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Pollution Indices of Heavy Metals in Urban Farm Soils along selected Highways in Lagos, Nigeria

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Abstract

Urban farm soil may be severely affected by heavy metal (HM) pollution, impairing environmental and human health. Proximity to pollution source such as roads can compromise soil quality, especially in ever-expanding cities with limited cropland. Pollution indices are useful tools for describing HM pollution of soils. Therefore, this study utilized pollution indices to assess HM pollution of urban farm soils along selected major highways in Lagos, Nigeria. Surface soil samples (0 –15 cm) were collected from the highway to the farms. Soil parameters (pH and organic carbon) and HMs (Cd, Cr, Co, Ni and Pb) were determined using standard methods and atomic absorption spectroscopy, respectively. Pollution indices: contamination factor (C_f), contamination degree (C_d), geoaccumulation index (I_{geo}), pollution load index (PLI), ecological risk (E_r) and risk index (RI) were used to determine HM pollution. Soil pH ranged from 5.36±0.34 – 6.97±0.24, indicating strongly acidic to neutral state. Organic carbon was > 4% across the study area. Soil HM (mg kg^{-1} soil) varied as follows: 1.30±1.06 to 7.76±5.65 (Cd), 2.85±0.49 to 29.54±17.25 (Ni), 0.08±0.07 to 1.53±1.65 (Cr) and 0.11±0.04 to 22.68±7.19 (Co), while Pb was generally very low. Only Cd exceeded the recommended limits. In terms of C_f, soils were moderately contaminated by Co (1.07) but very highly contaminated by Cd (7.27). Mean C_d showed moderate (8.34) contamination across the study sites, while mean PLI (0.42) suggested that most soils were unpolluted. Most of the I_{geo} values for Cd were >1 indicating moderate pollution in soils. Moreover, soils had high to dangerous E_r by Cd (95.12 – 567.80) and the RI values showed moderate to high risk in 50% of the study area. This urban farm soils showed relatively serious pollution with cadmium. There is the need to prevent and control sources of this heavy metal into the soil environment.

Indices de pollution des métaux lourds dans les sols agricoles urbains tout au long d'autoroutes sélectionnées à Lagos, Nigeria

Résumé

Les sols agricoles, aux milieux urbains peuvent être gravement affectés par la pollution par les métaux lourds (ML), ce qui pose de graves conséquences à la santé environnementale et humaine. La proximité d'une source de pollution telle que les routes peut compromettre la qualité du sol, en particulier dans les villes en expansion constante avec des terres cultivées limitées. Les indices de pollution sont des outils utiles pour décrire la pollution ML des sols. Par conséquent, cette étude a utilisé des indices de pollution pour évaluer la pollution par les métaux lourds des sols agricoles urbains le long de certaines autoroutes principales à Lagos, au Nigeria. Des échantillons de sol de surface (0 à 15 cm) ont été prélevés de l'autoroute jusqu'aux fermes. Les paramètres du sol (pH et carbone organique) et les ML (Cd, Cr, Co, Ni et Pb) ont été déterminés à l'aide de méthodes standard et de la spectroscopie d'absorption atomique, respectivement. Indices de pollution : facteur de contamination (Cf), degré de contamination (Cd), indice de géoaccumulation (Igeo), indice de charge polluante (PLI), risque écologique (Er) et indice de risque (RI) ont été utilisés pour déterminer la pollution ML. Le pH du sol variait de 5,36 ± 0,34 à 6,97 ± 0,24, indiquant un état fortement acide à neutre. Le carbone organique était > 4 % dans la zone d'étude. La ML du sol (mg kg-1 sol) variait comme suit : 1,30±1,06 à 7,76±5,65 (Cd), 2,85±0,49 à 29,54±17,25 (Ni), 0,08±0,07 à 1,53±1,65 (Cr) et 0,11±0,04 à 22,68 ± 7,19 (Co), tandis que Pb était généralement très faible. Seul Cd dépassait les limites recommandées. En termes de Cf, les sols étaient modérément contaminés par le Co (1,07) mais très fortement contaminés par le Cd (7,27). Le Cd moyen a montré une contamination modérée (8,34) sur les sites d'étude, tandis que le PLI moyen (0,42) a suggéré que la plupart des sols n'étaient pas pollués. La plupart des valeurs Igeo pour le Cd étaient > 1 indiquant une pollution modérée des sols. De plus, les sols avaient un Er élevé à dangereux par Cd (95,12 – 567,80) et les valeurs RI montraient un risque modéré à élevé dans 50 % de la zone d'étude. Les sols de ces fermes urbaines présentaient une pollution grave par rapport au cadmium. Il est nécessaire de contrôler les sources de ce métal lourd dans l'environnement du sol.

Introduction

Growing of crops within cities for human consumption has been popularly referred to as urban farming (McDougall *et al*., 2019). It has shown potential for poverty alleviation as well as improving food security in developing countries (Akinmoladun and Adejumo, 2011; World Bank, 2013; McDougall *et al*., 2019). Urban farming increases global food supply (McDougall *et al*., 2019) and more recently, has become a necessary strategy for advancing food and nutritional security during and after the COVD-19 pandemic (Lal, 2020).

However, limitation of cropland in urban areas leads to farming along highways. As a result, major cities in developing countries like Nigeria, use setbacks along major highways especially for edible vegetable farming (Atayese *et al*., 2009). Thus, urban farming in close proximity to highways in many cities in Nigeria is a common practice, making both plants and soils prone to contamination from vehicular emissions.

Moreover, Petit *et al*., (2011), stated that farms located close to major roads may be severely affected by road traffic pollution of both metallic and organic origin.

Despite the aforementioned benefits of urban farming, soil contamination by heavy metals such as cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb), from vehicular emission is one of the major concerns of urban farming along roadsides (Kacholi and Sahu, 2018; Gebeyehu and Bayissa, 2020). The problem of high concentrations of heavy metals, especially in agricultural soils, creates a global environmental issue due to the crucial importance of food production and security

(Chen *et al*., 2015). Also, direct or indirect exposure of heavy metal from contaminated soil can lead to chronic illnesses in humans. For example, Cd has been reported to cause prostatic hyperplasia, lung cancer, and other chronic diseases (Ma *et al*., 2022). Thus, monitoring of urban farm soils in peculiar locations such as along roadsides is essential to avoid compromise of food and soil quality.

Evaluating the degree of heavy metal pollution in soils requires the use of certain geochemical indices generally termed the pollution indices (Silva *et al*., 2019; Taghavi *et al*., 2023). Pollution indices are considered a useful tool for the comprehensive identification of soil contamination (Chen *et al*., 2015; Kowalska *et al*., 2018). As such, pollution indices are important for the effective assessment of soil contamination with heavy metals (Kowalska *et al*., 2018). In this study, some pollution indices including geoaccumulation index (I_{geo}), pollution load index (PLI), ecological risk (ER) were considered among others.

Increased cultivation of contaminated soil is on the rise due to the ongoing expansion of urban areas in developing countries like Nigeria. Thus, urban areas like Lagos, Nigeria, already experiencing intensive traffic activities, owing to the growing population and vehicle numbers, is likely to encounter significant accumulations of heavy metals in and around roadside surroundings.

Moreover, it has been recognized that urban farming is strongly practiced in available spaces, mainly those situated along roads (Atayese *et al*., 2009; Sahu and Kacholi, 2016). Thus, it is important that continuous monitoring of levels of heavy metals in soils which can potentially transfer to edible vegetables is regularly conducted. Therefore, the objective of this study was to utilize pollution indices to assess HM pollution of urban farm soils along selected major highways in Lagos, Nigeria.

Materials and Methods

Study area and sampling sites

The study was carried out in Lagos State which lies in the southwestern part of Nigeria between 6°05' to 6°30' N and 2°45' to 4°30' E. Two sampling sites were selected based on the presence of urban vegetable farms (> 10 years) and located along major highways, namely Lagos State University-Iba road (6°28'27.8″N 3°12'09.1″E) and Lagos-Badagry expressway (6°27'27.8"N and 3°16'16.7"E) designated as Site 1 and Site 2, respectively. The soils and vegetable (Amarathus specie) have been previously assessed for heavy metals contamination (Atayese *et al*., 2009).

Sample Collection

Samples of soils were collected from the roadside at a distance of 20m, 40m and 60m into the vegetable farms along LASU-Iyana Iba road (Site 1) and Lagos-Badagry expressway (Site 2). Representative soil samples were collected from the vegetable (*Corchorus Olitorius* – CO; *Celosia Argentea* – CA and *Amaranthus Hybridus* – AH) plots of the farm at a depth of 0 – 15 cm. The soil samples were sorted to remove non-soil materials, air-dried and sieved (2 mm) before storing in clean Ziploc bags for laboratory analysis. A small amount of the 2-mm sieved soil was finely ground for heavy metal, organic carbon, and total nitrogen analyses.

Sample Analysis

Soil pH and electrical conductivity (EC) were prepared using a 1:2.5 and 1:5 soil and water ratio, respectively and determined with the pH and conductivity/TDS meters (Mettler Toledo seven Multi Meter), respectively. Soil organic carbon was determined by the Walkley and Black (1934) method. For the heavy metals (Cd, Co, Pb, Ni, and Cr) analysis, finely ground soil samples (2.0 g) were separately digested in a di-acid mixture of concentrated HCl and HNO_3 in a ratio of 3:1. The concentration of heavy metals was determined by a thermo-solar atomic absorption spectrophotometer. The quality assurance process were as follows: all samples (in field and laboratory) were carefully handled to avoid cross-contamination; containers were properly cleaned by washing and rinsing, and only distilled water was used for all dilutions and preparation of samples and reagents. Additionally, all measurements were performed in replicates.

Pollution Indices and Ecological Risk Assessment

Heavy metal contamination in soil samples was evaluated by using the contamination factor (C_f), degree of contamination (C_d), geo-accumulation index (I_{geo}), pollution load index (PLI), potential ecological risk factor (E_r), and potential ecological risk index (RI) (Muller 1969; Hakanson 1980; Tomlinson *et al*., 1980). The classification of the values of the pollution indices are described in Table 1. The pollution indices were calculated from the equations (1 – 6) below:

$$C_f = \frac{C_n}{B_n} \quad (1)$$

$$C_d = \sum C_f \quad (2)$$

$$I_{geo} = Log_2 \frac{C_n}{1.5\ B_n} \quad (3)$$

$$\mathrm{PLI} = \sqrt[n]{C_f(1) \times C_f(2) \times \ldots \times C_f(n)} \quad (4)$$

$$E_r^i = T_r^i \times C_f^i \quad (5)$$

$$RI = \sum_{i=1}^{n} E_r^i \quad (6)$$

Where Cn is the measured concentration of the heavy metal, Bn is the background concentration of the same heavy metal. Background values are usually derived from unpolluted soils. However, when this information is not available, the global background values for soils have been used (Kabata-Pendias, 2011). Constant 1.5 is used to minimize the effect of any geogenic variations and small anthropogenic influences (Wang *et al*., 2018). T_r^i is the toxic response factor of a metal. The toxic response factors for Cd, Cr, Co, and Ni are 30, 2, 5 and 5, respectively (Häkanson, 1980).

Statistical Analysis

Analysis of both soil physicochemical parameters and heavy metals was performed in duplicates and the data were presented as the mean ± standard deviation. Descriptive analysis was carried out with Excel 2013 and SPSS (version 21) software.

Results and Discussion

Soil Physicochemical parameters

The results of the soil physicochemical parameters are presented in Table 2. The pH of the study area ranged from 5.36 ± 0.34 – 6.97 ± 0.24, indicating the soils were strongly acidic to neutral in nature. Majority (66.0%) of soil samples was in the acidic pH range. Soil pH is one of the most important parameters influencing the release of metals, with increasing concentration of metals observed at lower pH (Krol *et al*., 2020). The pH values obtained in this study were lower than reported for agricultural soils along a major highway in north India (Gupta *et al*., 2021). Soil electrical conductivity (EC) in this study area varied from 342.18±374.61 – 987.50±116.71µS/cm. The organic carbon (OC) across the study area was > 4%, which is generally higher than in many soils in tropical areas. Although, the concentration of OC was not reported in a previous work at the same study area (Atayese *et al*., 2009), the high percentage obtained in this study reflects the heavy use of manure in urban farming in Nigeria. With respect to moisture content (MC), there was little difference between the sampling sites. Mean MC ranged from 1.44±0.40 – 1.77±0.60 in Site 1 and 2.26±0.51 – 3.02±0.35 in Site 2.

Table 1: Description and Classification of pollution indices

C_f	C_d	Classification	I_{geo}	Classification	E_r	Classification	RI	Classification
$C_f < 1$	$Cd < 6$	Low	Igeo = 0	Unpolluted	Er < 40	low	RI < 150	low
$1 < C_f < 3$	$6 = Cd < 12$	Moderate	0 < Igeo = 1	unpolluted to moderately polluted	40 < Er < 80	moderate	150 < RI < 300	moderate
$3 < C_f < 6$	$12 = Cd < 24$	Considerable	1 < Igeo = 2	moderately polluted	80 < Er < 160	considerable	300 < RI < 600	considerable
$C_f > 6$	$Cd = 24$	very high	2 < Igeo = 3	moderately to heavily polluted	160 < Er < 320	high	RI > 600	very high
			3 < Igeo = 4	heavily polluted	Ef > 320	dangerous		

C_f – Contamination factor, C_d – Degree of contamination, E_r – Potential risk factor, RI – Ecological risk index (Hakanson, 1980 and Tomlinson *et al*., 1980); I_{geo} – Geoaccumulation Index (Muller 1969)

Table 2: Soil physicochemical parameters

Parameters	Site 1			Site 2		
	Amaranthus Hybridus	***Celosia Argentea***	***Corchorus Olitorius***	***Amaranthus Hybridus***	***Celosia Argentea***	***Corchorus Olitorius***
pH	5.56±0.23	6.21±0.47	5.36±0.34	6.60±0.42	6.97±0.24	5.98±0.50
Electrical Conductivity (µS/cm)	534.42±375.29	342.18±374.61	800.50±74.47	987.50±116.71	601.17±299.10	867.33±185.03
Organic Carbon (%)	5.48±0.34	5.89±0.51	4.45±0.45	6.60±0.46	6.03±0.31	4.97±0.48
Total Nitrogen (mg/g)	0.45±0.01	0.51±0.04	0.39±0.04	0.57±0.04	0.52±0.03	0.43±0.04
Moisture Content (%)	1.77±0.60	1.44±0.40	1.76±0.25	2.26±0.51	2.35±0.31	3.02±0.35
Sand (%)	73.53±0.46	74.59±3.63	78.38±6.12	70.97±0.11	69.39±4.54	74.04±5.54
Silt (%)	5.56±0.09	4.63±0.36	6.27±0.20	7.17±0.28	8.09±0.38	9.13±0.67
Clay (%)	20.92±0.04	20.79±0.13	15.36±0.28	21.86±0.25	22.53±0.21	16.83±0.85
Texture	SCL	SCL	SL	SCL	SCL	SL

Mean = 3± Standard deviation; SCL – Sandy clay loam; SL – Sandy loam

Table 3: Concentrations of heavy metals in the urban farm soils

Location	Vegetable farm	Distance	Heavy metals				
		(m)	Cd	Ni	Cr	Co	Pb
Site 1	CO	0-20	1.12±0.27	7.37±0.42	0.11±0.01	7.64±0.16	BDL
		20-40	2.76±0.03	3.33±0.24	0.45±0.01	26.75±1.35	BDL
		40-60	2.46±0.56	4.79±0.31	0.70±0.02	22.24±1.43	BDL
		Mean	**2.11±0.87**	**5.16±2.04**	**0.42±0.30**	**18.88±9.99**	**-**
	CA	0-20	13.78±0.28	2.53±0.26	0.13±0.01	BDL	0.16±0.02
		20-40	6.91±0.92	3.41±0.14	0.03±0.01	BDL	0.09±0.00
		40-60	2.58±0.45	2.62±0.03	BDL	5.58±0.36	BDL
		Mean	**7.76±5.65**	**2.85±0.49**	**0.08±0.07**	**-**	**0.13±0.05**
	AH	0-20	1.95±0.12	18.91±0.78	0.87±0.02	8.44±0.48	BDL
		20-40	4.15±0.47	2.12±0.22	1.07±0.04	5.08±0.31	BDL
		40-60	3.30±0.39	1.20±0.33	BDL	BDL	BDL
		Mean	**3.13±1.11**	**7.41±9.97**	**0.97±0.14**	**6.76±2.38**	**-**
Site 2	CO	0-20	0.97±0.06	3.03±0.33	BDL	BDL	BDL
		20-40	BDL	0.06±0.04	0.07±0.01	1.84±0.44	BDL
		40-60	2.47±0.15	9.82±0.29	0.48±0.03	BDL	BDL
		Mean	**1.72±1.06**	**4.30±5.00**	**0.28±0.29**	**-**	**-**
	CA	0-20	2.50±0.16	0.15±0.01	0.50±0.01	30.62±2.10	0.13±0.01
		20-40	0.53±0.05	34.56±1.09	BDL	20.81±2.15	BDL
		40-60	0.86±0.06	1.13±0.11	BDL	16.60±0.87	BDL
		Mean	**1.30±1.06**	**11.94±19.59**	**-**	**22.68±7.19**	**-**
	AH	0-20	2.62±0.28	48.67±3.84	2.70±3.04	0.07±0.01	0.01±0.00
		20-40	2.77±0.19	24.79±2.39	0.36±0.01	0.14±0.01	BDL
		40-60	0.19±0.03	15.16±1.16	BDL	0.12±0.12	BDL
		Mean	**1.86±1.45**	**29.54±17.25**	**1.53±1.65**	**0.11±0.04**	**-**
Global soils background value[a]			0.41	29	59.5	11.3	27
USEPA	2002		0.48	72			200

[a]Kabata-Pendias (2011)

Heavy metal concentration in soil

The mean concentrations of heavy metals in the vegetable farm soils are shown in Table 3. Soil heavy metal concentrations varied across the study sites. Mean Cd varied from 1.30±1.06 to 7.76±5.65 mg kg^{-1} in soil sample under *Celosia Argentea* and Ni ranged from 2.85±0.49 under *Celosia Argentea* to 29.54±17.25 mg kg^{-1} under *Amaranthus Hybridus*. Soil concentrations of Cr were 0.08±0.07 under *Celosia Argentea* to 1.53±1.65 mg kg^{-1} under *Amaranthus Hybridus*, while Co varied from 0.11±0.04 under *Amaranthus Hybridus* – 22.68±7.19 mg kg^{-1} under *Celosia Argentea*. The concentrations of Pb in the soils of this study were several orders lower than that previously reported more than a decade ago in these sites (Atayese *et al*., 2009). The low Pb concentrations observed in this study could be attributed to its affinity to the high organic carbon content of the soils, thereby reducing its availability in the soil environment. It has been previously reported that higher Pb content binds to organic matter thereby reducing it mobility and bioavailability in soils (Ahmadipour *et al*., 2014). Also, the presence of soil organic matter, especially the humic substances have been shown to increase the adsorption of Pb in soils (Ahmed *et al*., 2019).

The concentrations of Ni, Cr, and Co in the soil were well below the USEPA standards while the level of Cd exceeded both the global soils background value and USEPA standard at all sites (Table 3). Mean Cd concentrations in soils under the three vegetables were higher in site 1 than in site 2 in the study. The mean Cd concentrations were about 4 – 16 times higher than the USEPA recommended levels indicating these soils were contaminated with Cd. Additionally, concentration of Cd was several times higher that the global soils background (Kabata-Pendias, 2011). The high concentrations of Cd might be due to the proximity of the sites to the very busy highways. Previous studies have shown that soils of urban farming within close proximity to highways are enriched with Cd (Krailertrattanachai *et al*., 2019). The mean Cd concentrations in this study were higher than the mean Cd concentration in roadside agricultural soils in Thailand (Krailertrattanachai *et al*., 2019). Road traffic has been reported as a source of contamination of the soil with Cd (Szwalec *et al*., 2020). Vehicular emissions as a source of Cd is further corroborated by the study of Ipeaiyeda and Ogungbemi (2020), that revealed high Cd levels in surface soils of automobile workshops in Nigeria. It is important to note that Cd is relatively mobile in soil and has high plant–soil mobility. Thus, it can enter the human body through the food chain (Du *et al*., 2020; Zhang *et al*., 2021), leading to adverse effects on environmental and human health (Du *et al*., 2020). High Cd concentrations in agricultural soils should raise concerns for food safety (Chen *et al*., 2015). Therefore, the presence of higher Cd concentrations in these urban farm soil environment should be of major concern.

Furthermore, the result in this study is consistent with other studies that reported accumulation of heavy metals in soils within close proximity to roadsides (Chen *et al*., 2010; Krailertrattanachai *et al*., 2019). The heavy metal concentrations were higher at 0 – 20 m distance to road in about half (50.0%) of the soil samples across the study except where the concentrations were below detection limit. These findings are similar to Krailertrattanachai *et al*., (2019), who reported varying but higher concentrations of different heavy metals in roadside agricultural soils. Thus, this suggests that the concentrations of heavy metal soils in close to the roadside decreased with increasing distance from the road (Krailertrattanachai *et al*., 2019).

Pollution Indices

Contamination Factor

Values of the C_f are presented in Table 4. Mean C_f value of heavy metals in urban farm soils followed the order Cd > Co > Ni > Cr. Cadmium had the highest mean C_f value of 7.27. Alam *et al*. (2022), also reported Cd as the heavy metal with the highest C_f in tea garden soils in their study.

According to the contamination classification by Hakanson (1980), the C_f values of Cd in 67.0% of sampled soil revealed considerable contamination ($3 < C_f < 6$) while one-third of the sample sites were categorised as very high contamination by Cd ($C_f > 6$). Again, only a few of the sampled urban farm soils were moderately contaminated ($1 < C_f < 3$) with Ni and Co. However, the C_f values of Cr at all sampling sites revealed very low contamination ($C_f < 1$). Higher C_f values implied that the heavy metal originated from anthropogenic sources (Alam *et al*., 2022). The high C_f values of Cd in the soils of this study may be ascribed to vehicular emissions.

Degree of Contamination

The degree of contamination (C_d) values are presented in Table 4. The degree of contamination (C_d) values for heavy metals in Site 2 indicated low degree of contamination ($C_d < 6$). Whereas C_d values revealed moderate to considerable contamination of the urban farm soils in Site 1. Generally, the mean C_d value (8.344) of the urban farm soils indicated a moderate contamination degree. Wang *et al*., (2018), observed moderate degree of contamination in agricultural soils irrigated with swine manure and recommended continuous monitoring of such soils.

Pollution Load Index

The pollution load index (PLI) is used in the assessment of the total degree of heavy metal contamination (Dytłow and Górka-Kostrubiec, 2021). According to Wang *et al*. (2010), PLI can be classified into the following classes: no pollution (PLI<1), moderate pollution (1<PLI<2), heavy pollution (2<PLI<3), and extremely heavy pollution (3<PLI). In this study, the PLI values (Table 4) ranged from 0.14 to 1.37. Specifically, the PLI calculations indicated that most of these urban farm soils belong to the unpolluted class (<1), except in the soil under *Celosia argentea* (Site 2) where the PLl was 1.37 indicating moderate heavy metal pollution (Table 4). Although, the mean PLI calculated for these urban farm soils, presented a value of 0.42 which represents "no pollution", monitoring of these soils should be given due consideration to avoid risks. The PLI has been employed to assess the level of environmental contamination in order to undertake monitoring or remedial activities focused on improving soil quality (Hołtra and Zamorska-Wojdyła, 2020).

Geo-accumulation Index

The geo-accumulation index (I_{geo}) values for heavy metals in the urban farm soils are shown in Fig 1. This contamination indicator can evaluate

Table 4: Contamination factors ¬ (C_f), degree of contamination (C_d), and pollution load index (PLI) of the urban farm soils

Location	Vegetable farm	Pollution Indices					
		C_f				C_d	PLI
		Cd	Ni	Cr	Co		
Site 1	CO	5.146	0.178	0.007	1.671	7.002	0.322
	CA	18.927	0.098	0.001	-	19.026	0.138
	AH	7.634	0.256	0.016	0.598	8.504	0.371
Site 2	CO	4.195	0.148	0.005	-	4.348	0.146
	CA	3.171	0.412	-	2.007	5.590	1.374
	AH	4.537	1.019	0.026	0.010	5.591	0.184
Min		3.171	0.098	0.001	0.010	4.348	0.138
Max		18.927	1.019	0.026	2.007	19.026	1.374
Mean		7.268	0.352	0.011	1.071	8.344	0.423

individual levels of heavy metal pollution in soil (Alam *et al*., 2022). Generally, the I_{geo} values for heavy metals in the samples ranged from –10.12 to 3.66 in this study. Specifically, the I_{geo} values of Cd ranged from 1.08 to 3.66, indicating these soils were moderately polluted to heavily polluted with Cd. Among the heavy metals, Cd had the highest I_{geo} value (3.66), while the I_{geo} values for Ni and Cr were < 0 indicating an unpolluted condition. A similar study also reported Cd and Ni had the highest and lowest I_{geo} values in tea garden soils, respectively (Alam *et al*., 2022). However, it should be noted that the I_{geo} values for Cd in their study were much lower than in the present study. Vehicular emission is the likely source of Cd in this urban farm soils. Akinsete and Olatimehin (2023) reported traffic as the origin of high Cd concentrations in roadside soils in urban areas of Ibadan, Nigeria. Other studies have noted I_{geo} values < 0 for Cd in agricultural soils, indicating unpolluted with this metal in a study area far away from the road, which is less affected from automobile exhaust (Wang *et al*., 2018).

Potential Ecological Factor and Risk Index

The ecological risk index (E_r) has been used to evaluate the toxicity of heavy metals in soils (Santos-Francés *et al*., 2017). The results of potential ecological risk factor (Er) and ecological risk index (RI) are presented in Table 5. The Er value for Cd varied from 95.12 to 567.80 across the study, indicating considerable to very high ecological risk. Generally, Site 1 exhibited a high risk level with mean Er value of 317.07±179.89, compared to Site 2 that exhibited a considerable risk level with mean Er value of 119.02±17.41. The potential risk factor for individual metal in this urban farm soils revealed Cd as the highest and was in the order: Cd > Co > Ni > Cr. This shows that the major potential ecological risk of heavy metals in the urban farm soils was from Cd, while Ni, Cr and Co had low ecological risk (< 40) across the study sites. This is similar to the study of Alam *et al*. (2022), where it was observed that all the heavy metals except Cd have low ecological risk. Furthermore, other studies have reported similar pattern with Cd exhibiting the highest Er value compared to other metals in street dust (Zhang *et al*., 2013), sediment (Pobi *et al*., 2019) and roadside soils (Akinsete and Olatimehin, 2023). It is evident that Cd in these urban farm soils is a major threat to ecology as recently reported for tea garden soil (Alam *et al*., 2022). Soils contaminated by heavy metals can cause serious ecological risks and negatively impact human health (Santos-Francés *et al*., 2017).

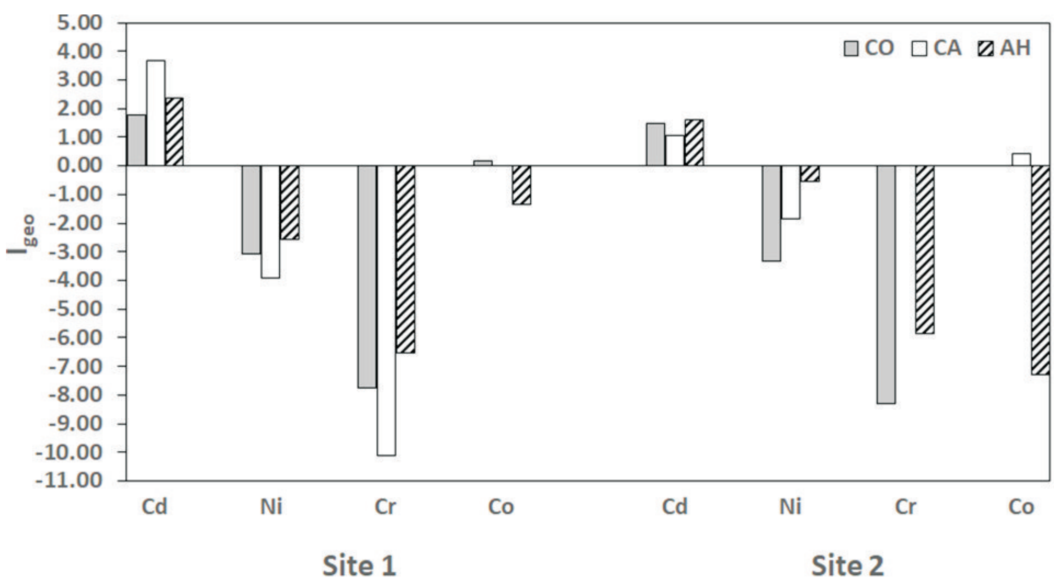

Figure 1: Geoaccumulation index (*I*geo) of heavy metals in the urban farm soils

Table 5: Potential ecological risk (Er) and risk index (RI) assessment of heavy metals in the urban farm soils

Location	Vegetable farm	Pollution Indices					
		E				RI	Risk Class
		Cd	Ni	Cr	Co		
Site 1	CO	154.39	0.89	0.01	8.35	163.65	Moderate
	CA	567.80	0.49	0.00	-	568.30	High
	AH	229.02	1.28	0.03	2.99	233.33	Moderate
	Mean	317.07±179.89	0.89±0.32	0.02±0.01	5.67±2.68	321.76±176.64	High
Site 2	CO	125.85	0.74	0.01	-	126.60	Low
	CA	95.12	2.06	-	10.04	107.22	Low
	AH	136.10	5.09	0.05	0.05	141.29	Low
	Mean	119.02±17.41	2.63±1.82	0.03±0.02	5.04±4.99	125.04±13.96	Low

The ecological risk index (RI) values which takes into account the various metals are shown in Table 5. The RI values can be classified as moderate to high for all soils in Site 1 but low for the soils in Site 2. More so, mean ecological risk index (RI) values were 321.76 ± 176.64 (Site 1) and 125.04 ± 13.96 (Site 2), and are classified as high and low ecological risk levels, respectively. This suggests that Site 1 of the study area is a threat to ecology as the RI values are considerably higher (Alam *et al*., 2022). It should be noted that Cd accounted for most of the total ecological risks, and contributed between 88.7% and 99.9% to the total RI across the study sites. Thus, Cd contributed significantly to the RI of these urban farm soils which can be attributed to the effect of anthropogenic activities, especially from vehicular emissions. Therefore, Cd is the heavy metal of greatest concern in the urban farm soils in this study.

Conclusion

The heavy metal concentrations and their degree of contamination of some urban farm soils in Lagos were investigated in this study. Among the heavy metals investigated, only cadmium exceeded both the global soils background value and USEPA limit, and this was amplified in Site 1. As a result, the high cadmium concentrations in these urban farm soils should raise concerns for food safety, particularly of *Celosia argentea*. Also, through the use of multiple pollution indices, the study evaluated the degree of heavy metal pollution in these urban farm soils. The results of the pollution indices clearly suggest that the degree of heavy metal contamination in the study area in terms of contamination factor decreased as follows: Cd > Co > Ni > Cr, and a large proportion of the soil samples revealed considerable to very high contamination by cadmium. Furthermore, while the pollution load index indicated that most of these urban farm soils belong to the unpolluted class, the geo-accumulation index indicated the soils were moderately polluted to heavily polluted with cadmium. Additionally, it was demonstrated that the major potential ecological risks of heavy metals in the urban farm soils was from cadmium. Generally, the soils portrayed high (Site 1) and low (Site 2) ecological risk index, implying that Site 1 of the study area is a threat to ecology and requires urgent attention. Overall, the findings in this study indicated that considerable attention should be given to reducing cadmium contamination in these urban farm soils. Moreover, the strategies to avoid mobility of cadmium from soil to other environmental media should be given substantial consideration by the appropriate agencies.

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