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Research article

Pollution status, health risk assessment of potentially toxic elements in soil and their uptake by *gongronema latifolium* in peri-urban of Ora-Eri, south-eastern Nigeria

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ABSTRACT

Pollution monitoring of potentially toxic elements (PTEs) in a typical peri-urban area in Ora-Eri, Nigeria has been unchecked. Thus, unified evaluation process was developed to assess the pollution load index and potential health risk to inhabitants in mapped regions. The environmental risk was evaluated using contamination factor, geo-accumulation index and Nemerow integrated index. The source of heavy metal pollution was identified by Pearson correlation statistics. Public health risk caused by intake of leafy vegetables and soil exposure were estimated in regard to location of the farmland. The soil was non-contaminated by lead (Pb), arsenic (As), selenium (Se) and chromium (Cr) but *gongronema latifolium* was contaminated with As exceeding WHO/FAO limit. The bioaccumulation of PTEs in the vegetable follows this order: Se > Pb > As > Cr. The retention of selenium in leaf is high because is an essential metalloid. The pollution status of the studied locations ranged from low to moderate. Arsenic is the main contributor to the ecological contamination. The potential hazard health risk ranged from 5.37E-03 to 2.75E-02 for adults and 5.40E-02 to 2.60E-01 for children. The cancer risk for adults (2.43E-06 to 1.24E-05) and children (8.75E-05 to 1.15E-04) exceeded the acceptable standard (1×10^{-6}) signifying gradual cancer effects. Therefore, the estimated hazard index and total cancer risk revealed that children are more prone to potential health risk than adults. Nevertheless, further continuous works should be carried out to monitor health risk in humans especially children and the control management policy of the peri-urban area should be adopted.

1. Introduction

Soils are usually contaminated by toxic elements either by natural sources such as bedrock weathering, volcanic eruption and atmospheric deposition (Meisam et al., 2021; Antoniadis et al., 2017) or through anthropogenic sources such as waste deposits, agricultural inputs (Umeh et al., 2020, 2021), industrial and urban emissions, metallurgical processes, mining activities (Ahmed and Jianhua, 2014), gasoline combustion exhausts and lubricating oil spills from auto-mobile workshops and petrol filling stations which in turn affects food quality and safety (Gebeyehu and Bayissa, 2020; Shaheen et al., 2019; Huang et al., 2018). Food is the major source of heavy metal intake by humans. Vegetables absorb trace elements and accumulate them in their parts at quantities high enough to cause health problems to both animals and humans, from plant consumption (Lere et al., 2021). Excessive concentration of metals beyond the maximum permissible limit can affect ground water, drinking wells, microorganism activities in the soil, plant growth and quality of food (Wang et al., 2020; Nganje et al., 2020; Antoniadis et al., 2019; Nduka and Umeh, 2021). Moreover, public health exposure to these toxic elements can lead to several nervous, cardiovascular, renal neurological impairment, bone diseases and several other health disorders (Ametepey et al., 2018). Vegetables are taken in both cooked and raw forms by human as an essential part of diet. Metals like cobalt, chromium, copper, iron, manganese, molybdenum, selenium and zinc when present in vegetables help in regulating human metabolism. Copper, zinc and iron are said to be essential elements for crop growth. However these

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micro-nutrients could be phytotoxic in higher concentrations. Being an essential element, at low doses selenium is an efficient anti-carcinogen, but induce carcinogenesis, cytotoxicity and genotoxicity at high doses (De Miguel et al., 2016). Selenium can be enriched in the agricultural soil due to human activities such as waste irrigation and application of selenium containing fertilizer (Huang et al., 2009). Manganese act as an activator and constituent of many enzymes present in human but lead, cadmium, arsenic and chromium can cause a series of chronic effects and can also damage the nervous and immune systems as well as have health detrimental effects such as lung cancer, kidney and liver dysfunction and bone fractures thereby contributing to decreased human life expectancy by 9–10 years within the affected areas (Jolly et al., 2013; Shaheen et al., 2020, Zafar et al., 2017). Cobalt, chromium and nickel are essential for humans but at concentrations higher than recommended may cause metabolic disorders (Jolly et al., 2013). Metal absorption by plants is dependent on multiple factors such as constituents of soils, capacity to exchange cations, organic matter, pH of soil, species of plant and its age (Zafar et al., 2017). In addition, agricultural soils are loose owing to continuous ploughing and can travel long distances as a result of wind. Therefore, farmers as well as the other residents and animals of the peri-urban areas are exposed to the heavy metal contaminated soils and plants through inhalation, ingestion and dermal ways (Iyama et al., 2022). Globally, several studies on toxic metals contamination and pollution on agricultural soils and plants as well as its ecological and health risk assessments have been reported in recent years (Ashraf et al., 2021; Gebeyehu and Bayissa, 2020; Zhang et al., 2018; Doabi et al., 2018; Mohammadi et al., 2022; Karimi et al., 2020). There is considerable health risk when the soil on which a plant is grown has high levels of traced metals (Shaheen et al., 2019).

Gongronema latifolium is a tropical rainforest plant primarily used as spice and vegetable in traditional folk medicine. It is commonly called 'utazi' and 'arokeke' in south eastern and south western parts of Nigeria respectively. It contains essential oils, saponins among others. It has anti-oxidative, anti-inflammatory and anti-bacterial properties. *Gongronema latifolium* leaves contain amino acids, fatty acids, potassium, sodium, calcium, phosphorus and cobalt (Eleyinmi, 2007).

In peri-urban area, Oraeri, agricultural soils from different farmlands are of different sources, contents and properties. The degree of contamination of the soils in the location by the potentially toxic elements and the associated human health risks are not well-studied. The farmlands are suspected to be contaminated but never previously investigated. This constitutes a knowledge gap that needs to be examined. Moreover, the PTEs have the potential of being incorporated into human food chain if in sufficient soil concentrations. This is proved by the fact that they have maximum oral reference dose limit beyond possible health risks. Anthropogenic activities potentially affecting the proposing farmlands through heavy metal contamination are the presence of a nearby dumpsite and a major roadside highway. In view of the above reports, the major aim of this study is to estimate some heavy metal accumulation in gongronema latifolium plant and soils on which the plant is grown in order to determine whether the plant is suitable for human consumption or not; to evaluate distribution source and the potential ecological risks via contamination factor (CF), geo-accumulation index (Igeo), and nemerow pollution index (P_N); and the health risks of the PTEs on mankind through inhalation, ingestion and dermal routes.

2. Materials and methods

2.1. Study area and sample collection

The selected study area is situated in Southeast Nigeria which lies between the mangrove forest and Guinea savanna (Figure 1). It is located at latitudes 04° 30′N and 07° 30′ N and Longitudes 06° 45′E and 08° 45′E.The average highest annual rainfall is about 1952mm, while the

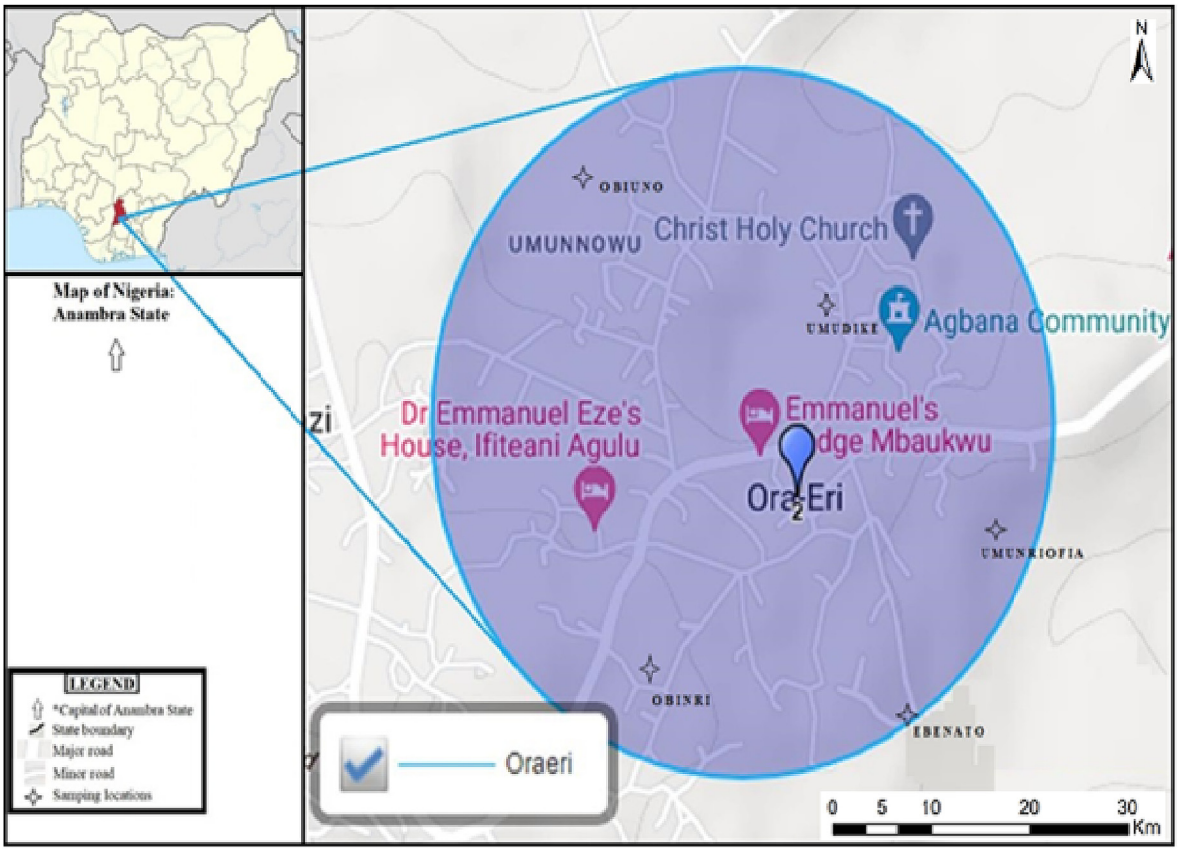

Figure 1. Map of sampling sites and study area.

mean daily temperature is 28 °C. Oraeri has a population of about 15000 persons as estimated by 2006 census in Nigeria. Five sites were selected for sampling; Obinri, Obiuno, Ebenator, Umunriofia and Umudike. The province encompassed by the study region includes mostly small villages and agricultural lands irrigated by groundwater. Significant food cultivated in this region is mainly cereal, legumes and vegetables. The peri-urban dwellers are farmers and petite business owners that survive on agricultural produce. *Gongronema latifolium* vegetable is a staple food that are mainly consumed and utilized by Nigerians as a result of its medicinal, economic and health benefits. Continual plant cultivation and harvesting can primarily induce toxic metallic and non-metallic substances in agricultural soil leading to their uptake by plants. The potential toxic metal emission secondary sources are traffic emissions, domestic wastes, and irrigated wastes.

Soil and leafy vegetable sampling were carried out on October, 2021. At each site, composite top soil samples of about 1kg by homogeneously mixing five subsamples at depth of 0–20 cm. Total of 35 soil samples were randomly collected with stainless steel auger. Similarly, 35 vegetable samples (*Gongronema latifolium)* of approximately 0.5kg were randomly collected from the studied locations. The soil and plant samples were packed into different polythene bags and transported to the laboratory until chemical analysis.

2.2. Chemical analysis

The soil samples were air-dried, ground and passed through 100-mesh sieve to remove debris. Edible plant samples were washed, oven-dried at 60 °C, ground and sieved by similar process. In the analysis, 1g of homogenized and powered soil and vegetable samples was acid digested with 3ml of 10M HNO_3, 9ml of 10M HCl and HF a in Teflon digestion vessel. The digested samples were added to each beaker and heated on electric hot plate at 180 °C for about 3 h, and allowed to cool at ambient temperature. The extracted clear sample solutions are transferred into 25 ml volumetric flask and diluted to brim with distilled water. Before the chemical analysis, the vessels used were decontaminated using 10% nitric acid solution and rinsed further with distilled water. All the solutions prepared were then immediately assayed for potential toxic elements using Atomic Absorption Spectroscopy (AAS 500F Model by PG instruments Ltd, UK) equipped with air/acetylene flame were used. Analytical grade reagents were used all through. The metal standards were prepared from their respective salts and used for the calibration curve for the elemental determination. The limit of detection (LOD) and the limit of quotation (LOQ) for the elements were calculated thrice the standard deviation for the digested blanks. Quality control measures for each batch, including calibration with reference samples, blanks, and replicate analysis, were followed throughout the analysis. **The accuracy and precision of PHEs analysis in agricultural soil were checked by analyzing a SRM 1570 standards (certified reference materials of the National Institute of Standards and Technology) for the respective potentially heavy metals in both soil and plant. The percentage recoveries of soil after spike analysis were within the range 89.8 - 96.70% (Cr = 89.8%, Pb = 92.1%, Se = 95%, and As = 96.70%) and average recovery of 93% for plant PTEs in reference, which indicates high accuracy of the analytical method for validation of the quality of assessment.**

2.3. Bioaccumulation factor (BAF)

The metal transfer from soil to plants and associated plant contamination can be identified Bio-accumulation factor indicator. BAF was calculated using Eq. (1) (Antoniadis et al., 2017; Zhang et al., 2018).

$$\mathrm{BAF} = \frac{C_{plant}}{C_{soil}} \tag{1}$$

C (mg/kg) is the potential toxic elements concentrations in plant and soil respectively.

2.4. Contamination factor

The contamination factor is a major tool for identifying the pollution and the contamination level in the environmental matrix. The level of contamination of agricultural soil by the heavy metal was expressed in terms of a contamination factor (CF) and determined by employing the model in Eq. (2) (Nganje et al., 2020):

$$\mathrm{CF} = \frac{\text{concentration of the metals in soil}}{\text{Target (background values)}} \tag{2}$$

Target or background values the geochemical baseline concentration of that metal in the soil (Alloway, 2010). The following contamination classes were used to define the contamination factor; $CF < 1$, low contamination; $1 \leq CF < 3$, moderate contamination; $3 \leq CF \leq 6$, considerable contamination and $CF > 6$, very high contamination.

2.5. Geo-accumulation index (I_{geo})

In this study, Igeo was used to identify degree of metal contamination of soil. The geo-accumulation index (Igeo) was calculated on the basis of Yuan et al. (2017) Eq. (3):

Table 1. Mean concentrations and bioaccumulation factor of traced elements.

Sample location	Quantity	Pb	Se	Cr	As
Obiuno	Soil	0.178 ± 0.001	0.365 ± 0.001	0.261 ± 0.00	2.935 ± 0.008
	Plant	0.101 ± 0.001	0.032 ± 0.001	ND	1.522 ± 0.005
	BAF	0.567	0.088	ND	0.519
Ebenator	Soil	0.186 ± 0.001	ND	0.023	2.609
	Plant	0.209 ± 0.00	0.778 ± 0.001	ND	ND
	BAF	1.124	ND	ND	ND
Umunriofia	Soil	0.221 ± 0.001	0.159 ± 0.002	0.194 ± 0.00	6.348 ± 0.01
	Plant	0.14 ± 0.001	1.318 ± 0.002	0.027 ± 0.001	3.13 ± 0.002
	BAF	0.633	8.289	0.139	0.493
Obinri	Soil	0.268 ± 0.001	0.143 ± 0.00	0.55 ± 0.00	7.609 ± 0.003
	Plant	0.078 ± 0.001	0.841 ± 0.007	0.144 ± 0.00	2.13 ± 0.006
	BAF	0.291	5.881	0.262	0.28
Umudike	Soil	0.291 ± 0.00	0.333 ± 0.002	0.306 ± 0.00	6.5 ± 0.005
	Plant	0.023 ± 0.00	1.302 ± 0.001	0.144 ± 0.00	7.044 ± 0.001
	BAF	0.079	3.91	0.471	1.084

$$\text{Igeo} = \log 2 \frac{\text{Cn}}{1.5\text{Bn}} \quad (3)$$

Where Cn is the measured metal concentrations in the examined sample; Bn is the geochemical background (Alloway, 2010) while the factor 1.5 is introduced to minimize the effect of possible variations in the background or control values which may be attributed to lithological variations (Al-Wabel et al., 2017). Seven contamination classes are used to define the degree of pollution intensity based on the increasing value of the index of geo-accumulation as follows: Igeo <0 uncontaminated; 0 ≤ Igeo <1 uncontaminated to moderately contaminated; 1 ≤ Igeo <2 moderately contaminated; 2 ≤ Igeo <3 moderately to strongly contaminated; 3 ≤ Igeo <4 strongly contaminated; 4 ≤ Igeo <5 strongly to extremely contaminated; Igeo >5 extremely contaminated (Al- Wabel et al., 2017).

2.6. Nemerow pollution index

The widespread effects of toxic contaminants and its interpretation at a particular water environment are revealed using Nemerow pollution index. The equation for calculating Nemerow pollution index (P_N) is as follows (Huiying *et al.*, 2019):

$$P_N = \sqrt{\frac{\overline{C_f}^2 + C_{fmax}^2}{2}} \quad (4)$$

P_N is the Nemerow pollution index, C_f the arithmetic mean of contamination factor of all traced elements, and C_{fmax} the maximum contamination factor among the metals. The P_N Nemerow index can be grouped into these classes: $P_N < 1$ (unpolluted); $1 < P_N \leq 2$ (slightly polluted); $2 < P_N \leq 3$ (moderately polluted); $P_N > 3$ (highly polluted) (Huiying *et al.*, 2019).

2.7. Health risk assessment

PTEs contaminations in soil and plant can pose severe health impact to humans and environment. Again, the proximity of the metals sources to the local population became a health threat. Therefore, it is important to access the extent of risk to the potential recipient. Non-carcinogenic and carcinogenic risk assessment of toxic element contaminations in soil and vegetable were evaluated according to United States Environmental Protection Agency theory (USEPA, 2000, 2001, 2011). Average daily dose (ADD) (mg/kg/day) of PTEs in soil and plant through ingestion, inhalation and dermal pathways was determined using Eqs. (5), (6), (7), and (8) (Huang et al., 2018; Agyeman et al., 2021):

$$\text{ADDplant} = \left(\frac{\text{Cplant} \times \text{IRplant} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}}\right) \quad (5)$$

$$\text{ADDing} = \left(\frac{\text{Csoil} \times \text{IRing} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}}\right) \quad (6)$$

$$\text{ADDinh} = \left(\frac{\text{Csoil} \times \text{IRinh} \times \text{EF} \times \text{ED}}{\text{PEF} \times \text{BW} \times \text{AT}}\right) \quad (7)$$

$$\text{ADDder} = \left(\frac{\text{Csoil} \times \text{SA} \times \text{AF} \times \text{DAF} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}}\right) \quad (8)$$

C_{plant} and C_{soil} are the concentrations of the metal toxicant in soil and plant (mg/kg); IR_{plant} and IR_{soil} are the ingestion rate (100 mg/day for adult and 200 mg/day for children); EF is the exposure frequency of the people (day/year); ED is the exposure duration (years); CF is the conversion factor in kg/mg, IR_{inh} is the inhalation rate of soil (20 m^3/day for adult and 10 m^3/day for children); PEF is the particulate emission factors (1.36×10^9 m^3/kg for both age groups); SA is the skin surface area (cm^2); AF is the skin adherence factor (0.7 mg/cm^2 for adult and 0.2 mg/cm^2 for children); DAF is the dermal absorption factor (0.1 for both age groups); BW and AT are the body weight (kg) and average exposed time (years), respectively.

Hazard quotient and hazard index can be computed as shown in Eq. (9) (De Miguel et al., 2016; Antoniadis et al., 2017)

$$\text{HI} = \sum HQ_{ij} = \sum \frac{ADD_{ij}}{RfD_i} \quad (9)$$

Where *i* is the number of exposure pathways, *j* is the number of PTEs. RfD is the reference dose of each traced element (De Miguel et al., 2016; Antoniadis et al., 2017).

If the value of HI < 1, there will be no non-carcinogenic health risk whereas if HI > 1, it is assumed to be an occurrence of adverse non-carcinogenic health risk.

The incremental tendency of an individual developing cancer over prolonged through exposure to the potential carcinogen can be assessed by cancer risk. Carcinogenic risk is computed using the following equation (Meisam et al., 2021; Wang et al., 2020):

$$\text{CR} = ADD \times SF \quad (10)$$

SF is the standard slope factor of individual metals (Ashraf et al., 2021). Cancer risk (CR) < 1×10^{-6} shows negligible carcinogenic risk, while 1×10^{-6} < CR < 1×10^{-4} and CR > 1×10^{-4} indicate tolerable risk and lifetime cancer risk to the human body (Meisam et al., 2021; Wang et al., 2020).

2.8. Statistical analysis

In this study, statistical analysis was performed for the experimental data for PTEs using IBM statistical package, SPSS (version 26) and Microsoft excel 2010 package. Heavy metal data were presented in replicates.

3. Results and discussion

3.1. The heavy metal concentrations in soil and leaf

The mean concentrations of **PTEs** in the sub-soil appear in the following order: As > Se > Cr > Pb for Obiuno and Umudike communities; As > Pb > Cr > Se for Ebenator and Umunriofia and Obinri recorded the rate of accumulation of metals in soil in the order of As > Cr > Pb > Se as shown in Table 1. In all indications, arsenic metal has the highest content in all the studied agricultural soil which can be traced to additional application of pesticide control and fertilizers in the soil. Umunriofia, Obinri and Umudike presented higher metals concentrations because of their proximity to dumpsite and major road sides. Nevertheless, the studied PTEs contents were below the permissible limit (WHO, 1993). The mean concentrations of Pb (0.178–0.291 mg/kg), Cr (0.023–0.550 mg/kg) and As (2.609–7.609 mg/kg) in the agricultural soils were found to be lower than that reported by Ashraf et al. (2021), Gebeyehu and Bayissa (2020). The range mean values of Se (0–0.365 mg/kg) content in the agricultural soils are inconsistent with Meisam et al. (2021), Zafar et al. (2017), Shaheen et al. (2020). The values of Se and As are lower than that reported by De Miguel et al. (2016) in agricultural soil. The findings of this current study depict that the level of heavy toxicity to the soil are at minimum at the moment irrespective of the farmland locations.

This study revealed that metal concentrations in the *gongronema latifolium* vegetable collected from different farmlands are less than the permissible level (WHO/FAO, 2007) except Arsenic (0.5 mg/kg). This is a clear indication that the leaf samples accumulate arsenic metal in significant quantity compared to other studied PTEs. Lead and Arsenic are the metals that induce toxic effects in the biochemical organs such as kidney, liver, spleen and lungs. Short-term intake of As and long-term consumption of Pb in the vegetable can severely pose health risk to the consumers. Gebeyehu and Bayissa, 2020 recorded the mean arsenic

concentrations of 1.93 and 5.73 mg/kg in tomato and cabbage samples. Similar research report was presented by Ametepey et al. (2018), Lente et al. (2012), Suruchi and Pankaj (2011) for Cr concentrations in vegetables. On the contrary, studies carried out in Ghana reported mean Pb content at the range of 5.59–10.51 mg/kg (Lente et al., 2012) and in Cao et al. (2014) depicted 2.652 mg/kg of Pb in vegetables. All the PTEs analyzed in the leafy vegetable were lower in content than the respective soil except selenium because it is among the essential elements found in vegetables which improve fertility and body immune system. The selenium ion is a metalloid that is deprotonated in soil solution during adsorption process thereby creating its absorption in plant.

3.2. Bioaccumulation factor

The diffusion of metallic ions from soil solution to the edible leafy plant serves as the main route for distribution of potentially toxic metals to the food chain (Sharma et al., 2018; Naser et al., 2012). The translocation and rate of accumulation of traced metals in leafy vegetables is dependent on the geological factor, physicochemical parameters of the agricultural, proximity to anthropogenic activities and plant species. The transferability of metals from soil to *gongronema latifolium* leaves has been estimated which is shown in Table 1 and percentage total accumulation of the studied metals in individual farmland is presented in Figure 2 as well. The overall bioaccumulation factor for Pb, Se, Cr and As is prominent in this order Umunriofia > Obinri > Umudike > Obiuno > Ebenator. The BAF of Se recorded for Umunriofia, Obinri and Umudike exceeded unity which shows that the agricultural soil is not the only source of selenium metal rather other sources inclusive. The uptake of these **PTEs** by *gongronema latifolium* depends on its concentration in the cultivated soil and properties of soil such as pH, texture, organic content, cation exchange capacity and soil conductivity. High values of BAF indicate low retention capacity of the soil (Iyama et al., 2022; Kumar et al., 2009). BAF that is above unity indicates hyper-accumulation (Eze and Ekenem, 2014), but values of 0.1 showed exclusion of toxic metals from plant tissues whereas values of 0.2 proved soil traced metals contaminations by anthropogenic processes (Khan et al., 2009). The BAF values obtained in this study showed high accumulation of toxicants in the leaves which signifying poor affinity of metal and metalloid to the soil colloids (Ogundele et al., 2019; Wang et al., 2012). The **PTEs** buildup in vegetable in five communities followed the order: Se > Pb > As > Cr. Moreover, Se is plant essential metalloid and most plants have the tendency to retain it.

3.3. Basic descriptive statistics

The basic descriptive experimental data of PTEs in agricultural soil are shown in Table 2. The statistical parameters showed that the mean concentrations differ from each other which depicts that the metals are not uniformly distributed among the examined samples. The frequency distribution histogram of PTEs is shown in Figure 3. The histogram plots revealed that Pb, Se and Cr exhibited bell-shaped distribution while As showed multi-modal structure. The non-bell-shaped nature of As implies non-dispersion of the metal in soil solution as a result of its complexity in

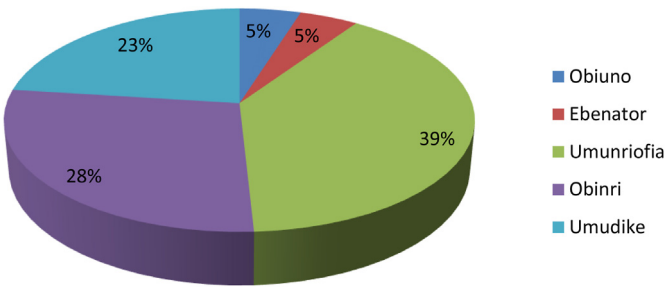

Figure 2. Total percentage distribution of BAF of studied HMs in soil locations.

Table 2. Descriptive statistics of PTEs concentration in agricultural soil of Ora-Eri

Statistics	Pb	Se	Cr	As
Minimum	0.178	0.000	0.023	2.609
Maximum	0.291	0.365	0.550	7.609
Mean	0.229	0.200	0.267	5.200
Std. Deviation	0.050	0.150	0.191	2.272
Variance	0.002	0.022	0.037	5.164
Skewness	0.309	-0.174	0.469	-0.403
Kurtosis	-2.395	-1.391	1.313	-2.859
Range	0.113	0.365	0.527	5.000

the domain ecosystem. Skewness is a degree of uneven description of asymmetric possibility of random variables. The skewness is zero for normal symmetric distribution round the mean. Again, kurtosis is a measure of relatively high or low distribution in comparison to normal distribution (Ugbede et al., 2020; SureshGandhi et al., 2014). From the tabulated data, it was noted that Pb and Cr were positively skewed while As and Se were negatively skewed. Pb and Cr showed low asymmetric nature. From all indications, there was no recorded symmetric of zero shewness for the analyzed metals which further suggest non-dominance of any of the metals. A positive kurtosis was denoted for Cr which depicts high or peak distribution whereas Pb, As and Se showed negative kurtosis indicating low or flat distribution.

3.4. Pearson correlation

The correlation coefficients were carried out by testing Pearson correlation statistics on pairs of elemental contaminants (Table 3). The reason was to explicate the mutual relationship and the link among the paired variables. Correlation coefficient values greater than ±0.5 are considered significant. As/Pb (R = 0.868), As/Cr (R = 0.744) and Cr/Pb (R = 0.653) pairs were significant while others are insignificant due to their weak correlation. The positive correlation coefficient suggested that As/Pb, As/Cr and Cr/Pb they are emanated from similar polluting sources. Hence, the PTEs were considered to have anthropogenic sources such as dumpsite, farmland and roadside automobile.

3.5. Soil pollution assessment

The outcome of contamination factor for the sub-soils in agricultural locations showed that the soils are low contaminated ($Cf < 1$) to moderately contaminated ($1 \leq Cf \leq 3$) with **PTEs** (Figure 4). The Cf ranged from 0 – 0.01 for Pb and Cr, 0–0.52 for Se and 0.56–1.62 for As. Arsenic is the highest contributor to the contamination in all the studied locations. Arsenic in the soil can be traced to anthropogenic emissions such as pesticides and wood preservative chemicals. Geo-accumulation values (Figure 5) depicts that the contaminated soil sample areas are practically unpolluted ($I_{geo} \leq 0$). The values of I_{geo} varied from -2.32 to -2.11 for Pb, -0.87 to 0 for Se, -2.51 to -2.06 for Cr and -0.43 to 0.03 for As in the sampled soil communities. The results (Figure 6) of Nemerow pollution index showed that the assessment level of terrestrial ecosystem ranged from unpolluted ($P_N < 1$) to slightly polluted ($1 \leq P_N < 2.5$). Sub-soils at Obiuno and Ebenator communities are unpolluted with these traced elements whereas Umunriofia, Obinri and Umudike are slightly polluted because they are situated close to major express road and dumpsite. Nemerow index is an incorporated approach for evaluation of pollutants in study locations as it takes inputs from other pollution indicators. Nevertheless, the assessed soil environments are safe for agricultural purposes at the moment should be monitored within long-term exposure.

3.6. Health risk assessment

Health risk assessment carried out in this present study was based on soil/vegetable-to-human exposure pathway via ingestion, inhalation and

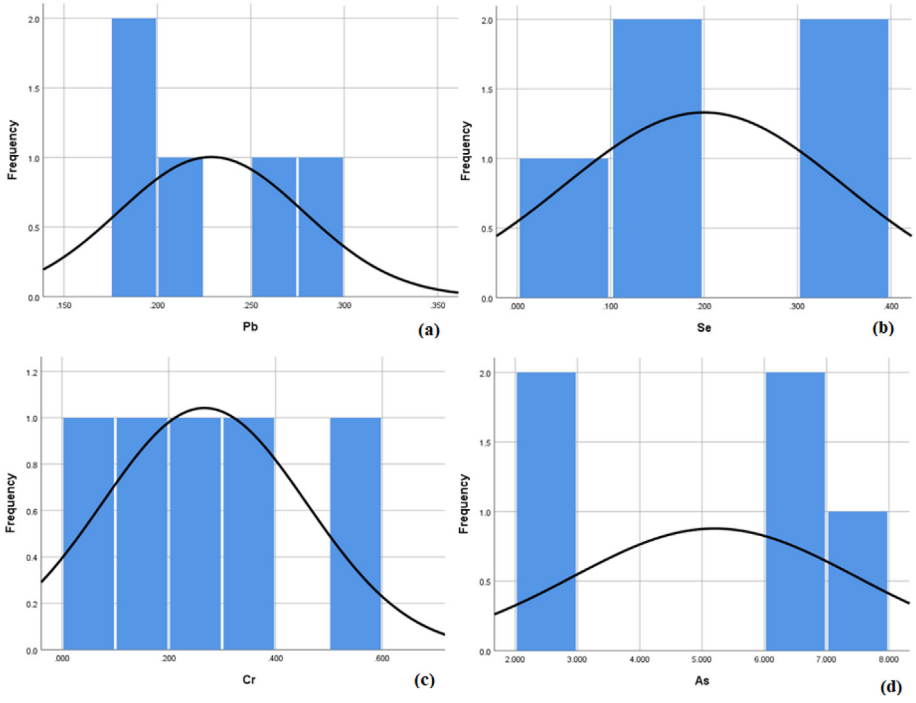

Figure 3. Frequency distribution histogram of traced elemental contents in peri-urban area.

Table 3. Correlation coefficient of toxic elements in soil samples.

	Pb	Se	Cr	As
Pb	1	0.219	0.653	.868*
Se	0.219	1	0.347	0.098
Cr	0.653	0.347	1	0.744
As	.868*	0.098	0.744	1

* correlation is significant at the 0.05 level.

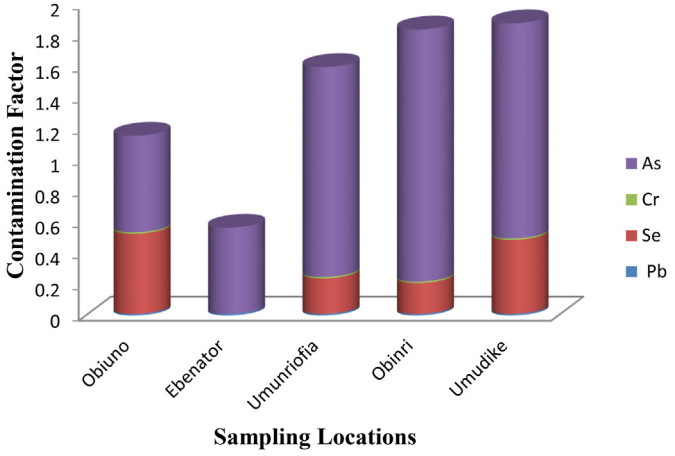

Figure 4. Contamination factor of PTEs from different agricultural soils.

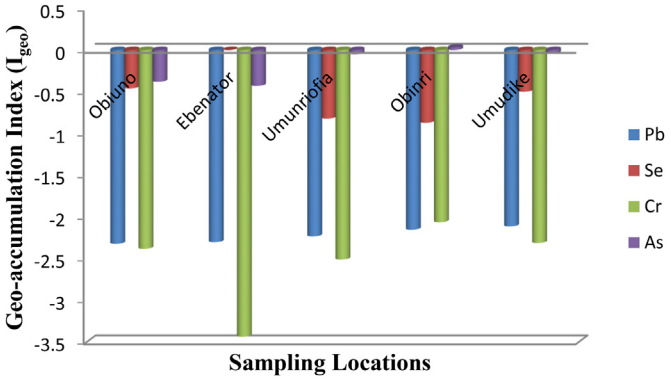

Figure 5. Geo-accumulation index of PTEs from different agricultural soils.

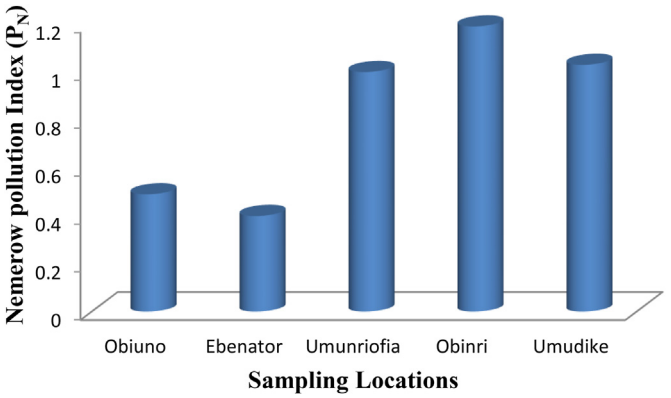

Figure 6. Nemerow pollution index of PTEs from different agricultural soils.

dermal contact. Calculated average daily dose (ADD) of different exposure route for group of populations are presented in Table 4 while further estimation to hazard quotient, hazard indices and cancer risk for Pb, Se, Cr and As are shown in Table 5. Ingestion of agricultural soil adhered to vegetables happened to be the main exposure pathway for Pb, Se, Cr and As to children and Adult followed by dermal and then inhalation routes for soil. Similar study was observed for ingestion of Cr and Pb of agricultural soil by Doabi et al. (2018) and Dehghani et al. (2017). There is more contribution of As to human exposure through soil ingestion followed by plant ingestion, dermal and then inhalation route. The

Table 4. Average daily dose (ADD) values for toxic metals with exposure route.

Sample location	Population	Exposure route	Pb	Se	Cr	As
Obiuno	Adult	Soil ingestion	1.07E-07	2.19E-07	1.56E-07	1.76E-06
		Inhalation	3.14E-11	6.43E-11	4.6E-11	5.17E-10
		Dermal	5.9E-10	1.21E-09	8.65E-10	9.73E-09
		Plant ingestion	6.05E-08	1.92E-08	0	9.12E-07
	Children	Soil ingestion	9.18E-07	1.88E-06	1.35E-06	1.51E-05
		Inhalation	5.13E-11	1.05E-10	7.52E-11	8.46E-10
		Dermal	1.49E-07	3.05E-07	2.18E-07	2.45E-06
		Plant ingestion	5.20E-07	1.65E-07	0	7.85E-06
Ebenator	Adult	Soil ingestion	1.11E-07	0	1.38E-08	1.56E-06
		Inhalation	3.28E-11	0	4.05E-12	4.6E-10
		Dermal	6.16E-10	0	7.62E-11	8.65E-09
		Plant ingestion	1.25E-07	4.66E-07	0	0
	Children	Soil ingestion	9.59E-07	0	1.19E-07	1.35E-05
		Inhalation	5.36E-11	0	6.63E-12	7.52E-10
		Dermal	1.55E-07	0	1.92E-08	2.18E-06
		Plant ingestion	1.08E-06	4.01E-06	0	0
Umunriofia	Adult	Soil ingestion	1.32E-07	9.53E-08	1.16E-07	3.8E-06
		Inhalation	3.9E-11	2.8E-11	3.42E-11	1.12E-09
		Dermal	7.32E-10	5.27E-10	6.43E-10	2.1E-08
		Plant ingestion	8.39E-08	7.90E-07	1.62E-08	1.88E-06
	Children	Soil ingestion	1.14E-06	8.2E-07	1E-06	3.27E-05
		Inhalation	6.37E-11	4.58E-11	5.59E-11	1.83E-09
		Dermal	1.85E-07	1.33E-07	1.62E-07	5.3E-06
		Plant ingestion	7.22E-07	6.79E-06	1.39E-07	1.61E-05
Obinri	Adult	Soil ingestion	1.61E-07	8.57E-08	3.3E-07	4.56E-06
		Inhalation	4.72E-11	2.52E-11	9.69E-11	1.34E-09
		Dermal	8.88E-10	4.74E-10	1.82E-09	2.52E-08
		Plant ingestion	4.67E-08	5.04E-07	8.63E-08	1.28E-06
	Children	Soil ingestion	1.38E-06	7.37E-07	2.84E-06	3.92E-05
		Inhalation	7.72E-11	4.12E-11	1.58E-10	2.19E-09
		Dermal	2.24E-07	1.19E-07	4.59E-07	6.35E-06
		Plant ingestion	4.02E-07	4.34E-06	7.42E-07	1.10E-05
Umudike	Adult	Soil ingestion	1.74E-07	2E-07	1.83E-07	3.9E-06
		Inhalation	5.13E-11	5.87E-11	5.39E-11	1.15E-09
		Dermal	9.64E-10	1.1E-09	1.01E-09	2.15E-08
		Plant ingestion	1.38E-08	7.80E-07	8.63E-08	4.22E-06
	Children	Soil ingestion	1.5E-06	1.72E-06	1.58E-06	3.35E-05
		Inhalation	8.38E-11	9.59E-11	8.82E-11	1.87E-09
		Dermal	2.43E-07	2.78E-07	2.55E-07	5.43E-06
		Plant ingestion	1.19E-07	6.72E-06	7.42E-07	3.63E-05

average daily dose of the PTEs calculated in both plant and soil from different communities follow the trend: As > Se > Pb > Cr. The absorption of contaminants is more pronounced in children than in adults because of the morphology of their body system.

The hazard quotient (HQ) and hazard index (HI) for both soil and leaf are shown in Table 5. The total hazard index across the study stations ranged from 5.37E-03 to 2.75E-02 for adults and 5.40E-02 to 2.60E-01 for children. This indicates non risk from non-carcinogenic effects (HI < 1) for short period of time. The HI obtained for vegetable is contrary to Iyama et al. (2022) but similar to Isiuku and Enyoh (2020) and Xue et al. (2012) reports on assessment of toxic metals in vegetables. Long exposure of these pollutants to populace especially in children can cause severe harm if not controlled. The highest contribution as regards to exposure pathway is ingestion of soil particles accounting for greater percentage of total risk followed by ingestion of vegetables and dermal absorption. Ingestion of soil is expected to be the primary exposure route of these elements than plant in outdoor settings because plant takes up lesser amount of metals from detected quantity in soil (Abdelhafez et al., 2012; Registry and Health, 2012; Ahmed and Jianhua, 2014). Exposure of PTEs through inhalation of suspended particles has insignificant effect on individual. Arsenic is the main contributor to hazard index in terms of non-carcinogenic toxicity which is consistent with De Miguel et al. (2007) and De Miguel et al. (2016) findings. The highest total HI was found in children at Umudike community while the least total HI was found in Adults at Ebenator community. Children are susceptible to more hazard index than adults as a result of higher soil and food intake particularly through incessant hand-to- mouth activity and their tendency to play on soil. Warming et al. (2015) reported that the hazard quotient of As is less than unity for both children and adults with tremendous exposure emanating from soil ingestion yet indicating non-pose of risk to human health by the garden soil elements.

Cancer disease in humans can be increased by prolonged exposure of the toxic metals (Pb, Cd, Cr and Ni) even at low concentrations (IARC 2011; Cao et al., 2014). Thus, the risk exposure of inhabitants was estimated based on the ADD values of aforementioned carcinogens. The carcinogenic risk (CR) values of studied PTEs in soil and *gongronema latifolium* (Pb, Se, Cr and As) are presented in Table 5. Arsenic present in soil is the major contributor to the total CR values which is in line with

Table 5. Risk characterization for adults and children in peri-urban area.

Sample location	Exposure route	HQ	Children	Total HI	Children	CR	Children	TCR	TCR
		Adults		Adults		Adults		Adults	Children
Obiuno	Soil Ingestion	5.97E-03	5.13E-02	9.10E-03	9.02E-02	2.75E-06	2.36E-05	4.15E-06	3.94E-05
	Inhalation	3.61E-05	5.91E-05			8.08E-10	1.32E-09		
	Dermal	5.01E-05	1.26E-02			1.52E-08	3.83E-06		
	Plant ingestion	3.05E-03	2.62E-02			1.39E-06	1.19E-05		
Ebenator	Soil Ingestion	5.21E-03	4.49E-02			2.38E-06	2.05E-05		
	Inhalation	3.09E-05	5.04E-05	5.37E-03	5.40E-02	7.01E-10	1.15E-09	2.43E-06	2.41E-05
	Dermal	3.28E-05	8.25E-03			1.32E-08	3.32E-06		
	Plant ingestion	9.68E-05	8.33E-04			3.51E-08	3.02E-07		
Umunriofia	Soil Ingestion	1.28E-02	1.10E-01			5.80E-06	4.99E-05		
	Inhalation	7.59E-05	1.24E-04	1.93E-02	1.87E-01	1.71E-09	2.79E-09	8.69E-06	8.25E-05
	Dermal	8.60E-05	2.17E-02			3.21E-08	8.08E-06		
	Plant ingestion	6.42E-03	5.52E-02			2.85E-06	2.45E-05		
Obinri	Soil Ingestion	1.53E-02	1.32E-01			7.05E-06	6.06E-05		
	Inhalation	9.27E-05	1.52E-04	1.99E-02	2.00E-01	2.07E-09	3.39E-09	9.06E-06	8.75E-05
	Dermal	1.21E-04	3.04E-02			3.90E-08	9.82E-06		
	Plant ingestion	4.39E-03	3.77E-02			1.97E-06	1.70E-05		
Umudike	Soil Ingestion	1.31E-02	1.13E-01			5.98E-06	5.15E-05		
	Inhalation	7.86E-05	1.28E-04	2.75E-02	2.60E-01	1.76E-09	2.88E-09	1.24E-05	1.15E-04
	Dermal	9.44E-05	2.38E-02			3.31E-08	8.34E-06		
	Plant ingestion	1.43E-02	1.23E-01			6.38E-06	5.48E-05		

results of Han et al. (2018) and Huiying et al. (2019). The total CR for adults ranged from 2.43E-06 to 1.24E-05 for the peri-urban communities while total CR for children ranged from 8.75E-05 to 1.15E-04, all exceeded the acceptable limit (1×10^{-6}) (MEPPRC 2014). Children were observed to have greater risk of developing cancer than adults which opposite of results obtained by Zafar et al. (2017). Arsenic in soil and vegetable has higher chance of cancer risk in children than other studied metals. Also, the results obtained in the present study showed that there is possibility of cancer risk emanating from impact of potentially toxic elements in soil and *gongronema latifolium* through oral pathway. The influence of anthropogenic activities has subsequently been posing a potential threat to human health and terrestrial environment. Therefore, there should be continuous monitoring of heavy metal status in agricultural soil to ensure environmental safety. Again, the distribution of these pollutants across the soil fractions must be put into consideration for risk evaluation.

4. Conclusion

This study observed that the mean concentration of PTEs in soil and *gongronema latifolium* were lower than the WHO permissible limits. Although, the mean concentration of As in the vegetable are above the recommended standard value. The bioaccumulation factor from soil to plant was significant in some communities at Oraeri province which indicate poor adsorption capacity of the soil. The ecological risk of the toxic elements was moderate. The non-carcinogenic risk for both age groups was below the safety level. The total cancinogenic health risk of Pb, Cr, and As in all the communities exceeded the acceptable level (1×10^{-6}). Once more, the total cancer risk is more pronounced in children than in adult through oral pathway. At present, the health effect is minimal but continuous exposure of these PTEs more especially As to the local residents will pose serious health challenge.

Declarations

Author contribution statement

Ebuka Chidiebere Mmaduakor: Conceived and designed the experiments.

Chisom Theresa Umeh: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Joy Ebele Morah & Azubuike Amos Ekwuofu: Contributed reagents, materials, analysis tools or data.

Daniel Omeodisemi Omokpariola: Analyzed and interpreted the data.

Somto Stephen Onwuegbuokwu: Wrote the paper; Performed the experiments.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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