, 2001).

### Potential Ecological risk index (PERI)

The ecological risk factor ( $E_i$ ) to quantitatively express the potential ecological risk of a given contaminant as used by Elnazer *et al.* (2015) is given by the mathematical equation:

$$\begin{aligned} \text{PERI} &= \sum E_i \\ E_i &= T_i \cdot \text{CF}_i \\ \text{CF}_i &= C_m / B_m \end{aligned} \quad [2]$$

Where  $T_i$  is the toxic-response factor for a given substance, and  $\text{CF}_i$  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 (PLI) and contamination factor (CF)

Pollution load index (PLI) for a set of 'n' polluting elements is defined as a value calculated from the geometric mean of the contamination factors of those elements. PLI is calculated by the following equation given by Elnazer *et al.* (2015) as;

$$\begin{aligned} \text{PLI} &= (\text{CF}_1 \times \text{CF}_2 \times \text{CF}_3 \times \dots \times \text{CF}_n)^{1/n} \\ \text{CF} &= C_m / B_m \end{aligned} \quad [3]$$

Where n is the number of metals studied,  $\text{CF}_1$  is the contamination factor of metal 1 in the study area. The PLI gives simple comparative means for assessing a site quality.

### Health risk assessment model

In this study, health risk was assessed by employing the internationally accepted model of the Environmental Protection Agency of the

United States (EPA, 1998 and Xue *et al.*, 2015). This study calculated the exposure of metals from top soil via dust particles, using some basic assumptions (Xue *et al.*, 2015, Muhammed *et al.*, 2020): (1) The movement of vehicles in and out of the market motor parks raises the top soil into the atmosphere constituting dust. (2) Human beings are exposed to these dusts via three primary pathways: ingestion ( $\text{CDI}_{\text{ing}}$ ), inhalation of resuspended particles from dust through the mouth and nose ( $\text{CDI}_{\text{inh}}$ ) and dermal absorption of metals in particles adhered to exposed skin ( $\text{CDI}_{\text{dermal}}$ ).

### Chronic daily intake (CDI)

Exposure is expressed in terms of daily dose and calculated separately for each metal and for each exposure pathways. The exposure dose ( $\text{CDI}$ ;  $\text{mgkg}^{-1}\text{day}^{-1}$ ) for each pathway is calculated as follows

$$\text{CDI}_{\text{ing}} = C \times \frac{\text{IngR} \times \text{EF} \times \text{ED} \times 10^{-6}}{\text{Bw} \times \text{AT}} \quad [4]$$

$$\text{CDI}_{\text{inh}} = C \times \frac{\text{InhR} \times \text{EF} \times \text{ED}}{\text{PEF} \times \text{Bw} \times \text{AT}} \quad [5]$$

$$\text{CDI}_{\text{dermal}} = C \times \frac{\text{SA} \times \text{SL} \times \text{ABS} \times \text{EF} \times \text{ED} \times 10^{-6}}{\text{Bw} \times \text{AT}} \quad [6]$$

In the present study, the minimum, maximum and the upper limit of the 95% confidence interval for the mean (95% UCL) were used. The meaning and value of all parameters used in the determination of CDI is given in Table 5 (Xue *et al.*, 2015).

### Lifetime average daily dose (LADD)

For cancer risk assessment, the lifetime average daily dose (LADD;  $\text{mgkg}^{-1}$ ) via inhalation for Cd, Cr and Pb was used. Inhalation was picked for cancer risk as this exposure pathway is assumed to be the fastest route of entry to the human system according to Xue *et al.*, 2015. The formula is given as follow

$$LADD = \frac{C \times EF}{PEF \times AT} \times \left( \frac{Inh_{child} \times ED_{child}}{Bw_{child}} + \frac{Inh_{adult} \times ED_{adult}}{Bw_{adult}} \right) \quad (7)$$

### Hazard quotient (HQ) and Hazard index (HI)

The HQ for non-carcinogenic risk of Pb, Cd, Cr, and Fe was calculated using the equation by USEPA (1999) and Anyanwu and Onyele, (2018)

$$HQ = CDI / RfD \quad [8]$$

Where, CDI is the daily dose of heavy metals (mg/kg) to which consumers might be exposed and RfD is the reference dose which is the daily dosage that enable individual to sustain this level of exposure over a long period of time without experiencing any harmful effects. This was applied to each exposure pathway in the analysis. The oral, dermal and inhalation reference dose of

## RESULTS AND DISCUSSION:

### Physicochemical quality and heavy metals concentrations of the soil

Soil samples were analyzed for some physicochemical properties of soil and their results are presented in Table 1. The pH of soil from studied locations ranged from  $7.28 \pm 5.14$  to  $7.48 \pm 5.14$ ; electrical conductivity ( $\mu\text{S}/\text{cm}$ ) of  $138.15 \pm 97.69$  to  $234 \pm 165.46$ . The particle size results were  $95.83 \pm 67.76$  to  $98.33 \pm 69.53$  % (sand),  $1.09 \pm 0.77$  to  $4.40 \pm 3.11$  % (silt) and  $0.002$  to  $0.9 \pm 0.26$  % (clay).

The soil pH from this study was slightly alkaline and Khadka and Lamichhane (2016) had shown that elevated pH enhances heavy metal retention in soil. The lead (Pb), cadmium (Cd), chromium (Cr) and iron (Fe) levels ranged from  $0.025 \pm 0.02$  to  $1.05 \pm 0.7$  (mg/g),  $0.03 \pm 0.02$  to  $1.06 \pm 0.07$  (mg/g),  $0.05 \pm 0.04$  to  $0.15 \pm 0.11$  (mg/g) and  $22.7 \pm 16.05$  to  $31.10 \pm 21.99$  (mg/g) respectively. The findings showed that they were all higher

these metals are given in Table 6 (Xue *et al.*, 2015)

### Carcinogenic risk (CR)

Carcinogenic risk is the probability of an individual developing any type of cancer from lifetime exposure to carcinogenic hazard. It is given as:

$$CR = CDI \times SF_i \quad [9]$$

Where  $SF_i$  is the slope factor of metal  $i$ , measured in  $\text{mgkg}^{-1}\text{day}^{-1}$ . In this study Cadmium and Chromium were used as the carcinogenic metal for assessment. The slope factor for Cd and Cr are stated in Table 6 (Xue *et al.*, 2015). The acceptable or tolerable risk for regulatory purpose is in the range of  $10^{-6} - 10^{-4}$  (Xue *et al.*, 2015).

than WHO's acceptable limit in soils (0.0008, 0.1 and 0.085 mg/g) for Cd, Cr and Pb respectively (WHO, 1996). It is also higher than their world average abundance in soil (0.0005, 0.1 and 0.022 mg/g) for Cd, Cr and Pb respectively (Kabata-pendias and Pendias, 2001). Xue *et al.* (2015), Elnazzer *et al.* (2015) and Olukanni and Adebisi (2012), detected a similar concentration of heavy metals in roadside soil and car parks in Baotou in China, Alexandria in Egypt and Otta metropolis in Ogun state, Nigeria respectively. The increased value of Pb can be due to vehicular emission from exhaust due to the use of alkyl-lead compounds as antiknock additives in petrol (Cormu *et al.*, 2005). Iron was found to be the dominant metal as compared with other heavy metals in the motor park soils. Iron is vital for almost all living organisms, functioning in a wide variety of metabolic processes, including oxygen transport, DNA synthesis, and electron transport (Akan *et al.*, 2013). The study also shows that the level of lead, cadmium and chromium are higher in the studied location than in the control soil. It agrees with Olukanni and Adebisi, (2012), Xue *et al.*

(2015) and Elnazzer *et al.* (2015) who noted that there is a positive correlation between vehicular activities and emissions and heavy metal concentration in soil. The significant increase of Cd content across these various locations can be traced to the populations of vehicular activities. Location five (EM5) which is the major central

### Microbiological quality of the soil

The results for microbial enumeration are stated in Table 2. The total heterotrophic bacterial and fungal counts ranged from 0.8 to 1.8 ( $\times 10^4$  cfu/g) and 0.3 to 0.7 ( $\times 10^4$  cfu/g) respectively. The predominant microbial isolates were *Bacillus* spp., *Salmonella* sp., *Serratia marcescens*, while the predominant fungal isolates were *Trichoderma* spp., *Penicillium citrinum*., and *Trichophyton rubrum*. This proves further, as other studies have shown that heavy metal pollution in soil affects the number, diversity, and activities of soil microorganisms (Giller *et al.*, 2009; Chibuike and Obiora, 2014). Though the diversity was similar for both the control and the heavy metal polluted soil, the population however of the control was fairly higher than that of the heavy metal polluted soil suggesting a disturbance of the soil microbial population (Table 3). Several studies have shown that more biological activities take place in top soil (from a few to <30 cm) with biological components occupying a tiny fraction (<0.5%) of the total soil volume and making up less than 10% of the total organic matter (Elliott *et al.* 1996; Pankhurst *et al.* 1997). These biological components consist mainly of soil organisms, with a greater abundance of microorganisms. Soil microorganisms are known to be the players in the decomposition of organic residues and global geochemical cycles which include nitrogen, sulphur, and phosphorus (Pankhurst *et al.* 1997); and also affect the physical properties of soil (Elliott *et al.* 1996).

park in the Ekiosa market had the highest number of buses and vehicles going in and out of it; it was hence not surprising to detect the highest amount of Cd content (1.06mg/g).

### Pollution and health risk assessment of the soil heavy metals

#### Pollution indices of the soil heavy metals

The single ( $I_{geo}$ , CF and  $E_i$ ) and integrated (PLI and PERI) contamination indices are given in Table 7-Table 8. The maximum value was recorded for cadmium (0.5, 63.6 and 2.12 for  $I_{geo}$ , CF and  $E_i$  respectively [Table 7]); 0.072 and 63.85 for PLI and PERI respectively [Table 8]. Location two (EM2) has the lowest integrated pollution index of 0.002 and 1.81 for PLI and PERI respectively (Table 8). The  $I_{geo}$  Values for Pb across the five motor park soil indicated that these soil samples are uncontaminated. The  $I_{geo}$  values for cadmium indicate a relatively higher anthropogenic input of cadmium into the soil where the results showed uncontaminated to moderately contaminated class ( $0 < I_{geo} < 2$ ). The obtained  $I_{geo}$  values for Cr is  $< 0$  in all soil samples, indicating these soil samples are uncontaminated with chromium. The CF value for lead and chromium are low ( $< 1$ ), but  $> 1$  in locations four and five for cadmium indicating a moderate CF. Correspondingly, the PLI of Location four (EM4) and Five (EM5) were  $> 1$  indicating a heavy metal polluted soil from increased vehicular activities. The three other locations had  $PLI < 1$  due to a relatively lower level of vehicular activities than that of EM4 and EM5.

The calculated  $E_i$  indicated that lead and chromium have low risk into the local ecosystem (Table 4), while cadmium reported the highest  $E_i$ , especially in location three (EM3) to five (EM5), ranging from 15 to 63.6 indicating moderate to



high risk respectively. The overall potential ecological risk of the observed metal in 40% of the studied soil showed moderate ecological risk with PERI < 100 but >50 (Table 7). The rest of the samples (60%) have low PERI. The bulk of the ecological risk comes from cadmium contamination. This finding is in agreement with the work of Yahaya *et al.* (2021).

### Health assessment indices of the soil heavy metals:

The Chronic Daily Intake (CDI;  $\text{mgkg}^{-1}\text{day}^{-1}$ ) of the assessed heavy metals of markets around Ekiosa motor parks is presented in Table 9. The CDI values of each exposure pathway for lead, cadmium, chromium and iron are represented. The maximum exposure dose was recorded for iron in all exposure pathways for both Children and adults recording  $1.89\text{E-}4$ ,  $5.29\text{E-}9$  and  $5.29\text{E-}7$  for ingestion, inhalation and dermal (for adults) respectively  $2.48\text{E-}5$ ,  $3.65\text{E-}9$  and  $9.89\text{E-}8$  for ingestion, inhalation and dermal (for children). Next was cadmium, recording  $6.45\text{E-}6$ ,  $1.80\text{E-}10$ ,  $1.80\text{E-}8$  for ingestion, inhalation and dermal (for adults) respectively and  $8.46\text{E-}7$ ,  $1.24\text{E-}10$ ,  $5.09\text{E-}10$  for ingestion, inhalation and dermal (for children) respectively. The maximum exposure doses for children and adults were detected via ingestion and highest for cadmium, which was calculated as  $6.45\text{E-}6$  and  $8.46\text{E-}7$  for adults and children respectively. In the case of children, the daily dose of all metal by ingestion are 2 to 3 order of magnitude higher than the other two routes of exposure, while the 95% UCL value of the total exposure dose of cadmium is higher in magnitude than Pb and cadmium in the three exposure routes. In the case of adults, the daily dose exposure of all metal by ingestion is 3 to 5 orders of magnitude higher than inhalation and dermal contact. In terms of total exposure amount (inferred in the 95% UCL), the degree of exposure is in the order of  $\text{Cd} > \text{Cr} > \text{Pb}$ . On the whole, children are exposed to more metal in top soil than adults in all the pathways but especially

by ingestion. This observation is a very low dosage when compared to other work (Xue *et al.*, 2015 and Elnazer *et al.*, 2015).

The results for the lifetime daily dose (LADD) for the cancer risk assessment (Pb, Cr and Cd) are given in Table 10. The mean values for chromium, cadmium and lead are  $1.65\text{E-}12$   $\text{mgkg}^{-1}\text{day}^{-1}$ ,  $7.93\text{E-}12$   $\text{mgkg}^{-1}\text{day}^{-1}$  and  $4.49\text{E-}12$   $\text{mgkg}^{-1}\text{day}^{-1}$  respectively; with 95% upper confidence limits of  $2.57\text{E-}12$   $\text{mgkg}^{-1}\text{day}^{-1}$ ,  $1.85\text{E-}1$   $\text{mgkg}^{-1}\text{day}^{-1}$  and  $1.44\text{E-}11$   $\text{mgkg}^{-1}\text{day}^{-1}$  respectively. The levels of carcinogenic risk ( $\text{mgkg}^{-1}\text{day}^{-1}$ ) for cadmium and chromium in the studied locations are given in Table 11. According to toxicological profile lead, chromium and cadmium have carcinogenic health effect (Gholizadeh *et al.*, 2019); however, from our estimation chromium and cadmium had relatively higher lifetime average exposure dose than lead, with an order of carcinogenic risk as  $\text{Cr} > \text{Cd}$  in all exposure routes except inhalation. Chromium recorded the highest level of carcinogenic risk values ( $4.00\text{E-}05$  and  $5.25\text{E-}06$ ,  $1.11\text{E-}09$  and  $7.71\text{E-}10$ , and  $1.11\text{E-}07$  and  $2.09\text{E-}06$ ) for ingestion, inhalation and dermal in both children and adults respectively. From the 95% UCL of the total exposure, all calculated values fell well below the acceptable limits and about 25% fell within the tolerable or acceptable limit ( $10^{-4}$  to  $10^{-6}$ ).

None of the metals of the pathways had a hazard index equal to unity (i.e. all  $\text{HI} < 1$ ) following the analysis of the Hazard Quotient (HQ) and hazards index (HI) for the studied metals (Table 12). The maximum value of HI recorded was 0.029 for location five (EM5) for Fe via ingestion. The maximum values of HQ were via ingestion for both adults and children respectively ( $7.98\text{E-}04$  and  $1.02\text{E-}05$ ,  $3.54\text{E-}04$  and  $4.13\text{E-}02$ ,  $1.04\text{E-}04$  and  $1.34\text{E-}06$ ,  $4.65\text{E-}05$  and  $4.39\text{E-}03$  for iron, lead, chromium and cadmium). Ingestion of dust particles is the main route of exposure for both children and adults, followed by dermal

absorption, similar to other studies (Xue *et al.*, 2015 and Elnazer *et al.*, 2015). The HQ for lead and chromium via ingestion and dermal are higher than that of cadmium (2 - 4 order of magnitude); the HQ level via inhalation for top soil for these metals is almost negligible when compared to other routes (ranging from E-08 to

E-09) except for chromium for children having a magnitude of E-04. All calculated HIs are well within the safe level limit ( $< 1$ ), inferring that there is no significant risk of these metals on the health of both children and adults in these sampled locations.

**Table 1:** Physicochemical quality and heavy metal concentration of soil collected from Ekiosa market Motor parks

Parameters	Location					
	EM1	EM2	EM3	EM4	EM5	CTR
<b>pH</b>	7.38 ± 5.21	7.28 ± 5.14	7.48 ± 5.14	7.40 ± 5.23	7.31 ± 5.16	6.92
<b>EC (µS /cm)</b>	138.15 ± 97.69	203.5 ± 143.90	234 ± 165.46	193.35 ± 136.72	147 ± 103.95	106.6
<b>Sand (%)</b>	95.83 ± 67.76	95.92 ± 67.82	98.33 ± 69.53	98.09 ± 69.36	96.28 ± 68.08	96.17
<b>Silt (%)</b>	4.40 ± 3.11	2.58 ± 1.82	1.41 ± 1.00	1.09 ± 0.77	2.82 ± 3.40	3.15
<b>Clay (%)</b>	0.005 ± 0.00	0.002 ± 0.00	0.26 ± 0.32	0.82 ± 0.64	0.9 ± 0.26	0.68
<b>Pb (mg/g)</b>	0.025 ± 0.02	0.04 ± 0.03	0.035 ± 0.03	0.055 ± 0.04	1.05 ± 0.7	0.01
<b>Cd (mg/g)</b>	0.035 ± 0.02	0.03 ± 0.02	0.23 ± 0.17	0.85 ± 0.06	1.06 ± 0.07	N/D
<b>Cr (mg/g)</b>	0.05 ± 0.04	0.07 ± 0.05	0.085 ± 0.06	0.10 ± 0.07	0.15 ± 0.11	0.02
<b>Fe (mg/g)</b>	24.05 ± 17.00	23.85 ± 16.86	22.70 ± 16.05	24.95 ± 17.64	31.10 ± 21.99	20.5

**Key:** EM (Ekiosa Market), ctr (control). **all values in are means of triplicates**

**Table 2:** Enumeration of Microbial population of soil collected from Ekiosa Market Mo v tor parks  
**Key:** EM (Ekiosa Market), ctr (control), all values in are means of triplicates

Parameters (x 10 <sup>5</sup> cfu/g)	Location					
	EM1	EM2	EM3	EM4	EM5	CTR
<b>THB</b>	1.0± 0.23	1.8 ± 0.54	0.8 ± 0.43	1.9 ± 0.33	1.7 ± 0.42	2.3 ± 0.26
<b>THF</b>	0.3 ± 0.30	0.3 ± 0.01	0.5 ± 0.11	0.5 ± 0.23	0.7 ± 0.34	2.7 ± 0.22

**Table 3:** Microbial diversity of the soil samples

Sample Code	Bacterial isolates present	Fungal isolates present
Control	<i>Bacillus pumulus.</i> , <i>Salmonella</i> sp., <i>Aurobacter aerogens</i>	<i>Aspergillus</i> sp., <i>Penicillium</i> sp.,
EM1	<i>Salmonella</i> sp., <i>Serratia marcescens.</i> , <i>Bacillus megaterium</i>	<i>Aspergillus tamari.</i> , <i>Aspergillus niger.</i> , <i>Penicillium citrinum</i>
EM 2	<i>Salmonella</i> sp., <i>E.coli</i>	<i>Trichoderma</i> sp., <i>Aspergillus niger.</i> , <i>Penicillium citrinum</i>
EM 3	<i>Serratia marcescens.</i> , <i>Salmonella</i> sp., <i>Bacillus megaterium</i>	<i>Trichoderma</i> sp., <i>Penicillium citrinum.</i> , <i>Penicillium chrysogenum</i>
EM4	<i>E.coli.</i> ,	<i>Penicillium citrinum.</i> , <i>Penicillium chrysogenum.</i> , <i>Trichophyton rubrum</i>
EM5	<i>Salmonella</i> sp., <i>Bacillus pumulus.</i> , <i>E.coli.</i> , <i>Bacillus megaterium</i>	<i>Aspergillus tamari.</i> , <i>Trichoderma</i> sp., <i>Aspergillus niger.</i> , <i>Trichophyton rubrum</i>

**Table 4:** Classes of Pollution assessment indices ( $I_{geo}$ , CF,  $E_i$ , PLI and PERI)

	Value	Soil quality
$I_{geo}$	$I_{geo} \leq 0$	Uncontaminated
	$0 < I_{geo} < 1$	Uncontaminated to moderately contaminated
	$1 < I_{geo} < 2$	Moderately contaminated
	$2 < I_{geo} < 3$	Moderately to strongly contaminated
	$3 < I_{geo} < 4$	Strongly contaminated
	$I_{geo} > 5$	Extremely contaminated
CF	$CF < 1$	Low CF
	$1 \leq CF < 3$	Moderate CF
	$3 \leq CF < 6$	Considerable CF
	$CF \geq 6$	Very high CF
$E_i$	$E_i < 15$	Low risk
	$15 \leq E_i < 30$	Moderate risk
	$30 \leq E_i < 60$	Considerable risk
	$60 \leq E_i < 120$	High risk
	$E_i \geq 120$	Very high risk
PERI	$PERI < 50$	Low PERI
	$50 \leq PERI < 100$	Moderate PERI
	$100 \leq PERI < 200$	Considerable PERI
	$PERI \geq 200$	Very high PERI
PLI	$PLI > 1$	Polluted
	$PLI = 1$	Baseline level
	$PLI < 1$	Not polluted

**Table 5:** Parameters for calculating chronic daily intake (CDI) for non-carcinogenic risk assessment

Symbol	Meaning	Value	
		Adult	Children
C	Exposure point concentration ( $\text{mgkg}^{-1}$ )		
IngR	Ingestion rate	100 ( $\text{mgday}^{-1}$ )	200 ( $\text{mgday}^{-1}$ )
InhR	Inhalation rate	20 ( $\text{m}^3\text{day}^{-1}$ )	7.6 ( $\text{m}^3\text{day}^{-1}$ )
EF	Exposure frequency	180 days year <sup>-1</sup>	
ED	Exposure duration	24 years	6 years
SA	Exposed skin area	5700 ( $\text{cm}^3$ )	2800 ( $\text{cm}^3$ )
SL	Skin adherence factor	0.07 ( $\text{mgcm}^{-1}$ )	0.2 ( $\text{mgcm}^{-1}$ )
ABS	Dermal absorption factor	0.001	
PEF	Particle emission factor	$1.36 \times 10^9 \text{m}^3\text{kg}^{-1}$	
Bw	Body weight	61.8 kg	16.2 kg
AT	Average time	ED $\times$ 365 for non-carcinogens and 26,280 for carcinogens	

**Table 6:** Reference dose and slope factor of metals in the present study

	Pb	Cd	Cr	Fe
RfD <sub>ing</sub>	3.50E-03	5.00E-01	3.00E-03	7.00E-03
RfD <sub>inh</sub>	3.52E-03	5.70E-06	2.86E-05	8.00E-01
RfD <sub>dermal</sub>	5.25E-04	5.00E-03	6.00E-05	7.00E-01
SF		6.1	41	

**Table 7:** The pollution assessment Indices of soil samples from Ekiosa Market motor parks

Parameters (Mg/g)	Exposure	LOCATIONS				
		EM1	EM2	EM3	EM4	EM5
Pb	<b>I<sub>geo</sub></b>	-10.37	-9.69	-9.52	-9.1	-4.97
Cd		-4.06	-4.64	-1.58	0.18	0.5
Cr		-10.55	-10.07	-9.79	-9.55	-8.87
Pb	<b>E<sub>i</sub></b>	0.0057	0.0091	0.01	0.014	0.24
Cd		2.7	1.8	15	51	63.6
Cr		0.002	0.002	0.0034	0.004	0.0064
Pb	<b>CF</b>	0.00114	0.00182	0.002	0.003	0.05
Cd		0.09	0.006	0.5	1.7	2.12
Cr		0.001	0.001	0.0017	0.002	0.0032

**Key:** Index of geoaccumulation ( $I_{geo}$ ), ecological risk index ( $E_i$ ) and contamination factor (CF)

**Table 8:** Pollution Load index and Potential ecological risk index

Index	Location					max	Min	95% UCL	
	EM1	EM2	EM3	EM4	EM5				
PLI	0.005	0.002	0.012	0.023	0.072	0.0228	0.072	0.002	0.058
PERI	2.71	1.81	15.01	51.02	63.85	26.88	63.85	1.81	62.56

**Key:** EM (Ekiosa Market), ctr (control), UCL (Upper confidence limit), pollution load index (PLI) and potential ecological risk index (PERI)

**Table 9:** Daily exposure dose (D) of heavy metals in top soils of Ekiosa market motor parks ( $\text{mgkg}^{-1}\text{day}^{-1}$ )

<b>ADULTS</b>		<b>LOCATIONS</b>					
<b>Parameters (Mg/g)</b>	<b>Exposure</b>	<b>EM1</b>	<b>EM2</b>	<b>EM3</b>	<b>EM4</b>	<b>EM5</b>	<b>95% UCL</b>
Pb	$D_{\text{ing}}$	1.52E-7	2.44E-7	2.74E-7	3.65E-7	6.39E-6	6.42E-07
Cd		2.74E-7	1.83E-7	1.52E-6	5.17E-6	6.45E-6	8.30E-07
Cr		3.04E-7	4.26E-7	5.17E-7	6.09E-7	9.74E-7	1.16E-07
Fe		1.46E-4	1.45E-4	1.38E-4	1.52E-4	1.89E-4	2.81E-05
Pb	$D_{\text{inh}}$	4.25E-12	6.8E-12	7.65E-12	1.02E-11	1.79E-10	1.22E-12
Cd		7.66E-12	5.10E-12	4.25E-11	1.45E-10	1.80E-10	1.70E-11
Cr		8.51E-12	1.19E-11	1.45E-11	1.70E-11	2.72E-11	3.46E-11
Fe		4.09E-9	4.06E-9	3.80E-9	4.24E-9	5.29E-9	2.56E-09
Pb	$D_{\text{dermal}}$	4.26E-10	6.8E-10	7.65E-10	1.02E-9	1.79E-8	4.73E-10
Cd		7.65E-10	5.10E-10	4.25E-9	1.43E-8	1.80E-8	9.36E-08
Cr		8.50E-10	1.19E-9	2.70E-10	1.70E-9	2.72E-9	6.42E-09
Fe		4.06E-9	4.05E-7	1.45E-9	4.24E-7	5.29E-7	8.30E-07
<b>CHILDREN</b>							
Pb	$D_{\text{ing}}$	2.0E-8	3.19E-8	3.59E-8	4.79E-8	8.38E-7	4.30E-08
Cd		3.59E-8	2.39E-8	2.0E-7	6.78E-7	8.46E-7	6.33E-06
Cr		3.99E-8	5.59E-8	6.78E-8	7.98E-8	1.28E-7	8.82E-08
Fe		1.92E-7	1.90E-5	1.81E-5	1.99E-5	2.48E-5	1.79E-05
Pb	$D_{\text{inh}}$	2.93E-12	4.69E-12	5.28E-12	7.04E-12	1.23E-10	1.77E-11
Cd		5.28E-12	3.52E-12	2.93E-11	9.97E-11	1.24E-10	2.46E-11
Cr		5.87E-12	8.21E-12	9.97E-12	1.17E-11	1.88E-11	5.02E-12
Fe		2.82E-9	2.8E-9	2.66E-9	2.93E-9	3.65E-9	1.37E-09
Pb	$D_{\text{dermal}}$	7.95E-11	1.27E-10	1.43E-10	1.91E-10	3.34E-09	2.50E-10
Cd		1.43E-10	9.54E-11	7.95E-10	2.70E-9	3.37E-09	5.85E-09
Cr		1.59E-10	2.23E-10	1.59E-11	3.18E-10	5.09E-10	4.30E-10
Fe		7.65E-8	7.58E-8	7.22E-8	7.93E-8	9.89E-08	6.33E-08

**Key:** EM (Ekiosa Market), ctr (control), UCL (Upper confident limit)

**Table 10:** Lifetime average daily dose (LADD) via inhalation of heavy metals in top soils of Ekiosa market motor parks ( $\text{mgkg}^{-1}\text{day}^{-1}$ )

Location	Cr	Cd	Pb
EM1	8.89E-13	8.00E-13	4.44E-13
EM2	1.23E-12	5.33E-13	7.11E-13
EM3	1.51E-12	4.44E-12	1.51E-12
EM4	1.78E-12	1.51E-11	1.07E-12
EM5	2.84E-12	1.88E-11	1.87E-11
Mean	1.65E-12	7.93E-12	4.49E-12
Max	2.84E-12	1.88E-11	1.87E-11
Min	8.89E-13	5.33E-13	4.44E-13
95% UCL	2.57E-12	1.85E-11	1.44E-11

**Key:** EM (Ekiosa Market), ctr (control), UCL (Upper confident limit)

**Table 11:** Carcinogenic risk (CR) of heavy metals in top soils of Ekiosa market motor parks ( $\text{mgKg}^{-1}\text{day}^{-1}$ )

Adults		LOCATIONS					
Parameters (Mg/g)	Exposure	EM1	EM2	EM3	EM4	EM5	95% UCL
Cd	CR <sub>ing</sub>	1.67E-06	1.12E-06	9.27E-06	3.15E-05	3.93E-05	3.11E-05
Cr		1.25E-05	1.75E-05	2.12E-05	2.50E-05	4.00E-05	4.36E-05
Cd	CR <sub>inh</sub>	4.67E-11	3.11E-11	2.59E-10	8.84E-09	1.10E-09	3.86E-09
Cr		3.49E-10	4.88E-10	5.94E-10	6.97E-10	1.11E-09	1.22E-09
Cd	CR <sub>dermal</sub>	4.67E-09	3.11E-09	2.59E-08	8.72E-08	1.10E-07	8.67E-08
Cr		3.49E-08	4.88E-08	1.10E-08	6.97E-08	1.11E-07	1.03E-07
Children							
Cd	CR <sub>ing</sub>	2.19E-07	1.48E-07	1.22E-06	4.14E-06	5.11E-06	4.07E-06
Cr		1.68E-06	2.29E-06	2.77E-06	3.27E-06	5.25E-06	5.73E-06
Cd	CR <sub>inh</sub>	3.22E-11	2.15E-11	1.79E-10	6.08E-10	7.56E-10	5.99E-10
Cr		2.40E-10	3.37E-10	4.09E-10	4.80E-10	7.71E-10	8.40E-10
Cd	CR <sub>dermal</sub>	9.70E-10	1.36E-10	4.85E-09	1.65E-08	2.06E-08	1.62E-08
Cr		6.52E-07	9.14E-07	6.52E-07	1.56E-06	2.09E-06	2.20E-06

**Key:** EM (Ekiosa Market), ctr (control), UCL (Upper confident limit)

**Table 12:** Hazard Quotient (HQ;  $\text{mgkg}^{-1}\text{day}^{-1}$ ) and Hazard Index (HI) of top soils of Ekiosa market motor parks

<b>ADULTS</b>		<b>LOCATIONS</b>					
<b>Parameters (Mg/g)</b>	<b>Exposure</b>	<b>EM1</b>	<b>EM2</b>	<b>EM3</b>	<b>EM4</b>	<b>EM5</b>	<b>95% UCL</b>
Pb	HQ <sub>ing</sub>	4.34E-05	6.97E-05	7.83E-05	1.04E-04	1.83E-03	7.98E-04
Cd		5.48E-07	3.66E-07	3.04E-06	1.03E-05	1.29E-05	1.02E-05
Cr		1.01E-04	1.42E-04	1.72E-04	2.03E-04	3.25E-04	3.54E-04
Fe		2.09E-02	2.07E-02	1.97E-02	2.17E-02	2.70E-02	4.13E-02
		HI	2.10E-02	2.09E-02	2.00E-02	2.20E-02	2.92E-02
Pb	HQ <sub>inh</sub>	1.21E-09	1.93E-09	2.17E-09	2.90E-09	5.09E-08	2.22E-08
Cd		1.34E-07	8.95E-08	7.46E-07	2.54E-06	3.16E-06	2.50E-06
Cr		1.43E-04	1.42E-04	1.33E-04	1.48E-04	1.85E-04	2.82E-04
Fe		5.11E-09	5.08E-09	4.75E-09	5.30E-09	6.61E-09	1.01E-08
		HI	1.43E-04	1.42E-04	1.34E-04	1.51E-04	1.88E-04
Pb	HQ <sub>dermal</sub>	8.11E-07	1.30E-06	1.46E-06	1.94E-06	3.41E-05	1.49E-05
Cd		1.53E-07	1.02E-07	8.50E-07	2.86E-06	3.60E-06	2.84E-06
Cr		7.08E-05	9.92E-05	2.25E-05	1.42E-04	2.27E-04	2.11E-04
Fe		5.80E-09	5.79E-07	2.07E-09	6.06E-07	7.56E-07	7.31E-07
		HI	7.18E-05	1.01E-04	2.48E-05	1.47E-04	2.65E-04
<b>Children</b>							
Pb	HQ <sub>ing</sub>	5.71E-06	9.11E-06	1.03E-05	1.37E-05	2.39E-04	1.04E-05
Cd		7.18E-08	4.78E-08	4.00E-07	1.36E-06	1.69E-06	1.34E-07
Cr		1.33E-05	1.86E-05	2.26E-05	2.66E-05	4.27E-05	4.65E-05
Fe		2.74E-05	2.71E-03	2.59E-03	2.84E-03	3.54E-03	4.39E-03
		HI	4.65E-05	2.74E-03	2.62E-03	2.88E-03	3.83E-03
Pb	HQ <sub>inh</sub>	8.32E-10	1.33E-09	1.50E-09	2.00E-09	3.49E-08	1.52E-09
Cd		9.26E-08	6.18E-08	5.14E-07	1.75E-06	2.18E-06	1.73E-07
Cr		9.86E-05	9.79E-05	9.30E-05	1.02E-04	1.28E-04	1.95E-05
Fe		3.53E-09	3.50E-09	3.33E-09	3.66E-09	4.56E-09	6.97E-09
		HI	9.87E-05	9.80E-05	9.35E-05	1.04E-04	1.30E-04
Pb	HQ <sub>dermal</sub>	1.51E-07	2.42E-07	2.72E-07	3.64E-07	6.36E-06	3.83E-07
Cd		2.86E-08	1.91E-08	1.59E-07	5.40E-07	6.74E-07	2.15E-07
Cr		1.33E-05	1.86E-05	1.33E-06	2.65E-05	4.24E-05	4.18E-05
Fe		1.09E-07	1.08E-07	1.03E-07	1.13E-07	1.41E-07	7.98E-07
		HI	1.35E-05	1.90E-05	1.86E-06	2.75E-05	4.96E-05



## CONCLUSION

The soil from this study contained considerable levels of lead, cadmium and chromium in comparison to world soil average abundance. From the studied samples, the results of igeo, CF and Ei indicate that the main soil pollutant is cadmium (Cd) and PLI and PERI calculations pointed to the pollution of two locations (which from observation had the highest vehicular activity) and low to

moderate PERI, the bulk of which is from cadmium contamination and the overall exposure dose calculated showed higher exposure dose rate for children than adults. Given the above, strict monitoring of vehicles with regards to their emission condition is recommended to protect the environment from heavy metal pollution and the inhabitants especially the children from exposure to cancer and non-cancer risk.

## REFERENCE

- Abdu, N., Abdulahi, A. A. and Abdulkadir, A. (2016). Heavy metal and soil microbes. *Environmental Chemistry Letter*. **2016**(15): 65 – 84
- Akan, J. C., Audu, S. I., Mohammad, Z. and Ogugbuaja. (2013). Assessment of heavy metals, pH, organic matter and organic carbon in roadside soils in Makurdi Metropolis, Benue State, Nigeria. *Journal of Environmental Protection* **2013**(4): 618-628
- Akbar K. F., Hale, W. H., Headley A. D. and Athar M. (2006). Heavy metal contamination of roadside soils of Northern England. *Soil and Water Resources* **1**(4): 158–163.
- Anyanwu, E. D. and Onyele, O. G. (2018). Human health risk assessment of some heavy metals in a rural spring, southeastern Nigeria. *African Journal of Environment and Natural Science Research* **1**(1): 15-23
- Barnett, H. L. and Hunter, B. B. (2006). *Illustrated Genera of Imperfect Fungi*. 4<sup>th</sup> Edn. 4th Edition, The American Phytopathological Society, St. Paul Minnesota., 225 pp.
- Chen, L., Zhou, S., Shi, Y., Wang, C., Li, B., Li, Y. and Wu, S. (2018). Heavy metals in food crops, soil, and water in the Lihe River Watershed of the Taihu Region and their potential health risks when ingested. *Science of the Total Environment*, **615**(1): 141 – 149
- Chibuikwe, G. U. and Obiora, S. C. (2014). Heavy metal polluted soils: effect on plants and bioremediation Methods. *Applied and Environmental Science*, **2014**(1): 67 – 73
- Elliott, L. F., Lynch, J. M., and Papendick, R. I. (1996). The microbial component of soil quality. In: *Soil Biochemistry*. Stotzky, G. and Bollag, J.-M. (eds.). Marcel Dekker Inc., New York, pp. 1-21.
- Elnazer, A. A., Salman, A. S., Seleem, E. M and Elsayed M. A. (2015). Assessment of some heavy metals pollution and bioavailability in roadside soil of Alexandria-Marsa Matruh highway, Egypt. *International Journal of Ecology* special issue, Article ID: 689420
- Giller, K. E., Witter, E. and McGrath, S. P. (2009). Heavy metal and soil microbes. *Soil Microbiology and Biochemistry*, **41**(10): 2031 – 2037
- Govindasamy, C., Packiasamy, R., Arul, M., Srinivasan, R. and Meena, N. (2011). Biochemical characterization of total

- heterotrophic bacteria (THB) in Muthukuda Mangroves, Southeast Coast of India. *African Journal of Basic and Applied Sciences*, **3**(6): 285-289
- Gyaneshwar, P., Kumar, G. N., Parekh, L., and Poole, P. (2002). Role of soil microorganisms in improving P nutrition of plants. In: Gyaneshwar, P (ed) *Food Security in Nutrient-Stressed Environments: Exploiting Plants' Genetic Capabilities*, Netherlands: Springer, pp. 133– 143
- Harley, J. P. and Prescott, L. M. (2002). *Laboratory Exercises in Microbiology*, 5<sup>th</sup> Edn. Mac Graw Hill, New York, 449 pp.
- Hu, X., Zhang, Y., Luo, J., Wang, T. J., Lian, H. Z and Ding Z. H. (2011). Bioaccessibility and health risk of arsenic, mercury and other metals in urban streets from a mega city, Nanjing, China. *Environmental Pollution*, **159**(0): 1215 – 1221
- Kabata-Pendias, A. and Pendias, H. (2001). *Trace Elements in Soils and Plants*. CRC Press, Boca Raton, Fla, USA, 2001
- Khadka, D. and Lamichanne, S. (2016). Assessment of soil fertility status of agricultural research station, Belachapi, Dhanusha, Nepal. *Journal of Maize Research and Development*, **2**(1): 43 – 57
- Liang, T., Kexin, L., Wang, L. and Yang, Z. (2015). Contamination and health risk assessment of heavy metals in road dust in Bayan Obo Mining Region in Inner Mongolia, North China. *Journal of Geographical Sciences* **25**(1): 1439 – 1451
- Likuku, A. S., Mmsolawa, B. K. and Gaboutloeloe, K. B. (2013). Assessment of heavy metal enrichment and degree of contamination around the copper-nickel mine in the selebi Phikwe region, eastern Bostwana. *Environment and Ecology Research* **1**(2): 15 – 17
- Massadeh, A. M., El-Khateeb, M. Y and Ibrahim, S. M. (2017). Evaluation of Cd, Cr, Cu, Ni and Pb in selected cosmetic products from Jordanian, Sudanese and Syrian markets. *Public Health*, **2017** (149):130 – 137
- Muhammad, S., Ahmad, K., Ali, W., Jadoon, I. A. K. and Rasool, A. (2020): Occurrence, source identification and potential risk evaluation of heavy metals in sediments of the Hunza River and its tributaries, Gilgit-Baltistan. *Environmental Technology and Innovation*, Special issue, 18, Article ID: 100700
- Olukanni, D. O. and Adebisi, S. A. (2012). Assessment of Vehicular Pollution of Road Side Soils in Ota Metropolis, Ogun State, Nigeria. *International Journal of Civil and Environmental Engineering*. **12**(4): 40-46
- Omonigho, S. E. and Ugboh, R. O. (1998). Microbiological and physico-chemical analysis of moin-moin. *Nigerian Journal of Microbiology*, **12**(1): 69 - 73.
- Palov, D. D., Aleksova, M. R., Nikolova, R. N., Dinev, N. S. Kenarova, A. E., Boteva, S. B., Dimitrov, R. A. and Radeva, G. S. (2020). Relationships between soil microbial activity, bacterial diversity and abiotic factors along the heavy metal contamination gradient. *Ecologia Balkanica*. Special Issue, p31-39
- Pankhurst, C. E., Doube, B. M., and Gupta, V. V. S. R. (1997). Biological indicators of soil health: Synthesis. In: *Biological Indicators of Soil Health*. Pankhurst, C. E., Doube, B. M., and Gupta, V. V. S. R. (eds.). CAB International, pp. 419-435

- Sharma, P. (2009). *Manual of Microbiology, Tools and Techniques*. Ane books. Pvt. Ltd. New Delhi. 405 pp.
- Simon, E., Vidic, A., Braun, M., Fabian, I. and Tothmeresz, B. (2013). Trace element concentration in soils alongside urbanization gradient in the city of Wien, Austria. *Environmental Science and Pollution Research*, **20**(2): 917 – 924.
- Sioutas, C. (2010). Evaluation of the measurement performance of the scanning mobility particle sizer and aerodynamic particle sizer. *Aerosol Science and Technology* **30** (1): 1 – 5
- Suzuki, K., Yakubi, T. and Ono, Y. (2009). Roadside *Rhododendron pulchrum* leaves as bioindicators of heavy metal pollution in traffic areas of Okayama, Japan. *Environmental Monitoring and Assessment*, **149**(1-4): 133-141
- US Environmental Protection Agency (USEPA; 1999). Integrated risk information system. [online] Available at <https://www.epa.gov/iris/basic-information-about-integrated-risk-information-system>, accessed on 5 May 2020
- Van Der Heijden, M. G. A., Bardgett, R. D. and Van Straalen, N. M. (2008). The unseen majority: soil microbes as drivers of plant diversity and productivity in terrestrial ecosystems. *Ecology Letters*, **11**(1): 296– 310.
- Velea, T., Gherghe, L., Predica, V. and Krebs R. (2009). Heavy metal contamination in the vicinity of an industrial area near Bucharest. *Environmental Science and Pollution Research*, **16**(1):27–32
- Xue, X., Xinwei, L., Xiufeng, H and Zhao, N. (2015). Ecological and health assessment of metal in resuspended particles of urban street dust from an industrial city in China. *School of Tourism and Environment*, **108**(1):72 – 78
- Yahaya, S. M., Abubakar, F and Abdu, N (2021) Ecological risk assessment of heavy metal-contaminated soils of selected villages in Zamfara State, Nigeria. *SN Applied Sciences* 3 (168) <https://doi.org/10.1007/s42452-021-04175>