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## ASSESSMENT OF SELECTED HEAVY METALS IN LOCAL RICE, WATER AND RICE FIELDS SOIL FROM IBESE TOWN, OGUN STATE, NIGERIA

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### Abstract

*The importance of assessing the levels of toxic metals in the environment and food crops cannot be overstated. In this study, the levels and distribution of As, Ni, Cu, Pb and Zn in soil, water and rice from four rice fields in Ibese, Nigeria were determined using Colorimetric method (for As) and Atomic Absorption Spectrophotometry (for other selected metals). Soil properties including pH, electrical conductivity (EC), organic matter, organic carbon, soil particle size and cation exchange capacity (CEC) were determined using standard procedures. The contamination factor (CF), geoaccumulation index (Igeo), and health risk index (HRI) were evaluated. Pearson's correlation analysis (PCA) was performed to determine the relationship between the physicochemical parameters and the heavy metals (HMs). It was discovered that only the concentrations of As were above the maximum permissible level in three of the field soils. The levels of the HMs in rice samples were within the permissible limits. The range of sand, silt and clay in the fields were 86-94 %, 4-10 %, and 2-6 % respectively while the CEC and the % of organic matter of the soil samples were low. The pH range of the soil samples was 5.2-6.5. The CF suggested no contamination of the soil while the Igeo suggested no pollution to moderate pollution of the soil by the HMs. The HRI predicted that the rice was safe for consumption.*

**Key words:** Heavy-metals, rice, water, Ibese, agricultural-soil, health

## INTRODUCTION

The introduction of heavy metals into the environmental media—air, water, soil and sediment, began with the dawn of industrial revolution. The backbone of the then much coveted ‘revolution’ remained nothing but overwhelming agriculture.

The pace of the industrial revolution was so speedy that the normal course of the natural produce could not catch up with it. It became imperative therefore for the industrialists, scientists, governments and other stakeholders to come up with ideas that would catalyze the natural course. The catalysis was harnessed in such way that the food and other fundamental human needs were aimed to be produced in geometric progression to match the human population growth. Some of such ideas were production of insecticides, herbicides, fertilizers, practice of irrigation and others (Adel et al. 2020).

Through the production and application of these agrochemicals, heavy metals, including As, Pb, Ni, etc were introduced into, and distorted, the natural environment. Major anthropogenic sources of arsenic include wood preservatives, chemicals used in agriculture, industrial processes and products, mining and smelting. Due to its natural and anthropogenic occurrence, the entire population is exposed to arsenic and other heavy metals through food, especially rice, water and air (Andrew et al. 2008; Zhongmin et al. 2019; Rubina et al. 2019). Since then, the levels of these metals in the environment have become a major concern to the environmentalists and health workers.

These metals have been shown to constitute greatly health torsion when exposure to them is beyond threshold level. Among health disorder reported of them include: cancers of the skin, bladder, kidney and lung; diseases of the blood vessels of the legs and feet; diabetes, high blood pressure and reproductive disorders. Other diseases they caused include anemia, constipation, loss of appetite, damage to central nervous system (CNS) and death (Radim et al. 2010; Musa, et al. 2017; Farah F Ghazi, 2018; Mbeh et al. 2019). Arsenic (As) is also known to have induced straightened-head disease in rice (Azizur et al. 2008).

As a result of the aforementioned health implications, scientists have worked on the determination of exposure to these metals through environmental media (Okonkwo, 2010), including water and food, for example, rice (Deepmala et al. 2014; Anitha et al. 2015; Adedokun et al. 2016; Marquez et al. 2018; Hazrat et al. 2019; Chuanyu et al. 2019; Mbeh et al. 2019; Adel et al. 2020).

Rice is critical for food security and in the area of poverty alleviation in many countries (Frank, 2001; Maclean, 2002). Rice is one of the favourites foods for Nigerians. In the bid to be self-reliant in rice production, the Nigerian Government has put measures in place to encourage farmers on rice cultivation. Many towns and villages with comparative advantage have keyed into the policy. Ibese is one of the towns in Nigeria that engage in rice cultivation and production. Therefore this study aimed at determining the levels of the selected heavy metals in the rice fields, irrigation water and rice produced in Ibese town.

## METHODOLOGY

### Site Description

Ibese (6°58'19.79" N and 3°02'06.69" E) is a town in Yewa South Local Government Area of Ogun state, Nigeria, West of Africa. It is about 45 km from Abeokuta, the Ogun State

capital, and about 105 km from Ikeja, the capital city of Lagos State. The town and the surrounding areas, located between Igbogila and Ilaro, are rich in limestone. This has led to siting of two big cement factories in the area; Ibese Dangote Cement plant, the biggest in Africa, and Ewekoro Cement factory.

### **The Fields and their History**

The fields sampled had been engaged in farming for quite sometimes with occasional bush fallowing practice as a response to soil fertility demand. The fields are flooded during the raining season. Streams that are not completely dried off during the dried season run through the fields. The streams run into a bigger one during the raining season. The water from the streams is drunk by the farmers while on farm. The fields were not irrigated or fertilized, and no pesticides usage history was traceable. The fields have been cultivated by the same set of farmers, making the information got on the fields more reliable. All the farms are along the axis of the bigger stream. In this report, the fields (farms) are coded as A, B, C and D. Farm D is the most up the stream, followed by farm B; farm C is on the opposite side of the stream to farm B while farm A is the most down the stream. The four farms are situated at the southern region of Ibeseland.

### **Sample Collection and Preparation for Heavy Metals Determination**

The samples were collected in line with guidelines of appropriate procedures. Soil samples were randomly collected at depths of 0 – 15 cm and at 40 m intervals; and were placed in sealed polythene bags. The samples were air-dried, ground up and sieved with 4 mm mesh. Each sample was immediately placed in a polythene bag and tightly sealed. Water samples were collected randomly into pretreated plastic containers and preserved at pH <2. Composite rice sample was collected for all the fields. The water samples were collected in plastic containers, put in iced water cooler and stored in the refrigerator in the lab. These samples were used for the analyses. The rice and soil samples were digested in accordance with the EPA Method 3050b for Ni, Cu, Pb and Zn determinations while rhodamine B method for As (Christine 2010).

### **Determination of Physicochemical Parameters**

The soil sample prepared above was used for the analysis of the physicochemical parameters. Determination of Electrical Conductivity (EC), pH, Cation Exchange Capacity (CEC), Exchangeable Sodium (ExNa), Exchangeable potassium (ExK), Ca, Ca+Mg, Exchangeable Ca and Mg (ExCa/Mg) were done using the methods of Gupta (2001). Total Organic Carbon (TOC) was determined using Walkley-Black method and hydrometer was used for soil particle analysis.

### **Assessment of Human and Environmental Health Risk**

Contamination of agricultural soil by human factor was determined using Hakanson (1980) equation:

$$CF = \frac{HM_s}{HM_b}$$

Where CF is contamination factor,  $HM_s$  and  $HM_b$  are the concentrations of a metal in the sample and background level (Cu, Pb, Zn and Nickel (Taylor and McLennan, 1995) and As for agricultural soil with pH less than 6.5 (GB 1995)) respectively.  $CF < 1$ ;  $1 < CF \leq 3$ ;  $3 < CF \leq 6$ ;  $CF > 6$  are defined as low contamination, moderate contamination, high contamination and very high contamination respectively. The agricultural soil pollution as a function of levels of heavy metals was determined with geoaccumulation index (Igeo):

$$I_{geo} = \log_2 \frac{HM_s}{1.5 \times HM_b}$$

Where  $I_{geo} \leq 0$ ,  $I_{geo} 0-1$ ,  $I_{geo} 1-2$ ,  $I_{geo} 2-3$ ,  $I_{geo} 3-4$ ,  $I_{geo} 4-5$  and  $I_{geo} \geq 5$  are no pollution, moderate pollution, strong pollution, high pollution, very high pollution, severe pollution and extreme pollution respectively (Loska et al. 2004; Ali and Vinod 2019; Jin et al. 2019). Human health risk of exposure to heavy metals in rice grain was calculated with the daily intake and health risk equations. The daily intake:

$$DI = \frac{HM_r C_f D_{fi}}{B_{bw}}$$

where DI,  $HM_r$ ,  $C_f$ ,  $D_{fi}$  and  $B_{bw}$  are daily intake of metals, concentration of heavy metals in rice grain, conversion factor (0.085), daily intake of rice (0.345Kg/adult/day and 0.232Kg/child/day) and body weight (70Kg for adult and 32.7Kg for child) respectively (Chauhan and Chauhan 2014; Farrag et al. 2016; Adel et al. 2020). The health risk index (HRI):

$$HRI = \frac{DI}{RFD}$$

where RFD (reference oral dose mg/kg/day) are 0.0035, 0.014, 0.04, 0.3 and 0.91 for Pb, As, Cu, Zn and Ni respectively. If HRI is less than unity, then the rice is safe for consumption.

### Statistical Analysis

The correlation of the physicochemical parameters of the soil samples and the selected heavy metals was studied with the IBM SPSS Statistics 20 (SPSS 20).

## RESULTS AND DISCUSSION

### Heavy Metal Concentration in Soil Samples

The concentrations of heavy metals (As, Ni, Cu, Pb and Zn) in the soil samples from the Fields together with the maximum permissible levels of heavy metals adopted by FAO, EU, China, India and EEC Directive(1986) for agricultural soil are presented in Table 1. The critical total soil heavy metal concentration is defined as the range of values above which toxicity is considered to be possible. The data clearly show that the soil samples from fields A, B, C and D contain heavy metal concentrations below permissible limits set by the agencies but As concentrations in fields A, C and D slightly exceeded the maximum permissible levels. The heavy metals concentrations in the soils studied decreased in the sequence:  $Zn > Cu > As > Ni > Pb$ . The CF (Table 2) indicated that the levels of soil contamination with the determined HMs varied from low to moderate. The levels of pollution with the HMs as indicated by the  $I_{geo}$  were between no pollution and low pollution (Table 3).

### Arsenic (As)

Elevated concentrations of As (27.93mg/kg in D), (28.83mg/kg in C) and (21.32mg/kg in A) were detected in the soil samples which exceeded the permissible limit of 20 mg/kg adopted by EU and FAO. At near neutral pH, the soil As content is high and least in most acidic soil (Table 1). Paddy soil can be contaminated by the irrigation water and thus enhances more probable condition for bioaccumulation of arsenic in rice plants (Shao-wen et al. 2009; Bhattacharya et al. 2009; Akan et al. 2010; Wei and Yang 2010). Mining activities are capable of impacting the soil As level (Pereira et al. 2008). The soil As level between 20-30 mg/kg will reduce rice yield by about 27% and at >50 mg/kg of soil As level, reduction in

grain yield may reach 16-100% (John and Golam 2007; Azizur et al. 2008). In this study, three of the studied paddy fields contained **As** at levels above FAO permissible limit, though the activities that might impact the soils with heavy metals were said not to be practiced, like pesticide usage and contaminated irrigation water. The high **As** level determined in this study may be accounted for by limestone-rich soil of the region. Mineral resources in the soil may lead to elevated heavy metal contents of the soil (Williamson and Terrence 2004; Shigeru et al. 2006; Wuthiphun et al. 2007). However, soil **As** level of 40 mg/Kg is acceptable to the Great Britain Agricultural Soil Standard if pH is less than 6.5, of which this study soil samples met.

### **Nickel (Ni)**

The range of Ni concentrations determined in the soil samples was 7.17-21.43mg/kg: A 7.14 mg/Kg (at pH 5.7, TOM 1.14 %), B 21.43 mg/Kg (at pH 5.2, TOM 2.6 %), C 18.20 mg/Kg (at pH 6.0, TOM 1.5 %) and D 21.43 mg/Kg (at pH 6.5, TOM 0.4 %). This range is below the maximum permissible levels of 30mg/kg by FAO 50mg/kg by China and 100mg/kg by EU (Table 1). Soil can be impacted with **Ni** through irrigation activities (Mico 2006; Afshin and Farid 2007; Anita et al. 2010; Akan et al. 2010; Wei and Yang 2010; Odoh and Kolawole 2011). The level of Ni determined in this study is within the Ni levels reported for most agricultural soils world-wide.

### **Copper (Cu)**

The levels of Cu in the fields' soil samples were determined to be between 12.50 and 44.64mg/kg. The upper end of the range is below the maximum permissible level of 50mg/kg by FAO. Also, the range is adequately below the maximum permissible level of 100mg/kg by EU. The soil Cu level increased from most acidic to least acidic until near neutral pH (field D, pH 6.5) where Cu content dropped considerably (Table 1). Increase level of agricultural activities can increase soil **Cu** level (Shao-wen et al. 2009). Also irrigation practice and, indeed, type of water used can elevate soil Cu level (Afshin and Farid 2007; Anita et al. 2010; Akan et al. 2010). The level of Cu determined in this study is within the Cu levels reported for most agricultural soils by researchers.

### **Lead (Pb)**

Pb concentrations range of 9.68-12.90mg/kg was determined in the Fields' soil samples. Comparing this range to the FAO maximum permissible level of 50mg/kg and the EU maximum permissible level of 300mg/kg, one can conclude that the levels of Pb in the fields' soil is acceptable. Pb is fairly and equally distributed in the soil samples which are moderately acidic (Table 1). One of the sources of Pb in agricultural soil, especially by the road side, is leaded gasoline (Wei and Yang 2010). Irrigation has been identified as a source of Pb contamination (Afshin and Farid 2007; Akan et al. 2010). Background soil Pb level can be high in some area where agricultural activity is not taken place (ERM 2006) as a result of geological process.

### **Zinc (Zn)**

The concentrations of Zn in the fields' soil samples were determined to be between 46.67mg/kg and 56.36mg/kg. This range, when compare with FAO and EU agricultural soil Zn standards of 150mg/kg and 300mg/kg respectively, indicates save agricultural soils' Zn. Great Britain Agricultural Soil Standard has adjudged as save an agricultural soil with Zn content of 200 mg/Kg for soils with pH less than 6.5 (GB 1995). Fertilizer usages, waste air,

water, residue from industries and fall-out of automobile have been identified as source of Zn in agricultural soil (Shao-wen et al. 2009). Another pathway for Zn into the agricultural soil is irrigation (Odoh and Kolawole 2011; Adagunodo et al., 2018). Heavy metals are not biodegradable, once they are released and not cleaned up, they remain and continue accumulating in the soil.

Table 1: Levels of Heavy Metals and Physicochemical Parameters in Ibese Rice Farms

Sample	Parameter	A	B	C	D	EU	China	India	FAO
	As <sup>t</sup>	21.32	14.41	28.83	27.93	20			20
	Zn <sup>t</sup>	46.67	56.36	55.15	50.30	300	250	450	150
	Ni <sup>t</sup>	7.14	21.43	18.20	21.43	100	50	100	30
	Cu <sup>t</sup>	44.64	19.64	46.43	12.50	100	100	200	50
	Pb <sup>t</sup>	12.90	9.68	9.68	9.68	300	300	350	50
	pH	5.7	5.2	6.0	6.5				
	EC (mdS)	1.15	1.21	1.48	9.66				
	CEC (cmol/Kg)	1.30	1.98	1.52	0.84				
	ExNa (meq/100q)	5	5	4	4				
	ExK (meq/100q)	0.94	1	1	0.84				
	ExCa (meq/100q)	2.8	1.8	1.8	2.0				
	ExMg (meq/100q)	0.4	0.3	2.2	1.0				
	TOC (%)	0.66	1.51	0.86	0.23				
	TOM (%)	1.14	2.60	1.50	0.40				
	Clay (%)	6	4	2	2				
	Silt (%)	4	10	10	4				
	Sand (%)	90	86	88	94				

t=total;

Table 2: Contamination Factor (CF)

Heavy Metals	A	B	C	D
As	1.421 <sup>a</sup>	0.96 <sup>b</sup>	1.922 <sup>a</sup>	1.862 <sup>a</sup>
Zn	0.66 <sup>b</sup>	0.79 <sup>b</sup>	0.78 <sup>b</sup>	0.71 <sup>b</sup>
Ni	0.36 <sup>b</sup>	1.07 <sup>a</sup>	0.91 <sup>b</sup>	1.07 <sup>a</sup>
Cu	1.79 <sup>a</sup>	0.79 <sup>b</sup>	1.86 <sup>a</sup>	0.5 <sup>b</sup>
Pb	0.65 <sup>b</sup>	0.48 <sup>b</sup>	0.48 <sup>b</sup>	0.48 <sup>b</sup>

a-moderate contamination; b-low contamination



Table 3: Geoaccumulation Index (Igeo)

Heavy Metal	A	B	C	D
As	-0.08 <sup>a</sup>	-0.64 <sup>a</sup>	0.36 <sup>b</sup>	0.31 <sup>b</sup>
Zn	-1.19 <sup>a</sup>	-0.92 <sup>a</sup>	-0.95 <sup>a</sup>	-1.08 <sup>a</sup>
Ni	-2.07 <sup>a</sup>	-0.49 <sup>a</sup>	-0.72 <sup>a</sup>	-0.44 <sup>a</sup>
Cu	0.25 <sup>b</sup>	-0.94 <sup>a</sup>	0.31 <sup>b</sup>	-1.74 <sup>a</sup>
Pb	-1.22 <sup>a</sup>	-1.63 <sup>a</sup>	-1.63 <sup>a</sup>	-1.63 <sup>a</sup>

a- no pollution;

b- moderate pollution

### Heavy Metal Concentration in Water Samples

The heavy metals concentrations in the water samples from Ibese farms stream decreased in the sequence: Zn>Cu>Ni>Pb>As.

#### Arsenic (As)

A range of As concentrations: 0.26 -1.02 mg/L were detected in the water samples which ambiguously exceeded the limit values of 0.001 mg/L and 0.05 mg/L adopted by WHO and UK/USEPA respectively (Table 4) for drinking water. The level of As in water determined in this work may be due to mineral rich-soils of the area as it has been proposed that soil mineral can impact running water heavy metal content (FAO 2007); and the streams where the samples were collected were not treated for portability. Drinking water is the largest source of exposure to **As** in the households (Bhattacharya et al. 2009) and the presence of Zn and/or Se in drinking water can reduce severity of **As** poisoning (Richard et al. 2003). The deeper the source, the more the **As** level of the water (John and Golam, 2007).

#### Nickel (Ni)

The range of **Ni** concentrations determined in the fields' water samples was BDL - 5.36 mg/L. This range, like As, is above the maximum permissible levels of 0.02 mg/L, 0.05 mg/L and 0.10 mg/L by WHO, UK and USEPA respectively, but **Ni** level in field A water is below detection limit (Table 4). Industrial effluent is a source of **Ni** in the environment (Macdonald and Christopher 2011). Hair loss has been linked with exposure to **Ni** in drinking water (Hanaa et al., 2002). Proper treatment of water is a method of reducing human exposure to Ni through drinking water.

#### Copper (Cu)

The levels of Cu in the fields' water samples were determined to be between 1.25 and 5.00 mg/L. A (1.25mg/L) is generally below maximum permissible limits of 1.3 mg/L, 2 mg/L and 3 mg/L by USEPA, WHO and UK respectively. B (2.86 mg/L) meets the UK maximum permissible level while out of the USEPA and WHO maximum permissible levels. C and D (4.25mg/L and 5.00mg/L respectively) are above all the maximum permissible levels (Table 4). Drinking water contaminated with Cu may induce liver cirrhosis and chronic anemia in the exposed person (Hanaa et al., 2002). The samples in this study were not treated for portability.

**Lead (Pb)**

Lead (Pb) concentrations in the water samples were averagely out of tolerable limits, save B, where Pb level is below detection level. A, C and D (0.32 mg/L, 3.39 mg/L and 5.00 mg/L respectively) are all above the 0.01 mg/L and 0.015 mg/L maximum permissible levels set by WHO and USEPA respectively (Table 4). Drinking water contaminated with Pb and Cd may cause renal failure (Hanaa et al., 2002).

**Zinc (Zn)**

The concentrations of Zn in the fields' water samples were determined to be between 1.79mg/L and 9.42mg/L. No maximum permissible level has been set for Zn in drinking water (Table 4).

**Table 4: Levels of Heavy Metals in Water Samples**

Sample	Parameter	A	B	C	D	WHO	UK	USEPA
Water (mg/L)	As	0.32	1.02	0.63	0.26	0.001	0.05	0.05
	Zn	1.76	1.82	9.42	2.50			
	Ni	BDL	2.50	2.86	5.36	0.02	0.05	0.10
	Cu	1.25	2.86	4.25	5.00	2	3	1.3
	Pb	0.32	BDL	3.39	5.00	0.01		0.015

**BDL—below detection limit**

Therefore, the waters studied here are not suitable for drinking considering the levels of **As, Ni, Cu and Pb** in them (Hanaa et al., 2002; Rai et al., 2019).

**Heavy Metals Concentrations in Rice Sample**

The rice grain samples' heavy metals concentrations in the rice (with husk) in this work decreased in the sequence: Zn>Cu>As>Pb>Ni.

**Arsenic (As)**

The level of **As** concentration determined in rice sample was 0.77 mg/g. This value is found below the maximum permissible limit value of 1.0 mg/g adopted by WHO/FAO (Table 5). It was reported that varieties of rice have different **As** accumulation capacities (Andrew et al. 2008). Variability in the types of soils is also a factor that determines **As** accumulation in rice plant (Haw-Tarn et al. 2004; Paul et al. 2005). Soil contaminated with e-waste may lead to translocation of **As** in rice plant (Jianjie et al., 2008). Soil **As** level is reported to be proportional to the amount up-taken by the rice plant (Paul et al., 2005; Bhattacharya et al., 2009).

**Nickel (Ni)**

The Ni concentration determined in the rice sample was below detection limit (Table 5). Meanwhile, India has set 1.5 mg/g Ni as maximum permissible limit in rice. The soil Ni level can be elevated through contaminations (Jianjie et al., 2008; Haw-Tarn et al., 2004).



**Copper (Cu)**

The level of Cu in rice sample was determined to be 1.16 mg/g. This level is generally below maximum permissible limits of 40 mg/g and 30 mg/g by WHO/FAO and India respectively (Table 6).

**Lead (Pb)**

Pb concentration in the rice sample was 0.16 mg/g. This value is generally below the 0.30 mg/g, 2.50 mg/g and 5.00 mg/g maximum permissible limits by EU, India and WHO/FAO respectively (Table 5). The soil Pb background level can be elevated by activities like mining, waste disposal, pesticide and/or herbicide and effluent discharge which can accumulate in rice grain (Zhuang et al., 2009; Jianjie et al., 2008; Haw-tarn et al., 2004).

**Zinc (Zn)**

The rice Zn level was determined to be between 4.33 mg/g. When this value is compared with 60 mg/g and 50 mg/g maximum permissible limits by WHO/FAO and India respectively, one will but conclude that the rice investigated here is not posing Zn load on the consumers (Table 5). Although rice is the largest source of exposure to Cs, Co, Fe, Mn, Rb, Se, and Zn in some areas (Richard et al., 2003).

Table 5: Concentration of Heavy Metals in Rice

Sample	Parameter	Result	WHO/FAO	EU	India	SPEA
	<b>As</b>	<b>0.77</b>	<b>1.0</b>			
	<b>Zn</b>	<b>4.33</b>	<b>60</b>		<b>50</b>	<b>50</b>
	<b>Ni</b>	<b>BDL</b>			<b>1.5</b>	<b>2</b>
	<b>Cu</b>	<b>1.16</b>	<b>40</b>		<b>30</b>	
	<b>Pb</b>	<b>0.16</b>	<b>5</b>	<b>0.30</b>	<b>2.5</b>	<b>0.5</b>

BDL: below detection limit

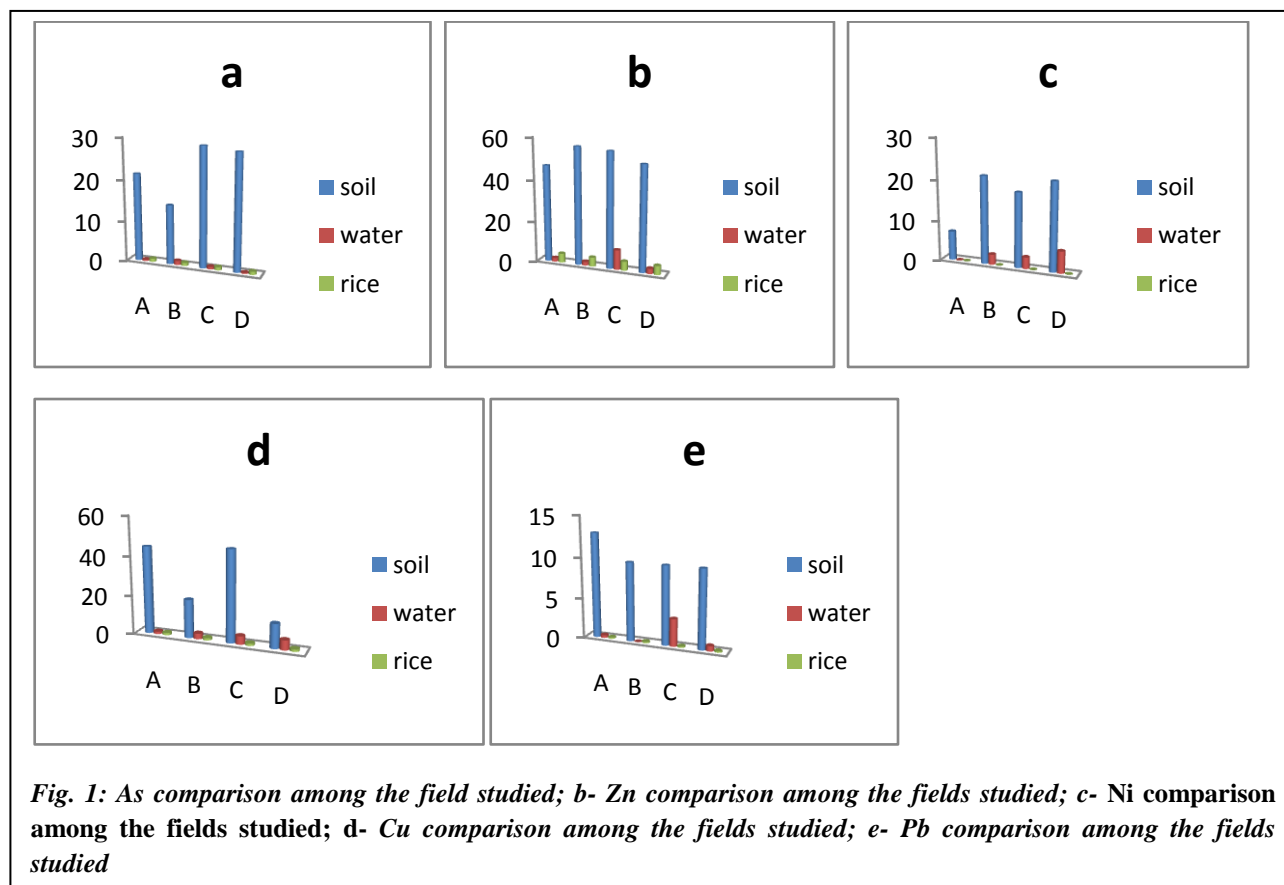
Table 6: Daily Intake (DI) and Human Risk Index (HRI)

	As		Zn		Ni		Cu		Pb	
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
DI	0.00032	0.00046	0.00181	0.00261	ND	ND	0.00049	0.00007	0.00007	0.0001
HRI	0.022	0.033	0.006	0.0087	ND	ND	0.01225	0.0175	0.02	0.0286
Status	safe	safe	safe	safe	safe	safe	safe	safe	safe	safe

ND: not detected

The analysis data revealed that heavy metals contents of the rice are below the maximum permissible limits set by all the agencies: national, regional and international (Table 5). HRI results (Table 6) also revealed that the levels of the determined heavy metals in the rice pose no health risk.

The soil samples are shown to be highest in the heavy metals determined in this study, followed by water samples and then rice sample (Fig. 1). Zn concentration is shown by the results to be the highest in soil, water and rice samples studied, followed by Cu, As, Pb and Ni respectively i.e Zn>Cu>As>Pb>Ni. The trend of levels of heavy metals here is comparable with results of other works like Zhuang et al. (2009) (Zn>Cu>Pb>Cd), Jianjie et al. (2008) (Cu>Pb>Ni>As), Haw-Tarn et al. (2004) (Zn>Cu>Ni>As>Pb), Deepmala et al. (2014), Anitha et al. (2015) (Zn>Cu>Cd>As>...), and Nattanan et al. (2019) (Zn>V>Cr>Cu>Pb≈Ni>Co>Cd).



*Fig. 1: a- As comparison among the field studied; b- Zn comparison among the fields studied; c- Ni comparison among the fields studied; d- Cu comparison among the fields studied; e- Pb comparison among the fields studied*

Table 7: Pearson's Correlation Analysis

HEAVY METAL IN SOIL	pH	EC	CEC	ExNa	ExK	ExCa	ExMg	TOC	TOM	CLAY	SILT	SAND
As	<b>0.905</b>	<b>0.501</b>	<b>-0.722</b>	<b>0.906</b>	-0.435	-0.088	<b>0.799</b>	<b>-0.778</b>	<b>-0.772</b>	<b>-0.640</b>	-0.259	<b>0.621</b>
Zn	-0.364	-0.253	<b>0.689</b>	-0.156	<b>0.609</b>	<b>-0.909</b>	0.336	<b>0.698</b>	<b>0.701</b>	<b>-0.518</b>	<b>0.937</b>	<b>-0.660</b>
Ni	0.150	0.445	0.126	-0.471	-0.069	<b>-0.933</b>	0.240	0.191	0.191	<b>-0.793</b>	0.471	-0.033
Cu	-0.155	<b>-0.696</b>	0.174	0.089	<b>0.536</b>	0.412	0.404	0.055	0.061	0.333	0.149	-0.338
Pb	-0.184	-0.354	-0.155	<b>0.577</b>	-0.044	<b>0.980*</b>	-0.439	-0.194	-0.197	<b>0.870</b>	<b>-0.577</b>	0.098

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

### Soil Particle Size Characteristics

The mineral fraction of the soil consists of two classes of inorganic materials. The skeletal minerals are the coarse and silt particles. They are fragmented minerals and rocks of the grade size of sand and silt which provides the bulk of the soils but play little or no important role in the chemical property of the soil. The second material class consists of the clay mineral, products of rock weathering and having significant effect on both physical and chemical properties of the soil. Their contribution to soil chemical property results from their comparatively large surface area and permanent surface area (Etim 2009). Table 1 gives percentage sand, silt and clay across the fields studied. The percentage range of sand, silt and clay determined in the fields were 86-94 %, 4-10 %, and 2-6 % respectively. Using the United States Department of Agriculture (USDA) soil textural classification chart, the studied soil samples are thereby classified as: A-loamy sand, B-loamy sand, C-sand and D-sand. Clay rarely exists in pure forms in soils. They usually have humic colloids and hydrous oxide precipitates linked to them. The combined organo-mineral colloidal complex plays a very important role in controlling the concentrations of ions in soil solution. Clay particles are negatively charged and attracted positively charged ions present in the soil solution. The lower clay contents of the studied soil samples have explained why the samples were slightly acidic. The lower clay contents of the samples have little capacity to bind the cations ( $H^+$ ,  $Al^{3+}$ ,  $Na^+$ ,  $K^+$ ,  $Ca^{2+}$ ,  $Mg^{2+}$ ) in solutions. The soil solutions then became slightly acidic and provided matrix for heavy metals dissolution. ExNa was directly correlated with As and Pb (Table 7). ExK was directly correlated with Zn and Cu. ExCa was inversely correlated with Zn and Ni; and directly and significantly correlated with Pb, while ExMg was directly correlated with As. Clay was inversely correlated with As, Zn and Ni and directly correlated with Pb. Silt was directly correlated with Zn and inversely correlated with Pb. Sand was directly correlated As and inversely correlated with Zn.

### Cation Exchange Capacity (CEC) and Organic Matter (OM)

An important property of any given soil is its CEC. A high value of CEC is a general indication of a high degree of chemical activity. Since organic matter plays an important role in metal binding, some researchers have tested whether organic carbon (OC) compounds influence metal leaching (Akan, 2010). Metals such as Ni and Zn may be influenced in their solubility characteristics in the presence of OC (Fotovat et al., 1996). Table 1 shows the average CEC of soil samples and the percentage of OM determined. These physico-chemical

parameters were generally low for studied samples. As it was previously discussed, the average clay content, hence negatively charged centre, of the soil samples were low. This condition invariably led to low CEC values. CEC was inversely correlated with As and directly correlated with Zn (Table 7).

### **Electrical Conductivity (EC)**

This is a measure of total solute concentration in soil extracts. The EC of the fields A, B, C, D are determined to be 1.15, 1.12, 1.48 and 9.66 (mdS/m) respectively (Table 1). These values have non-deleterious effect on crops. The EC was directly correlated with As and inversely correlated with Cu (Table 7).

### **Conclusion**

This study shows that the level of arsenic in the soil samples is averagely higher than FAO standards (20mg/kg) for agricultural soil but levels of other heavy metals determined are generally low. The concentrations of these heavy metals in water are much higher than WHO standards for drinking water. The data obtained revealed that the heavy metals contents of the rice are below the maximum permissible limits. Therefore the rice is quite safe for consumption, but the farmers may desist from drinking the water to avoid heavy metals toxicity. Though some of these heavy metals are essential minerals at trace levels, continuous exposure to them through drinking water at the determined levels in this study may put the health of the exposed group at risk, especially the children.

**Conflict of Interest:** The authors declare that they have no conflict of interest.

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