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Research Article

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Human health risk assessment of potential toxic elements in paddy soil and rice (*Oryza sativa*) from Ugbawka fields, Enugu, Nigeria

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Abstract: The potential toxic elements (Cu, Zn, Pb, Ni, Fe, Cr, Cd, Mn and Hg) were accumulated from rice grains and soil from an Ugbawka farm, Enugu State, Nigeria, which were determined to evaluate the potential health risk to rice consumers. The mean levels of metals found in soil (mg/kg) were as follows: Ni (0.57±0.24), Pb (2.44±0.17), Zn (3.35±2.05), Cu (0.71±0.33), Mn (37.72±10.97), Fe (13 856.6±31.43), Cr (2.51±0.98), Cd (0.51±1.36), and Hg (0.02±0.38); however metals found in rice grains (mg/kg) were: Ni (0.81±0.72), Pb (0.94±0.70), Zn (8.22±2.97), Cu (0.59±0.42), Mn (13.30±4.56), Fe (13.28±0.73), Cr (15.00±10.00), Cd (0.36±0.07), and Hg (0.002±0.23). A small percentage (2.5%) of the soil samples were above the Chinese Maximum Allowable Concentration for cadmium in soil while cadmium and lead levels in the rice grains were above WHO permissible limit. Pearson's correlations showed significant correlations amongst some metal pairs in soil and grains showing similarity in origin. The estimated daily intake of Pb was higher than the safety levels given by JECFA. Hazard Quotient for Pb and Total Hazard Index of all the metals were above one. This indicates possible potential health risk and adverse effect resulting from consumption of rice from Ugbawka farm.

Keywords: Potential toxic elements; Rice; Soil; Hazard Quotient; Total Hazard Index.

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1 Introduction

Contamination of agricultural soil and farm crops by potential toxic elements as a result of rapid industrialization has become a topic of great concern to the public as well as policy makers. This is due to food safety issues and potential health risks cause by toxic elements as they have detrimental effects on soils' ecosystems [1]. Although, potential toxic elements (PTEs) occur naturally in the earth crust and they tend to concentrate more in agricultural soil because of regular and indiscriminate applications of commercial fertilizers, herbicides, pesticides, biosolids, sewage sludge, smelting, refining and burning of fossil fuel, mining etc., which contains these PTEs in large proportions [2]. Soil is the most important reservoir of PTEs in the terrestrial ecosystem and the concentrations of PTEs in soils is an indicator of pollution status of the environment [3]. Exposure to PTEs is not limited only to the ingestion or inhalation of contaminated particles, but also, the ingestion of plants grown in the contaminated soil.

Potential toxic elements pose serious environmental problems, limit plant productivity and threaten human health [4]. These PTEs enter the food chain due to uptake and accumulation by crops. Some of these PTEs (Zn, Mn, Cu, Ni, Cr, and Fe) are micronutrient and are required in small concentrations by both plants and animals. They are essential in rice plant growth and development. These essential PTEs play biochemical and physiological functions in plants and animals by helping in redox reaction, and participating directly on being an integral part of several enzymes [5]. Zinc deficiency in soil causes stunted growth of crop plants like rice and reduces its overall productivity [6]. However, when these essentials elements exceed the recommended limit in food and plants, they become toxic and harmful to man and animals at high levels of exposure [7]. PTEs like cadmium, lead and mercury are xenobiotics with no biological

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importance. Lead, mercury and cadmium are potential carcinogens and are associated with diseases such as brain damage, cardiovascular, kidney, blood, nervous, and bone diseases [8].

Studies have shown that PTEs concentrations in rice are closely associated with their levels in soils [9]. The evaluation of metal uptake by crops from soils is vital for human risk assessment models [10]. The estimated daily intake rates can be predicted from ingestion, inhalation and dermal contact of these PTEs from different media such as soil, drinking water, ambient air and food [11]. The hazard quotient (HQ) established by the US Environmental Protection Agency [12] has been widely used to evaluate potential health risk associated with long term exposure to metals in different media.

Nigeria is the second largest importer of rice in the world, buying at least two million metric tons per year from exporting countries like China and Thailand [13]. Nigeria is ranked the highest producer and consumer of rice in the West African region [13]. An average Nigerian consumes 24.8 kg/year of rice representing 9 % of the annual calorie intake [14]. Consumption of rice contaminated with PTEs can result to negative health impact. In China and Japan, reports have shown that human renal dysfunction is connected to contamination of rice with Cd [15]. Potential toxic elements such as Cd, Cr, Ni and Hg released from mining, industrial and waste effluent are common pollutant of arable soil [16]. Zhao et al. [17] reported that 99 % of paddy soil samples from Nanxun county off South east China, had Cd levels exceeding the natural background value indicating widespread Cd contamination in the local soils.

In view of this concern for food safety, this study assessed the concentrations of Pb, Cd, Zn, Cr, Fe, Mn, Cu, Hg, and Ni in rice grains and soil cultivated in Ugbawka rice field. Risk assessment studies were also carried to ascertain any potential risk to the consumers. Possible potential health risk was observed in one of the PTEs.

2 Materials And Methods

2.1 Study Area

The samples were collected from Ugbawka agricultural fields in Nkanu-East Local Government Area, Enugu State, Nigeria (Figure 1). The area lies at the base of the escarpments of Udi hills and is bordered on the north by Agbani and Akpugo, and on the south by Nomeh, Nara and Mburubu. It lies on latitude 6°31' North and longitude 7°32'East. All the rivers in the town normally rage their torrents during the rains, and traverse the area in a south-easterly direction. The town has low-lying well-watered and to a large extent fertile area. Shrubs and mangrove vegetation cover the vast farmlands and the residential neighborhoods. During the rainy season, the town (especially the southern part) is swampy. This accounts for her rich agricultural produce. There are little or no major industrial activities in the town except for pockets of artisan activities like motorcycle and generator repair shops, welding and mechanic workshops. The Ugbawka rice field is the second largest rice field in Enugu State after Ada rice field in Adani Enugu State. Ada rice field has been studied by Ihedioha et al. [18].

2.2 Sampling and sample preparation

The rice farm was divided into four zones and samples were collected from four different zones labelled 1, 2, 3 and 4 (Figure 1) of the rice farm in December, 2015. The sampling zones have the following coordinates: zone 1 = 6°28'30"N 7°32'56"E, zone 2 = 6°26'30"N 7°30'46"E, zone 3= 6°24'30" N 7°33'40"E and zone 4 = 6°30'44"N 7°31'33"E. Ten samples of each of grain, and soil were collected from each zone. A total of 80 samples were collected for this study. Five sub samples (from 0 to 10 cm depth) were randomly collected within a distance of 10 m in each sampling zone to make a composite. Ten composite soils were collected in each sampling zone. The soil pHs were measured at site of sampling using a digital Labotronic-LT-1 pH meter (Labotronics, Haryana, India). Rice grains were collected from the corresponding soil sampling zone for computing correlations between heavy metal concentration of soil and grain. All samples were kept in clean polythene bags and brought to the laboratory for analyses. Soil samples were air dried in the laboratory for several days at ambient temperature, pulverized and sieved through a 2 mm stainless steel mesh. Rice grain samples were washed with deionized water and hulls were removed. The dehusked rice grain samples were oven dried at 105 °C for 1hr, then at 70 °C to constant weight and then ground with mortar and pestle to fine powder.

2.3 Digestion and PTEs analysis

Soil and ground rice samples (5 g) each were digested with 20 mL mixture of HNO_3 and $HClO_4$ in 2:1 ratio until a clear solution was obtained [19]. The digest were cooled, filtered, transferred to 50 mL volumetric flask,

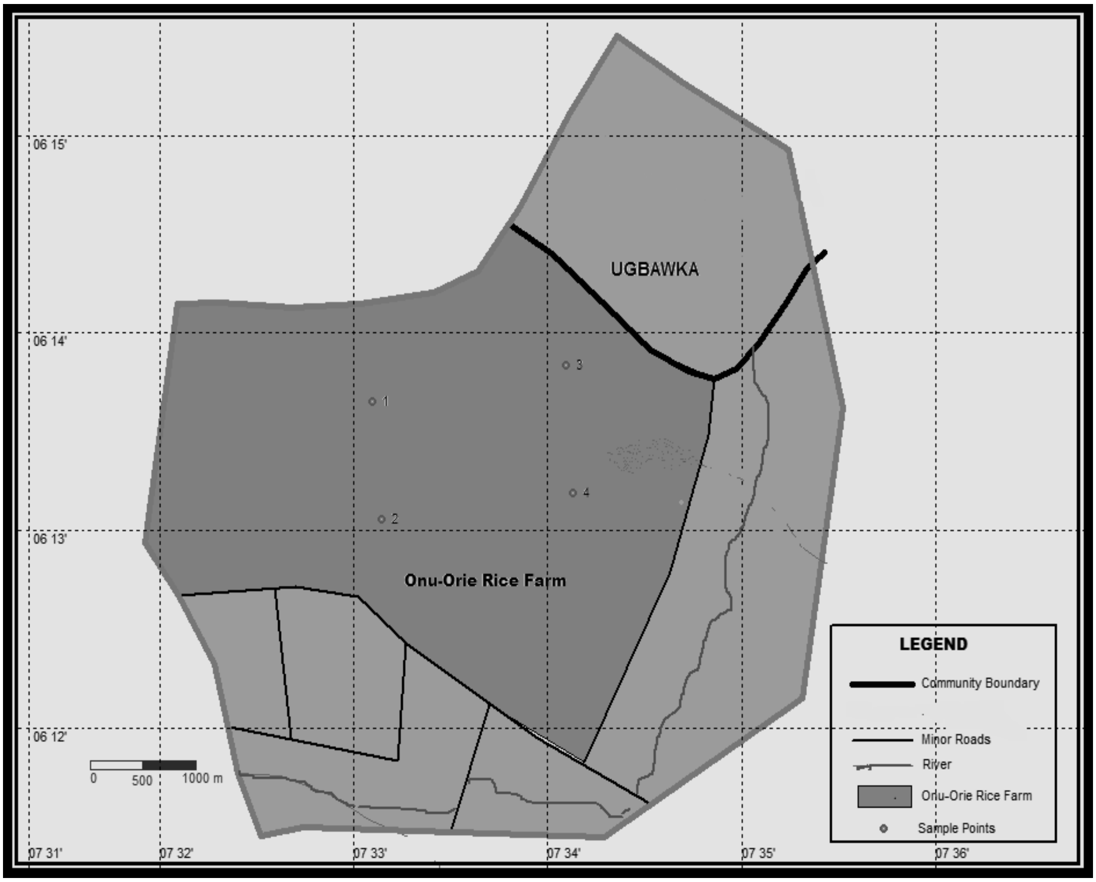

Figure 1: Map of study area.

made up to volume with distilled water and kept in clean plastic vials before PTEs composition analysis. The concentrations of Pb, Ni, Cd, Zn, Cu, Mn, Cr, and Fe were determined with Varian AA-7000 Agilent Atomic Absorption Spectrophotometer (Agilent Technologies, Tokyo, Japan) equipped with air acetylene flame. Mercury was determined by cold vapour [20] using a Buck 211 Atomic Absorption Spectrophotometer (Buck Scientific, **East Norwalk**, Connecticut, USA). All the analysis was done in triplicates.

2.4 Quality control procedure

Recovery analysis was carried out in order to establish the precision and accuracy of the analytical procedure. The PTEs concentrations in triplicate samples of un-spiked and spiked rice and soil samples were determined. Spiking was done by adding various standard solutions of the PTEs solution to 5 g of ground samples, which was later subjected to the digestion procedure. The percent recovery was calculated as:

$$\% \text{ Recovery} = \frac{x-y}{z} \times 100 \quad (1)$$

where X = concentration of the spiked sample, Y = concentration of the un-spiked sample, Z= spiking concentration

Sample blanks were prepared by digesting 20 mL of the digestion mixture as described in section 2.3, and later analyzed for the same metals. The detection limits of the PTEs were determined by the lowest possible dilution of the analyte. The detection limits (mg/L) were: Pb = 0.004, Cd =0.002, Cr = 0.02, Mn= 0.01, Cu =0.02, Zn =0.05, Ni =0.02, Fe =0.05, Hg = 0.003. The mean recoveries (%) of the PTEs obtained in soil were: Pb 87±2.0, Cd 96±4.0, Zn 97±1.53, Cu 94±1.53, Mn 91±1.53, Fe 99±0.58, Cr 90±1.53, Ni 98±1.0 and Hg 95±1.53. The mean recoveries (%) obtained in rice grains were: Pb 88±1.0, Cd 94±3.5, Zn 95±1.53, Cu 97±1.53, Mn 93±1.53, Fe 97±0.58, Cr 92±1.53, Ni 99±1.53 and Hg 97±1.0.

2.5 Human Health Risk Assessment

Hazard quotient (HQ) and total hazard index (THI) were used to estimate the non-carcinogenic risk of rice consumers [12]. The hazard quotient characterizes the health risk of non-carcinogenic adverse effects due to exposure to toxicants:

$$EDI = \frac{C \times IR \times ED \times EF}{BW \times AT} \times 10^{-3} \quad (2)$$

$$HQ = \frac{EDI}{RfD} \quad (3)$$

$$THI = HQ_1 + HQ_2 + \ldots\ldots + HQ_n \quad (4)$$

Where EDI is the estimated daily intake, C is PTE concentration in rice (mg/kg), IR is rice ingestion (g/person/day), ED is exposure duration (70 years), EF is the exposure frequency (350 days/year), RfD is the oral reference dose (mg/kg/day), BW is the average body weight (60 kg) and AT is the average time for non-carcinogens (365 day/year × ED). The oral reference doses for the metals in mg/kg/day were Zn=0.3, Pb=0.004, Cd=0.001, Mn=0.14, Cu=0.04, Fe=0.7, Ni=0.02 and Cr (III) =1.5, Hg=0.0001 [12]. Cr (III) value for RfD was used to represent Cr in this study because of the unstable nature of Cr (VI) under acidic condition in the stomach (reduction of Cr (VI) to Cr (III)) [21]. There is no probable adverse health risk if HQ < 1 while potential non-carcinogenic effects would likely occur when HQ ≥ 1 [12]. The total hazard index is calculated to evaluate the potential risk of adverse health effects from a mixture of chemical components in the sample. The THI was calculated as the sum of HQ (assuming additive effects) [12]. If THI <1, chronic risks are assumed to unlikely happen, whereas non-cancer risks are likely to occur if THI ≥ 1[12].

2.6 Data analysis

All statistical analysis was performed using statistical package SPSS 20.0 for windows (IBM Corp., Armonk, NY, USA). Difference in heavy metal concentration in grain and soil were detected using One Way Analysis of Variance (ANOVA). Pearson's correlation analysis was used to ascertain the correlation pattern of various metal pairs in soil and rice grain samples. Graphs were plotted with OriginPro 6.1 (OriginLab Corporation, Northampton, Massachusetts, USA).

Ethical approval: The conducted research is not related to either human or animal use.

3 Results And Discussion

3.1 Potential toxic elements in soil:

Figure 2 presents the results of the concentrations of potential toxic elements in the soil. The mean concentration of the PTEs were in the following order Fe>Mn>Zn>Cd>Cr>Pb>Cu>Ni>Hg. The trend of these PTEs recorded in this study was similar to (Mn>Zn>Cr>Pb>Ni>Cd) reported in Ada rice fields in Enugu, Nigeria [18]. The PTEs concentrations were compared with some Nigerian and international standards. Concentrations of all PTEs in the samples analyzed (Table 1) were below the standard limits stipulated for agricultural soils by Nigerian Department of Petroleum Resources [22], China [23], and Canada [24] except cadmium whose concentration was above the limit set by China [23]. However, 2.5% of sample exceeded the Chinese limit of cadmium in soil [23]. The high concentration of Fe in the soil could be attributed to soil pH, soil aeration and reactions with organic matter. The pH of the soil samples ranged from 3.3- 4.4 with a mean of 3.85±0.10. Reports have shown that the concentration of iron in the soil increases sharply as soil pH decreases and vice versa [25]. Additionally, poorly aerated soils have increased Fe availability particularly if the soil is acidic. Fe is necessary for plant growth which is underlined by cellular metabolisms [26].

It has been shown that PTEs in soils are mainly from natural occurrence, derived from parent materials and anthropogenic sources [27]. The high level of Mn can be attributed to the use of agrochemicals, fertilizers and pesticide in these farmlands. Ramachandran et al. [28] has reported that manganese is a major constituent of rock phosphate fertilizer. The concentration of all the PTEs except Ni, Zn and Cr were higher in the soil samples than in the rice grains. This could be as a result of weak adsorption properties from the soil to other parts of the plants by these metals [29].

The concentration of lead, copper, chromium, manganese and zinc were lower than values reported by Satpathy et al. [30] in soil while that of cadmium in this study was higher. Also, higher concentrations of these metals have been reported in paddy soil in Macedonia [31], China [32] and eastern Nigeria [18] (Table 2). The risks of heavy metal transfer into the food chain are dependent on the mobility of the heavy metal species and their availability in the soil [33]. Some metals like Cd, Cu and Zn are usually released with industrial emissions linked to acid rain and are drained away from watershed soils, bedrocks and lake sediments under acidic conditions [34

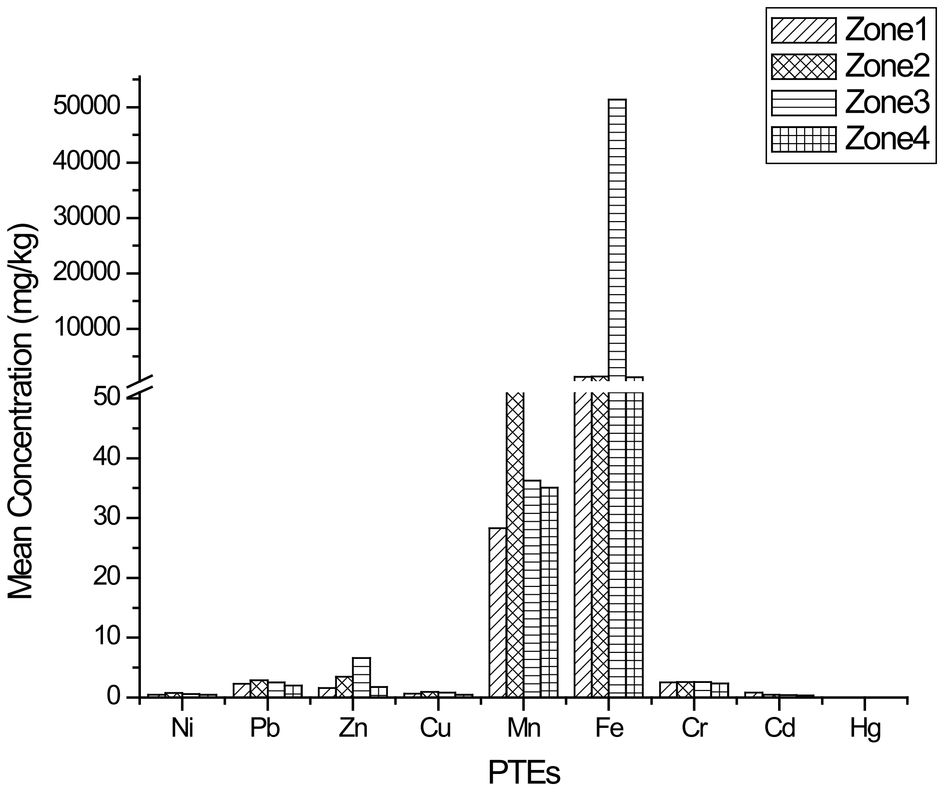

Figure 2: Mean Concentration of PTEs (mg/kg) in soil samples from the different zones.

Table 1: Total Mean Concentration of PTEs (mg/kg) in soil and grain samples from all the zones.

Matrix		Ni	Pb	Zn	Cu	Mn	Fe	Cr	Cd	Hg
Soil	Total Mean ± SD	0.57± 0.24	2.44± 0.17	3.35± 2.05	0.71± 0.33	37.72± 10.97	13856.6± 31.43	2.51± 0.98	0.51± 1.36	0.02± 0.38
	DPR Target value	35	85	140	-	476	-	100	0.80	85
	MAC	40	80	100	-	-	-	90	0.30	-
	CCME	50	70	200	-	-	-	64	1.40	-
Rice grain	Total mean ± SD	0.90±0.51	0.60±0.46	11.74±3.87	0.79±0.47	15.69± 4.99	14.71±0.87	14.17± 6.15	0.45± 0.08	0.002± 0.23
	WHO	10*	0.2	50	-	-	-	1.0	0.1	-
	MHPRC	-	0.02	-	-	-	-	-	0.2	0.02

Department of Petroleum Resources [22]; Maximum Allowable Concentration, China Environmental Quality Standard for Soil (GB 15618-1995) [23]; Canadian Council of Ministers of Environment [24]
WHO [35]; *WHO [36]; MHPRC [37]

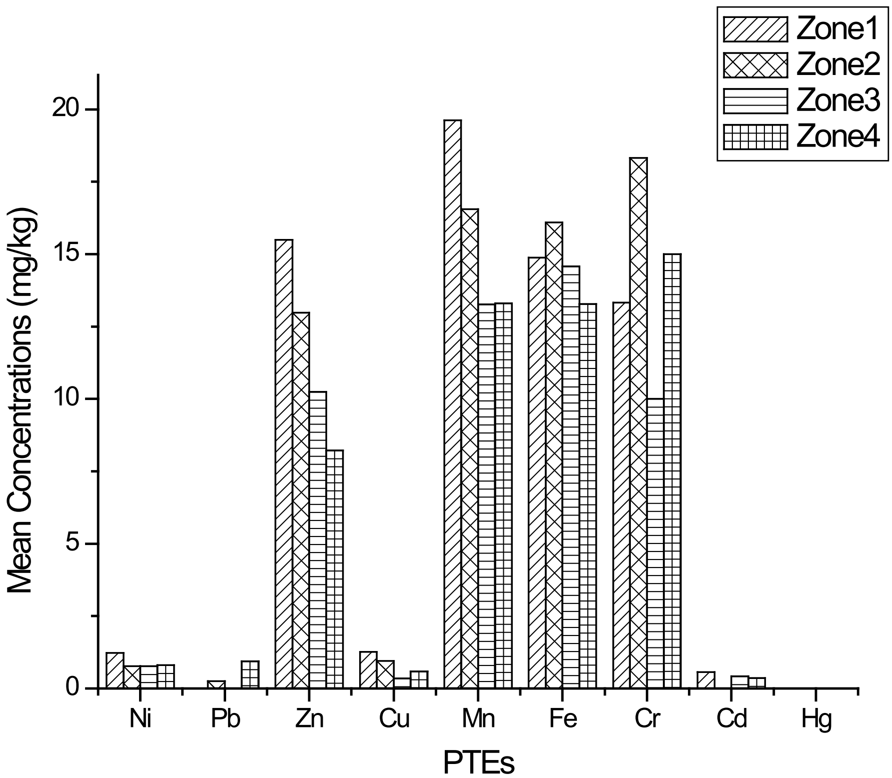

Figure 3: Mean Concentration of PTEs (mg/kg) in rice grain samples from the different zones.

3.2 Potential toxic elements in rice grain

The concentrations of PTEs in the grain were shown in Figure 3. Result showed the following values (mg/kg) for rice grains, 0.39-2.7 for Ni, 1.26-19.02 for Zn, 0.23-2.31 for Cu, 2.96-28.03 for Mn, 5.00-28.20 for Fe, 10.00-40.00 for Cr, 0.28-0.75 for Cd, 3.98-3.98 for Pb and 0.0005-0.004 for Hg. The mean concentration obtained in rice grain was in the following order: Cr>Fe>Mn>Zn>Pb>Ni>Cu>Cd>Hg. As a result of non-availability of established Nigerian standard limits of PTEs in rice, the results of this study were compared with those of other countries and international organizations (Table 1). Concentrations of chromium, zinc and nickel in rice grains were within the limits of FAO/WHO [35] and WHO. [36] (1 mg/kg, 50 mg/kg, 10 mg/kg respectively) for human consumption. Also, concentration of mercury was lower than MHPRC [37]. However, 20% of the samples exceeded WHO [36] limit for cadmium. The result indicates that the concentration of Cd may have been influenced by various anthropogenic activities and use of chemical fertilizers and pesticide [27]. The concentration of lead in rice grains was higher than WHO [36] permissible limit for human consumption (Table 1). The Ugbawka community is a rural community with little industrial activities. However, there are many artisan workers involved in welding and mechanic works. Indiscriminate disposal of lead acid batteries, vehicular emissions and sewage water irrigation [38] can lead to Pb accumulation in rice grains.

Table 2 presents a comparison of heavy metal concentrations in this study with other studies from various parts of the country and other countries. Most of the metals concentrations in this study were lower than those reported by other authors for soil and rice grain except in few cases (Table 2).

3.3 Correlation matrix

The correlation coefficient matrix indicates the degree of correlation between logarithms of elemental concentration [43]. The correlation matrix for the metals in the soil was presented in Table 3. Significant positive correlation between pairs of elements of soil samples- Fe-Ni and Zn-Mn were observed. These positive correlation suggests that the common source of their origin is probably agrochemicals especially phosphate, nitrate and ferrous sulphate fertilizers used in rice cultivation [44]. Miclean et al. [45] reported a significant correlation for lead, cadmium and copper in plants and its surrounding soil.

Table 2: Comparison of results of this study with reports of various studies.

Country	Matrix	Ni	Pb	Zn	Cu	Mn	Fe	Cr	Cd	Hg	Ref.
This study (Eastern)	Soil	0.57± 0.24	2.44± 0.17	3.35± 2.05	0.71± 0.33	37.72± 10.97		2.51± 0.98	0.51± 1.36	0.02± 0.38	
	Rice	0.90± 0.51	0.60± 0.46	11.74± 3.87	0.79± 0.47	15.69± 4.99	14.71± 0.87	14.17± 6.15	0.45± 0.08	0.002± 0.23	
Nigeria (Northern)	Rice	-	0.156-0.514	-	-	-	-	Nd	Nd	Nd	Otitoju et al. [39]
Nigeria (Market samples)	Rice	Nd	Nd	5.74	Nd	-	15.33	0.12	Nd	Nd	Emumejaye [40]
Nigeria (Western)	Rice	-	0.256-0.614	-	-	-	-	Nd	Nd	Nd	Alani [41]
Nigeria (Eastern)	Soil	3.97± 2.93	4.64± 2.18	20.26± 18.60	-	71.84± 19.82	-	16.03± 17.27	0.83± 0.83	-	Ihedioha et al.[18]
	Rice	3.12± 1.49	3.99± 1.43	65.37± 58.09	-	37.81± 5.82	-	4.34± 6.73	1.10± 0.53	-	
China	Soil	33.9	51.4	-	-	348	-	27.2	1.40	14.9	Zeng et al. [32]
	Rice	0.591	0.023	-	-	8.83	-	0.106	0.312	0.069	
Macedonia	Soil	-	128	206	33	-	-	-	0.9	-	Rogan et al. [31]
	Rice	-	0.196	27.86	3.0	-	-	-	0.069	-	
Brazil	Rice	-	0.4-14.5	-	-	-	-	-	-	0.3-13.4	Batista et al. [42]
India	Soil	-	5.3-19.8	3.8-33.8	-	12.5-53.9	-	1.3-7.8	0.02-0.6	-	Satpathy et al.[30]
	Rice	-	0.01-1	3.2-7.2	-	5.6-7.5	-	0.1-0.6	0.02-0.05	-	

However, significant negative correlation was observed in Cd-Fe, and Cr-Hg showing that an increase in one metal concentration will result to a decrease in the other. In grains, significant positive correlations were found between elemental pairs which are Zn-Fe, Ni-Cr, Mn-Zn, Mn-Cu and Mn-Fe (Table 4). This could also be as a result of application of agrochemicals such as fertilizer in the farm.

Analysis of variance test showed significant differences ($p < 0.05$) in the Cu, Mn, Ni, Fe and Hg concentrations in both grain and soil.

3.4 Daily intake and potential health risk of PTEs through rice consumption

Rice consumption has been considered as a major source of human exposure to potential toxic elements since rice is one of the most stable staple foods in most countries [46]. Estimated daily intake (EDI) is a common index for transfer of metal from plants to humans [47]. Table 5 showed estimated daily intake (EDI) and hazard quotient of PTEs through rice consumption for adults. The daily intake of PTEs was evaluated using average concentration of each PTE in rice grain and consumption rate [12]. The daily consumption of rice in Nigeria is 70 g/person/day [14]. The estimated daily intake (EDI) of Ni, Pb, Zn, Cu, Mn, Fe, Cr , Cd, and Hg were 54, 279, 909, 67, 1159, 1042, 1050, 29, and 0.28 µg/person/day respectively. Comparing these with the recommended safe value (Table 5) as stipulated by international organizations like WHO [48-50], Joint FAO/WHO Expert Committee Food Additive (JECFA) [51, 52], and NRC [53, 54], the daily intakes of Pb exceeded the safe limit by 129 %. This could be due to high level of Pb in the rice grain. It indicates that long term consumption of rice from this field could result to high exposure of Pb to consumers. EDI for lead (1941 µg/day) greater than the safe values have been reported by Bian et al. [47] on rice grown on soil irrigated with biogas slurry in Taihu Basin, China. The EDI of Zn and Cr were 2% and 9% of the safe

Table 3: Pearson's correlations between different metals in the soil.

	Zn	Fe	Cr	Ni	Pb	Cd	Hg	Cu	Mn
Zn	1								
Fe	0.350	1							
Cr	0.203	0.561	1						
Ni	0.223	0.618	0.556	1					
Pb	-0.153	-0.210	-0.625	-0.408	1				
Cd	-0.280	-0.876**	-0.339	-0.439	-0.085	1			
Hg	0.002	-0.510	-0.611	-0.584	0.179	0.548	1		
Cu	0.333	0.362	-0.243	0.083	-0.183	-0.381	0.044	1	
Mn	0.646*	0.219	-0.236	0.090	0.273	-0.449	-0.126	0.442	1

*Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 4: Pearson's correlations between different metals in the grain.

	Zn	Fe	Cr	Ni	Pb	Cd	Hg	Cu	Mn
Zn	1								
Fe	0.647*	1							
Cr	0.212	0.283	1						
Ni	0.396	0.135	0.653*	1					
Pb	0.397	0.229	0.218	0.136	1				
Cd	0.263	0.085	0.489	0.588	0.591	1			
Hg	0.203	0.573	-0.027	-0.137	-0.247	-0.534	1		
Cu	0.649*	0.563	0.562	0.515	0.469	0.351	0.162	1	
Mn	0.912**	0.668*	0.281	0.370	0.634*	0.324	0.277	0.722*	1

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

value respectively. These values were low even though the levels of Zn and Cr reported in the grain were not that low. Low EDI for Zn and Cr in rice grains has also been reported by Ihedioha et al. [18]. The EDI of Hg was low (4%) which were in agreement with the low level of mercury in the rice grain. Different studies have reported higher EDI values for mercury. Huang et al. [55] and Batista et al. [42] has reported higher EDI (0.1 µg/bw/day) and (0.2 µg/bw/day) of mercury in adult from China and Brazil respectively. The EDI of cadmium was 59% of the safe value. Lee et al. [56] reported a higher EDI (14.3 µg/bw/day) of Cd in adult than in the present study. The EDI of Ni and Mn were 18 % and 28 % of the safe value. Similar EDI for nickel (0.86 µg/kg bw/day) has been reported in Taiwanese rice [57]. Similar EDI for copper (1.66 µg/kg bw/day) has also been reported in rice contaminated with chemical fertilizer at the East Coast of India [30]. The Hazard quotient has been considered as an important parameter for evaluating risk associated with consumption of food contaminated with PTEs. The hazard quotient and total hazard index of PTEs through rice consumption are shown in Table 5.

The hazard quotient of PTEs for a 60 kg adult from rice consumption was in the order: Pb>Cd>Mn>Zn>Ni>Cu>Fe>Cr. Lead has the highest hazard quotient through rice consumption, which is greater than one. Thus, it can pose a potential risk and may cause adverse health effect on consumers. The THI for rice consumption for a 60 kg adult is 2.118 with relative

Table 5: Estimated daily intake (for 60 kg adult) of the metal from rice consumption with the Hazard quotient.

Metals	Daily intake (µg/person/day)	Daily intake (µg/kg bw/day)	Safe value	Exceeding percentages of safe values	Hazard Quotient
Ni	54	0.9	5[a]	18	0.045
Pb	279	4.65	3.6[b]	129	1.163
Zn	909	15.14	1000[c]	2	0.05
Cu	67	1.11	6.6[g]	17	0.028
Mn	1159	19.32	40-70[d]	28	0.138
Fe	1042	17.36	-	-	0.025
Cr	1050	17.5	50-200[e]	9	0.012
Cd	29	0.49	0.83[f]	59	0.49
Hg	0.28	0.005	0.14[b]	4	0.05
THI					2.118

[a]WHO [48], [b]JECFA [51], [c]JECFA [52], [d]NRC [53], [e]WHO [49], [f]NRC [54], [g]WHO [50]

contribution as follows: Ni (2.12%), Pb (62.80%), Zn (2.36%), Cu (1.32%), Mn (6.52%), Fe (5.30%), Cr (0.57%) and Cd (23.14%). Ihedioha et al. [18] and Zhuang et al. [58] reported THI greater than one in rice consumed from Ada field, Enugu, Nigeria and Dabaoshan site, South China, respectively. The findings from this study indicate that there is a possible potential health risk associated with Pb in rice from Ugbawka farm, which could be harmful to its consumers. Although, Satpathy et al. [30] reported that health risk of a single metal exposure through rice consumption could be assumed to be safe, however, the populace may be at risk due to combination of several toxic heavy metals [59]. The THI for rice consumption of adult was 2.118. This shows that adults may experience adverse health effect much later as the accumulation of heavy metals over a period of time can lead to bioaccumulation. This study was carried out to assess the intake of PTEs through rice consumption. However, exposure to PTEs can be through other food such as contaminated vegetable, fruit, fish, meat and milk [47] and other sources like dust inhalation and dermal contact [60].

4 Conclusion

The present study carried out in Ugbawka farm in Nkanu-East, Enugu State Nigeria determined the concentrations of some PTEs in paddy soils and grains. Concentration of cadmium in soil as well as cadmium and chromium in the rice grains exceeded the limit of listed international organization. Strong correlations were observed among some metal pairs in soil and grains. This indicated that those metals were similar in origin probably from use of the phosphate, nitrate and ferrous sulphate fertilizer used in the study area. The estimated daily intake of Pb was higher than the tolerable intake set by the following organizations JECFA and WHO. The hazard quotient of Pb was above one indicating potential health risk and adverse effect that can result from consumption of rice from Ugbawka farm.

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