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HEAVY METALS IN PADDY SOILS AND THEIR UPTAKE IN RICE PLANTS COLLECTED ALONG OGBESE RIVER, SOUTHWEST NIGERIA: IMPLICATIONS FOR CONTAMINATION AND HEALTH RISK

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ABSTRACT

This investigation was aimed at ascertaining the amount of metals and their absorption in the rice and paddy soils of the Ogbese River in Ondo State, Nigeria. Forty samples were gathered for this investigation along the River. Every sample was taken using legal international sampling methods. Additionally, rice crops were gathered in five separate places. Using atomic absorption spectrometer, the values of Zn, Cd, Cu, Pb, and Fe were determined for each sample. Assessments of the risk of contamination and health problems were performed using reliable models. According to the findings, the mean amount of Zn, Cd, Cu, Pb, and Fe in the local soils were 4.84, 0.19, 0.25, 1.31, and 397.44 mg/kg, respectively, whereas the corresponding concentrations in paddy rice grain were 0.35, 0.02, 0.12, 0.02, and 3.25 mg/kg. The bioaccumulation factor (BAF) and transfer factor (TF) of elements from soils to crops were both 1, indicating that there was no appreciable absorption of metals by plants. Heavy metals in soils had Pollution Load Index values greater than one, suggesting that the soils were contaminated. In rice grains, the contamination load index of heavy metals revealed that Cd had values >1 in 80% of the samples. This demonstrated that Cd was a significant rice contaminant in the area. Children's Zn, Cd, Cu, Pb, and Fe Targeted Health Quotient (THQ) readings were all less than 1, suggesting that they were not exposed to any non-carcinogenic health problems. THQ for adults were less than 1 for Zn, Cd, Cu, and Pb, but > 1 for Fe. Adults may get non-carcinogenic health problems if they ingest too much Fe in the grains. To avoid any health problems brought on by their use, it is advised that heavy metals in the soil and rice grains in this region be routinely examined.

Keywords: Contamination, Health risk; Heavy metals, Nigeria, Ogbese river, Paddy soils, Rice.

INTRODUCTION

Numerous anthropogenic activities have an impact on the environment that might be either favorable or unfavorable (Adewumi and Laniyan, 2020). Loss of biodiversity, destruction of soil ecosystems, and harm to human well-being are all detrimental outcomes of human activity (Zulkafflee *et al.,* 2019). Limits for heavy metals in plants have been established by organizations including the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). Due to geological and human-made processes, plants are polluted with heavy metals, especially in paddy rice environments (Adewumi *et al.,* 2021; Satpathy *et al.,* 2014). Heavy metals are substances that pollute soil and render it inappropriate for plant absorption. Examples of these substances are zinc, copper, cadmium, lead, and mercury (Adewumi and Laniyan, 2020).

One of the most common grains produced and consumed in Nigeria is rice (*Oryza sativa*). Agricultural methods such as the use of chemicals, which are significant sources of toxic metals in the paddy environment, may be deleterious to the growth of crops (Satpathy *et al.*, 2014). This issue is exacerbated by the presence of toxic metals in polluted irrigation water (Khai and Yabe, 2013). Although Zn, Cu, and Cd are necessary for plants to flourish, their abundance in the agricultural system may have an adverse effect on crop output (Khai and Yabe, 2013). Cadmium, for instance, is harmful to human health. The malfunction of the human kidney might be caused by too much Cd there (Haider *et al.*, 2021). Metals are easily absorbed by the human body system from edible plant portions, such as grains (Haider *et al.*, 2021). When rice is planted, harvested, transported, and stored, it is frequently subjected to heavy metal contamination (John, 2012).

The term "human health risk assessment" (HHRA) describes the negative impacts of human exposure to environmental hazards (USEPA, 2022). Scientific and statistical models are necessary to determine and quantify possible risks for human exposure (Adewumi *et al.,* 2021). Information already available uses exposure routes to compute numerical values to assess possible dangers (Adewumi *et al.*, 2021). Hazard identification, dosage response, exposure evaluation, and risk characterization are all components of HHRA (USEPA, 2022). When assessing health risks, classifications of cancer-causing and non-cancerous risks are employed (Adewumi *et al.*, 2021). Health risk assessment strives to safeguard all presumably affected inhabitants by taking into account variables such as gender, nutrient intake, hereditary factors, and life phases that may be more susceptible to harmful effects or that are immensely or disproportionately vulnerable, such as childhood or ethnic groups (USEPA, 2022). Kids are a distinct set of people who, due to their weakened immune systems, are more susceptible to health threats than adults (Adewumi *et al.*, 2020).

No study has been carried out to determine the level of heavy metals in paddy soils and rice along Ogbese river neither has their been research efforts that investigated the health risks of heavy metals in these media. In this study, the amount of heavy metals in paddy soils and rice along the Ogbese River, Southwest Nigeria including the potential human health risk assessments were investigated.

MATERIALS AND METHODS

Sampling Area

Samples of paddy soil and plants were taken from the Ogbese region of Nigeria's Ondo State. Within latitudes 7°5'N and 7°25'N and longitudes 5°7'30" and 5°32'30"E are where the sample region is situated. Uso to the east, Ikere to the north, and Akure to the east border this region. The River Ogbese originates in Ayede-Ekiti, Ekiti State, and travels through Ondo State to reach Edo State. The River travels downstream for approximately 265 km and is a tributary of the River Ose. The watershed lies between 740 m and 37 m above sea level in height. It is a significant river in Ondo State's northern and central regions (Akinbile and Olatunji, 2018). The typical yearly rainfall is between 1,500 mm to 3,500 mm. While the maximum average daily temperature of 32 °C is recorded in March, the lowest daily temperature of 22 °C is recorded between December and February. The watershed's yearly average relative humidity is 75%, and during the rainy season it increases to 90%. (Obiora-Okeke *et al.,* 2021). The study area is underlain by Precambrian rocks (Adewumi *et al.,* 2018).

In January 2018, during the dry season when the River is not inundated, forty paddy soils were gathered. Paddy rice grains were gathered in five samples during the harvest in August 2018. Using an uncontaminated hand auger, surface soil samples were collected at a depth of 20 cm and kept in well-labeled, clean bags. To facilitate convenient sampling and data processing, the research area was separated into four sections: S1 (upper paddy environment), S2 (mid-upper paddy environment), S3 (lower-mid paddy environment), and S4 (lower paddy environment). The samples were processed in the laboratory using a sedimentological sieve, ground, and air dried at room temperature. The Buck Scientific Atomic Absorption Spectrometer, manufactured in the United States, was used to test toxic elements such as Pb, Zn, Cu, Cd, and Fe found in soil and rice.

Sample Preparation of Paddy Rice Plant

Five samples of rice grains totaling 100 grams from each sampling site were produced. The samples were created using the Zulkafflee *et al.* (2019) technique. Aqua regia was used for wet digestion on all samples.

Statistical Analysis

The University of Amsterdam's JASP 0.16.3 open source statistical program was used to statistically analyze the data. The USEPA (2022) models were used to compute the Health Risk Assessment (HRA).

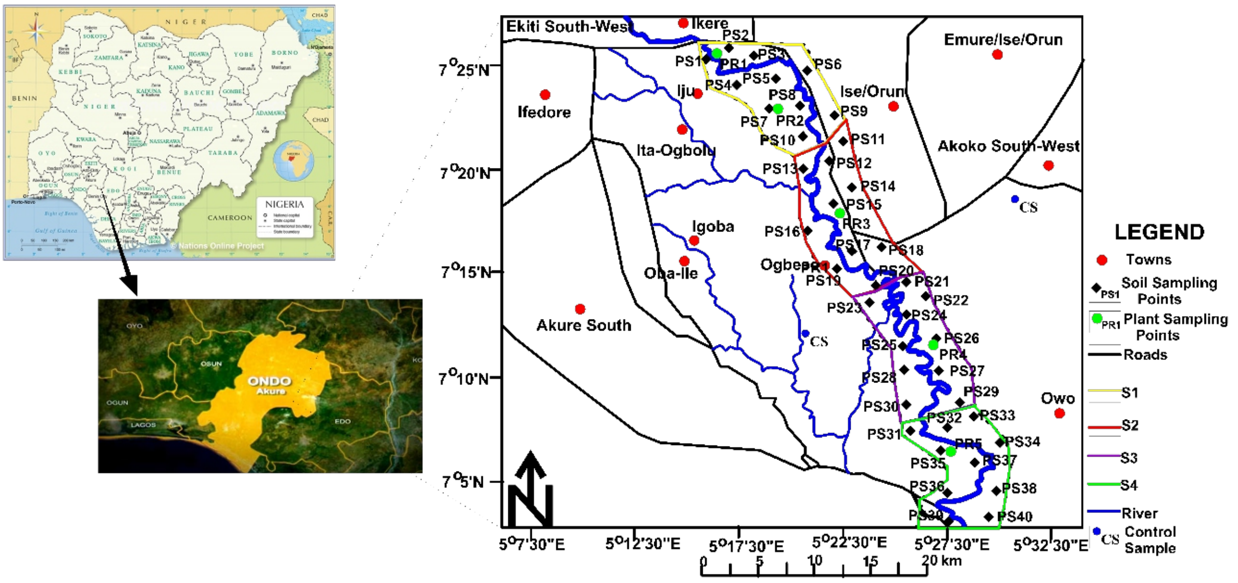

Figure 1: Location of the study area.

Contamination Assessment

Using the Contamination Factor (CF), Contamination Degree (CD) following Hakanson (1980) technique and the Pollution Load Index (PLI) using Tomlinson et al (1980) model the amount of impact of pollutants in paddy soils was assessed. Equation (1) was used to compute the contamination factor.

Four categories are used to categorize CF: CF ≤ 1 (Low contamination value); 1 ≤ CF < 3 (Moderate contamination value); 3 ≤ CF < 6 (Considerable contamination value), and 6 ≥ CF (Very high contamination value). Equation 2 was used to calculate the contamination degree (CD). CD is divided into four categories: CD ≤ 8 (low extent of pollution); 8 ≤ CD < 16 (Moderate extent of pollution); 16 ≤ CD < 32 (Considerable extent of pollution); CD ≥ 32 (Very high extent of pollution). Equation 3 was used to obtain the pollution load index (PLI). PLI < 1 indicate no pollution; PLI=1 shows that only small amount of pollutants are available while PLI > 1 indicates decline in the level of site quality.

$$Contamination\ Factor = \frac{Mean\ Metal\ Concentration}{Concentration\ of\ Element\ in\ Background\ Soils}\ (Equation\ 1)$$

$$C_d = \sum_{i=1}^{n} C_f^i\ (Equation\ 2)$$

where C_d stands for Contamination Degree, C_f stands for Contamination Factor.

$$Pollution\ Load\ Index\ (PLI) = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times \ldots CF_n}\ (Equation\ 3)$$

where C_f stands for Contamination Factor

Equation 4 represents the contamination load index (CLI) used to calculate the level of crop contamination for each metal.

$$CLI = \frac{C_{Crop}}{MPC}\ (Equation\ 4)$$

where C_{crop} represents the amount of metals in plants' edible parts while MPC is the highest level of heavy metals that can be present in plants (Codex Alimentarius Commission, 2001). A crop is considered to be contaminated with a heavy metal if the CLI of the metal in that crop is more than 1 (Moradi *et al.*, 2015).

Heavy Metals Transfer in Paddy Soils and Rice

Equation 5 was used to compute the bio-accumulation factor (BAF), which measures a crop's ability to store a certain metal in relation to its abundance in the soil substrate. (Singh and Ghosh, 2005)

$$BAF = \frac{C_{Plant}}{C_{Soil}}\ (Equation\ 5)$$

where C_{plant} and C_{soil} stand for the concentrations of heavy metals in edible plant portions and soil, respectively. When BAF > 1, it means that the metal has successfully bio-accumulated from the soil.

The transfer factor (TF) from equation 6 was used to assess toxic metal migration in crops from the root to the shoot.

$$TF = {}^{C_s}/_{C_r} \quad (Equation\ 6)$$

where Cs and Cr are the amounts of metal in the shoot and root, respectively, expressed in mg/kg. Plants carry elements from the root to the stem effectively when TF > 1. (Bakers and Brooks, 1989).

Hazard Quotient (HQ) and Lifetime Cancer Risk (LCR)

An approach for calculating the non-carcinogenic threat to citizens is the Hazard Quotient (HQ). It is utilized to measure the health risk of non-carcinogenic heavy metals in the environment. While negative health consequences are unlikely to occur when HQ < 1, non-carcinogenic effects are more likely to happen with HQ ≥ 1 (Adewumi and Laniyan, 2020). The likelihood that a person will get cancer over the course of their lifetime is measured using the term lifetime cancer risk (LCR). For instance, an LCR of 10^{-4} means that there is a 1 in 10,000 chance that someone may acquire cancer. USEPA III Risk-Based Concentration created LCR (Adewumi and Laniyan, 2020). The formulae for calculating the hazard quotient (HQ) and lifetime cancer risk are shown in equations 7 and 8. (LCR). While the lifetime average dose (ADD) in mg/kg/day was multiplied by a cancer slope factor (CSF) to determine the lifetime average dose (LCR), the lifetime average dose (ADD) to reference dose (RfD) ratio (HQ) is used instead (Equation 8).

$$HQ = ADD\ (\frac{mg}{kg} perday)/RfD\ (mg/kg\ per\ day) \qquad (Equation\ 7)$$

$$LCR = ADD\ \left(\frac{mg}{kg}\ per\ day\right) \times CSF(mg/kg\ per\ day)\ (Equation\ 8)$$

where CSF (mg/kg/day) is a cancer slope factor, ADD (mg/kg/day) is a metric used to compute the oral exposure dosage for a specific time, and RfD (mg/kg/day) is the estimated maximum permitted dose for humans through daily exposure.

Total Hazard Quotient (For Plants)

The health hazards related to the eating of paddy rice by the local people were assessed using the Target Hazard Quotient (THQ). According to the procedures employed by Chien *et al.* (2002), THQ was calculated using Equation 9 for the intake of Pb, Zn, Fe Cd, Cu and Cu from consuming these crops (2002).

$$THQ = \frac{FI \times ED \times MC \times EF}{BW \times RfDo \times AT} \times 0.01\ (Equation\ 9)$$

where EF denotes exposure frequency (365 days annually), ED denotes exposure duration (for adults, 70 years), FI denotes food intake rate (g per person per day), MC denotes oral reference dosage (mg/kg/day), RfDo denotes oral heavy metal concentration (mg/kg), and BW denotes average body weight (adults weigh 70 kg, whereas children weigh 15 kg). In this study, the number of exposure years is assumed to be 365 days Average time for non-carcinogens is abbreviated as AT. For adults and kids, the respective food intake were 600 g and 198.4 g daily. The RfDo for Pb, Cu, Fe, Cd and Zn were 0.004, 0.04, 0.7, 0.003, 0.1 mg/kg daily, respectively, according to Nadal *et al.* (2003), where 0.01 is the unit conversion factor. When THQ is < 1, there might not be any impact to human health, but there may be some danger if it is greater than 1 (Moradi *et al.*, 2015).

RESULTS AND DISCUSSION

RESULTS

Heavy Metals in Paddy Soils and Plants

Table 1 shows the results of the quantity of heavy metals in the paddy soils of the research region. The results revealed that the range values for Zn, Cd, Cu, Pb, and Fe in sampling area S1 were, respectively, 2.84–6.91, 0.11–0.28, 0.12–0.62, 0.48–2.83, and 276.12–516.19 mg/kg, while those for pH and OMC were, respectively, 6.09–6.82 and 2.17 - 2.98. All of the parameters' p-values were less than 0.001. The range values for Zn, Cd, Cu, Pb, and Fe in sample area S2 were, respectively, 3.16–7.28, 0.14–0.36, 0.18–2.75, 0.66–2.02, and 265.19 - 609.16 mg/kg, while those for pH and OMC were, respectively, 6.11–6.69 and 2.36–2.84. The p-value was less than 0.001. Zn, Cd, Cu, Pb, and Fe range values in sample area S3 were 4.82–6.88, 0.11–0.41, 0.17–1.42, 0.14–3.74, and 206.17– 618.25 mg/kg, respectively, whereas pH and OMC range values were 6.22–6.81 and 2.12–2.87. The p-value was less than 0.001 for all metals except for Cu and Pb where it was greater than 0.001. Zn, Cd, Cu, Pb, and Fe had range values in sample area S4 of 2.65–6.74, 0.19–0.44, 1.63–3.22, and 195.87–462.78 mg/kg, respectively, whereas pH and OMC had range values of 6.17–6.77 and 2.17–2.68. The p-value was less than 0.001.

Figure 2 displays the levels of heavy metals in paddy rice plants from the research location. Zn, Cd, Cu, Pb, and Fe concentrations in the roots of paddy rice plants vary from 1.26 to 2.46 mg/kg, 0.06 to 0.09, 0.08 to 1.64 mg/kg, 0.06 to 0.91 mg/kg, and 16.48 to 25.62 mg/kg, respectively (Figure 2), with average values of 1.71, 0.08, 0.43 mg/kg, 0.25 mg/kg, and 22.17 mg/kg, respectively. In the shoots of paddy rice plants, Zn, Cd, Cu, Pb, and Fe ranged from 0.42 to 1.88, 0.02 to 0.05, 0.03 to 0.98, 0.02 to 0.05, and 8.17 to 13.45 mg/kg, with mean values of 0.90, 0.25, 0.04, and 10.45 mg/kg, respectively. Zn, Cd, Cu, Pb, and Fe concentrations in paddy rice plant grains ranged from 0.11 to 1.06, 0.01 to 0.03, 0.01 to 0.44, 0.01 to 0.02 and 2.14 to 4.28 mg/kg, respectively, with mean values of 0.35, 0.02, 0.12, 0.02 and 3.25 mg/kg.

Table 1: Concentration of heavy metals in paddy soils.

Sampling Location	Statistical Parameter	Zn (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Fe (mg/kg)	pH	OMC
S1	Minimum	2.84	0.11	0.12	0.48	276.12	6.09	2.17
	Maximum	6.91	0.28	0.62	2.83	516.19	6.82	2.98
	Mean±SEM	4.84±0.41	0.19±0.02	0.25±0.05	1.31±0.28	397.44±21.40	6.38±0.07	2.51±0.08
	PV	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001
S2	Minimum	3.16	0.14	0.18	0.66	265.19	6.11	2.36
	Maximum	7.28	0.36	2.75	2.02	609.16	6.69	2.84
	Mean±SEM	4.84±0.43	0.24±0.02	1.05±0.23	1.33±0.14	453.92±29.43	6.39±0.06	2.62±0.05
	PV	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001
S3	Minimum	4.82	0.11	0.17	0.14	206.17	6.22	2.12
	Maximum	6.88	0.41	1.42	3.74	618.25	6.81	2.87
	Mean±SEM	5.97±0.26	0.19±0.03	0.54±0.13	1.66±0.38	372.12±44.49	6.42±0.06	2.47±0.08
	PV	p < 0.001	p < 0.001	p > 0.001	p > 0.001	p < 0.001	p < 0.001	p < 0.001
S4	Minimum	2.65	0.19	0.19	1.63	195.87	6.17	2.17
	Maximum	6.74	0.44	1.56	3.22	462.78	6.77	2.68
	Mean±SEM	4.46±0.38	0.29±0.02	0.65±0.13	2.40±0.18	282.25±25.79	6.42±0.06	2.38±0.05
	PV	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001
Control Sample		1.78	0.10	0.11	0.14	106.75	6.27	2.02
USEPA (2002)		1100.00	0.48	270.00	200.00	-	-	-
China[1]		136.95	0.66	30.45	55.77	-	-	-
India[2]		33.80	0.60	5.40	19.80	-	-	-
Bangladesh[3]		160.03	-	0.22	188.61	27,774.66	-	-
Tanzania[4]		73.40	0.52	16.90	26.20	-	-	2.40

[1]Zhong *et al.* (2010); [2]Satpathy *et al.* (2014); [3]Halim *et al.* (2014); [4]Machiwa (2010). SEM implies Standard Error of the Mean. PV stands for p-value

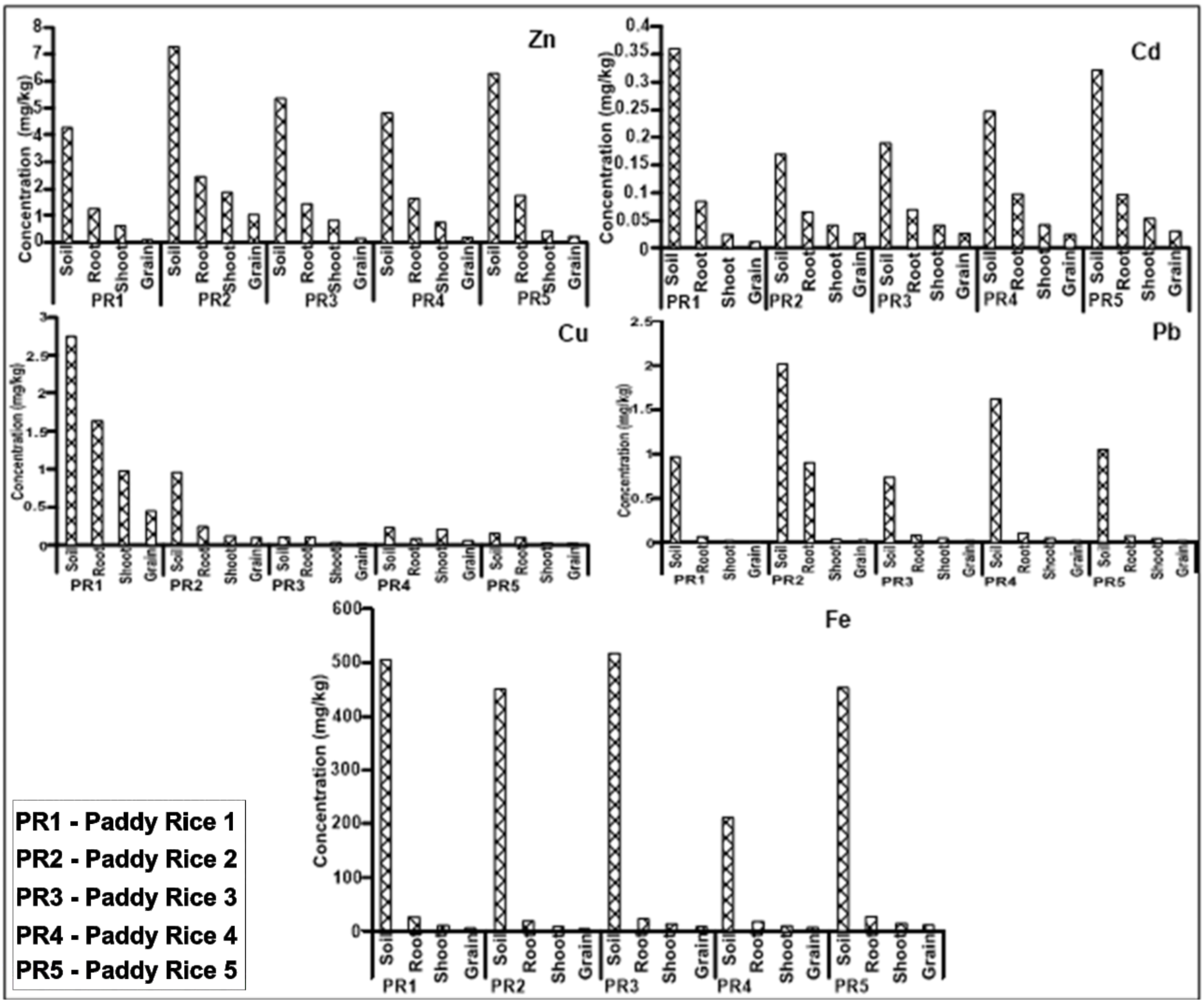

Figure 2: Concentration of heavy metals in paddy rice roots, shoots and grain.

Table 2: FAO/WHO maximum permissible values of metals in plant.

Metal	FAO/WHO maximum permissible values (mg/kg)
Zn	99.40
Cd	0.20
Cu	73.30
Pb	0.30
Fe	425.50

Metal Transfer in Paddy Soils and Plants

Figure 3 displays the results of the bio-accumulation factor (BAF) and transfer factor (TF) of heavy metals in paddy rice plants. Zn, Cd, Cu, Pb, and Fe had BAF values for PR1 of 0.14, 0.07, 0.36, 0.02, and 0.02, respectively. Zn, Cd, Cu, Pb, and Fe had respective TF values of 0.02, 0.03, 0.16, 0.01 and 0.007. Zn, Cd, Cu, Pb, and Fe had BAF values for PR2 of 0.26, 0.24, 0.11, 0.02, and 0.01, respectively. TF for Zn, Cd, Cu, Pb, and Fe were, respectively, 0.14, 0.15, 0.10, 0.01, and 0.007. Zn, Cd, Cu, Pb, and Fe had BAF values for PR3 of 0.16, 0.22, 0.42, 0.06, and 0.03, respectively. TF for Zn, Cd, Cu, Pb, and Fe were, respectively, 0.03, 0.13, 0.26, 0.03, and 0.004. Zn, Cd, Cu, Pb, and Fe had BAF values for PR4 of 0.15, 0.22, 0.29, 0.03, and 0.04, respectively. TF for Zn, Cd, Cu, Pb, and Fe were respectively 0.04; 0.14; 0.07; 0.02; and 0.01. Zn, Cd, Cu, Pb, and Fe had BAF values for PR5 of 0.07, 0.23, 0.21, 0.05, and 0.03, respectively. Zn, Cd, Cu, Pb, and Fe each had a TF of 0.04; 0.13; 0.09; and 0.009, respectively.

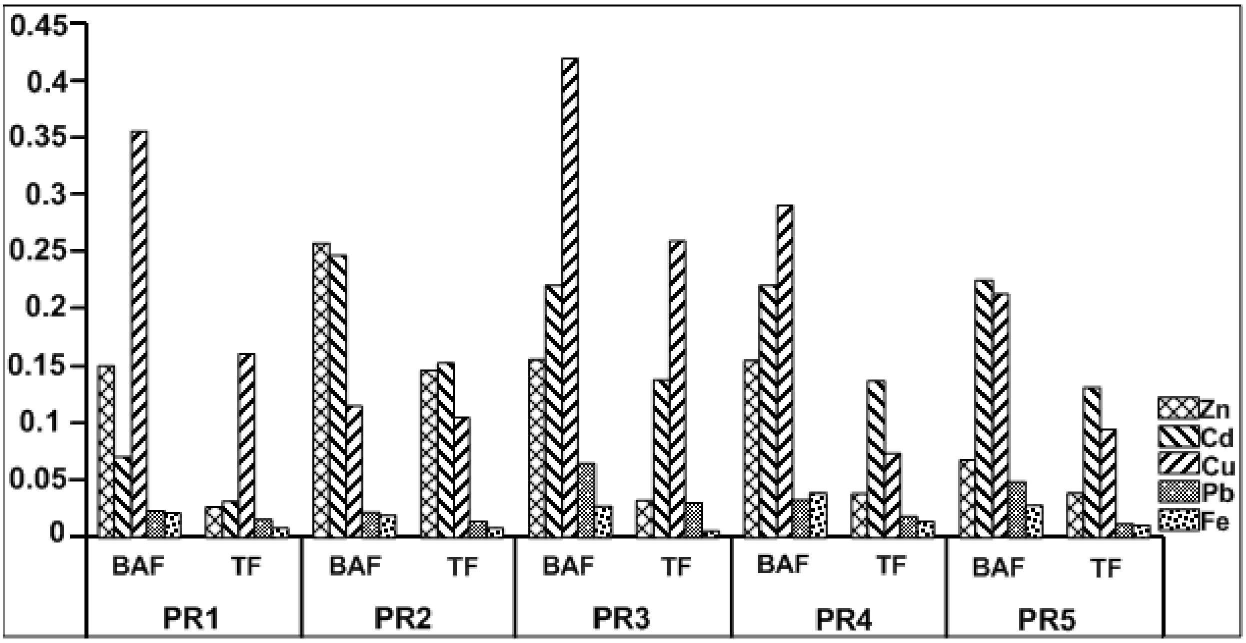

Figure 3: Bioaccumulation and transfer factors of toxic metals in paddy rice of the study area

Contamination Assessment of Heavy Metals in Paddy Soils and Plants

Table 3 shows the findings of the contamination factor (CF), contamination degree (CD), and pollution load index (PLI) of heavy metals in paddy soils. Zn, Cd, Cu, Pb, and Fe had average CFs of 2.72, 2.38, 9.55, 9.52, and 4.26 for S1 and 2.73, 1.93, 2.25, 9.39, and 3.73 for S2, respectively. Zn, Cd, Cu, Pb, and Fe had average CFs for S3 of 3.36, 1.91, 4.89, 11.86, and 3.49, respectively. Zn, Cd, Cu, Pb, and Fe had average CFs of 2.51, 2.87, 5.89, 17.21, and 2.65 for S4, respectively. S1, S2, S3, and S4 all had average CDs of 28.41, 20.01, 25.50, and 31.11, respectively. For S1, S2, S3, and S4, the pollution load index (PLI) was 4.46, 3.11, 3.69, and 4.31, respectively. Figure 4 displays the contamination load index (CLI) of heavy metals in paddy rice grain. While Cd's CLI ranged from 0.55 to 1.33, Zn's CLI ranged from 0.18 to 1.77. For Cu, the CLI range was 0.01 to 0.04, whereas for Pb, it was 0.006 to 0.014. CLI values ranged from 0.005 to 0.01.

Table 3: Contamination assessment of heavy metal in paddy soils.

		CF Zn	CF Cd	CF Cu	CF Pb	CF Fe	CD	PLI
S1	**Minimum**	1.78	1.40	1.64	4.72	2.49	22.82	3.71
	Maximum	4.09	3.60	15.37	14.43	5.71	37.02	6.02
	Average	2.72	2.38	9.55	9.52	4.26	28.41	4.46
S2	**Minimum**	1.60	1.10	1.10	3.43	2.59	13.43	1.69
	Maximum	3.89	2.80	5.64	20.22	4.84	30.03	1.98
	Average	2.73	1.93	2.25	9.39	3.73	20.01	3.11
S3	**Minimum**	2.71	1.10	1.55	1.00	1.94	13.25	2.31
	Maximum	3.87	4.10	8.37	26.72	5.80	37.70	4.97
	Average	3.36	1.91	4.89	11.86	3.49	25.50	3.69
S4	**Minimum**	1.49	1.90	1.73	13.50	1.84	23.48	3.45
	Maximum	3.79	4.40	14.19	22.43	4.34	39.30	5.06
	Average	2.51	2.87	5.89	17.21	2.65	31.11	4.31

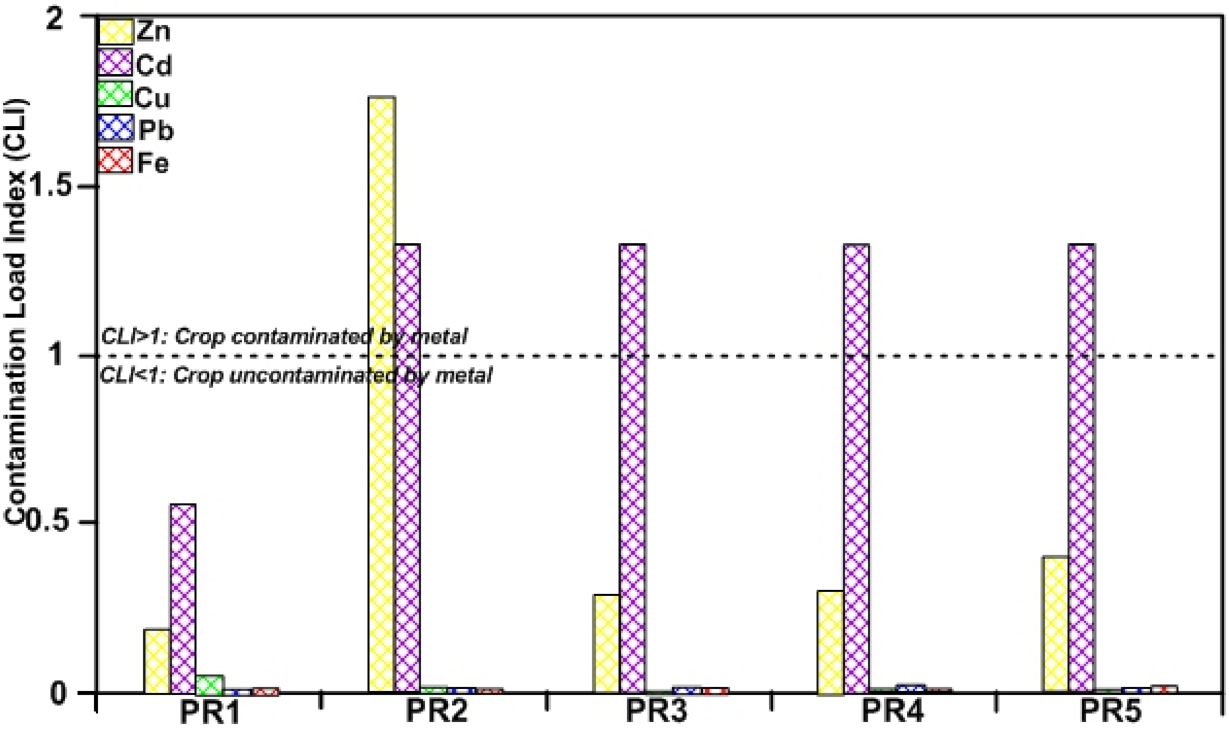

Figure 4: Contamination load index (CLI) for heavy metals in paddy rice grain

Human Health Risk Assessment

Figures 5, 6, and 7 show the risk evaluation of heavy metals for human health. Humans are exposed to non-carcinogenic health concerns if HQ (for soils) and THQ (for plants) levels are greater than 1, but to cancer-causing illnesses if LCR (for soils) values are less than 0.0001. (USEPA 2022). Figures 5 and 6 show the heavy metal hazard quotients (HQ) for paddy soils in the research region. For children, the HQ for Zn, Cd, Cu, Pb, and Fe through oral intake of these metals in soils from sampling site S1 are 2.06E-4, 6.08E-3, 3.63E-4, 4.73E-3, and 8.29E-1, respectively. Metals in paddy soils in S1 had an overall hazard index (HI) of 8.41E-1. With an overall hazard index (HI) of 7.35E-1, the mean HQ for S2 for non-cancer causing health risk in youngsters from oral consumption of Zn, Cd, Cu, Pb, and Fe was 2.06E-4, 4.94E-3, 8.54E-5, 4.67E-3, and 7.26E-1, respectively (Figure 5). The average HQ for non-cancer illnesses caused by oral exposure to Zn, Cd, Cu, Pb, and Fe in paddy soils at sampling site S3 was 2.55E-4, 4.88E-3, 1.86E-4, 5.89E-3, and 6.79E-1, respectively, with an overall HI of 6.91E-1. The mean HQ for oral ingestion of Zn, Cd, Cu, Pb, and Fe in soils at sampling site S4 were 1.90E-4, 7.33E-3, 2.24E-4, 8.55E-3, and 5.15E-1, with a total HI of 5.31E-1 (Figure 5).

For adult, average HQ for non-carcinogenic health risk through ingestion of Zn, Cd, Cu, Pb and Fe for sampling site S1 were 2.21E-5, 6.52E-4, 3.89E-5, 5.07E-4 and 8.88E-2. The overall HI was 9.00E-2. For S2, the mean HQ for non-carcinogenic health risk in adult through oral intake of Zn, Cd, Cu, Pb and Fe were 2.21E-5, 5.29E-4, 9.14E-6, 5.00E-4 and 7.78E-2, respectively with overall HI of 7.88E-2. For soils in sampling site S3, the average HQ for non-cancer causing diseases through oral intake of Zn, Cd, Cu, Pb and Fe were 2.73E-5, 5.23E-4, 1.99E-5, 6.32E-4 and 7.28E-2 each with overall HI of 6.91E-1. The mean HQ for oral ingestion of Zn, Cd, Cu, Pb, and Fe in soils at sampling site S4 was 2.04E-5, 7.86E-4, 2.40E-5, 9.17E-4, and 5.52E-2, with a total HI of 5.69E-2 (Figure 6).

Figure 7 shows the LCR for Pb in paddy soils of the research region for both adults and children. In soils of S1, S2, S3, and S4, the average LCR for Pb in children was 6.13E-8, 6.05E-8, 7.64E-8, and 1.11E-7, respectively. LCR for Pb in soils of S1, S2, S3, and S4 for adults was 3.28E-8, 3.24E-8, 4.09E-8, and 5.94E-8, respectively (Figure 7).

For plants, the range of targeted health quotient

(THQ) for Zn, Cd, Cu, Pb and Fe for adults were 3.03E-2 to 6.86E-3, 2.22E-1 to 9.43E-2, 1.01E-1 to 6.02E-2, 1.47E-1 to 3.43E-4, and 9.17E-1 to 1.83E+0, respectively. Zn, Cd, Cu, Pb, and Fe THQ ranges for children were 1.06E-2 to 7.94E-3, 1.15E-3 to 4.85E-4, 7.05E-4 to 1.94E-2, 9.70E-4 to 1.15E-3, and 9.43E-2 to 1.25E-1, respectively (Table 4).

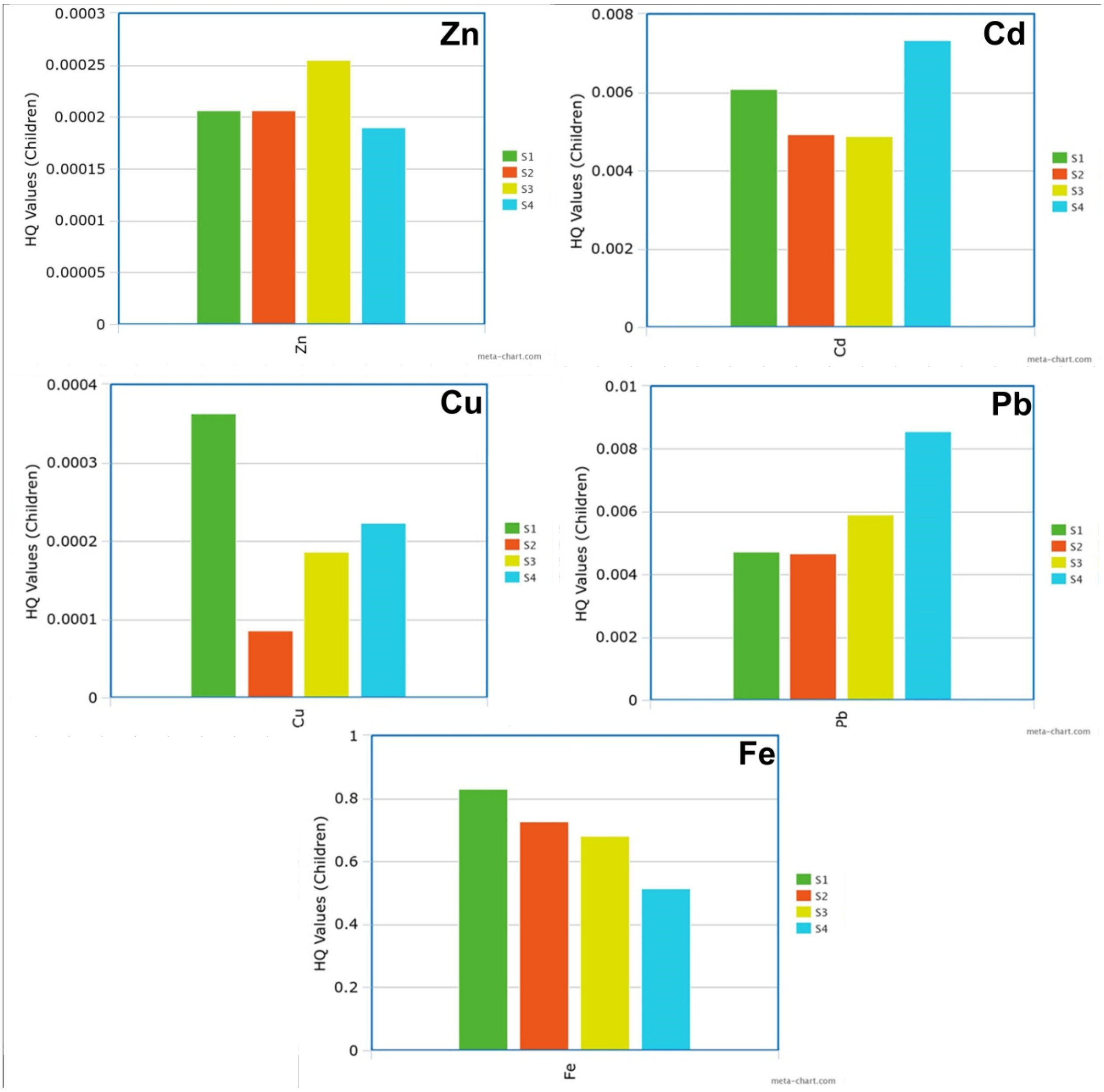

Figure 5: Hazard Quotient (HQ) values of heavy metals for non-cancerous health risk for children in paddy soils of 4 different sampling areas.

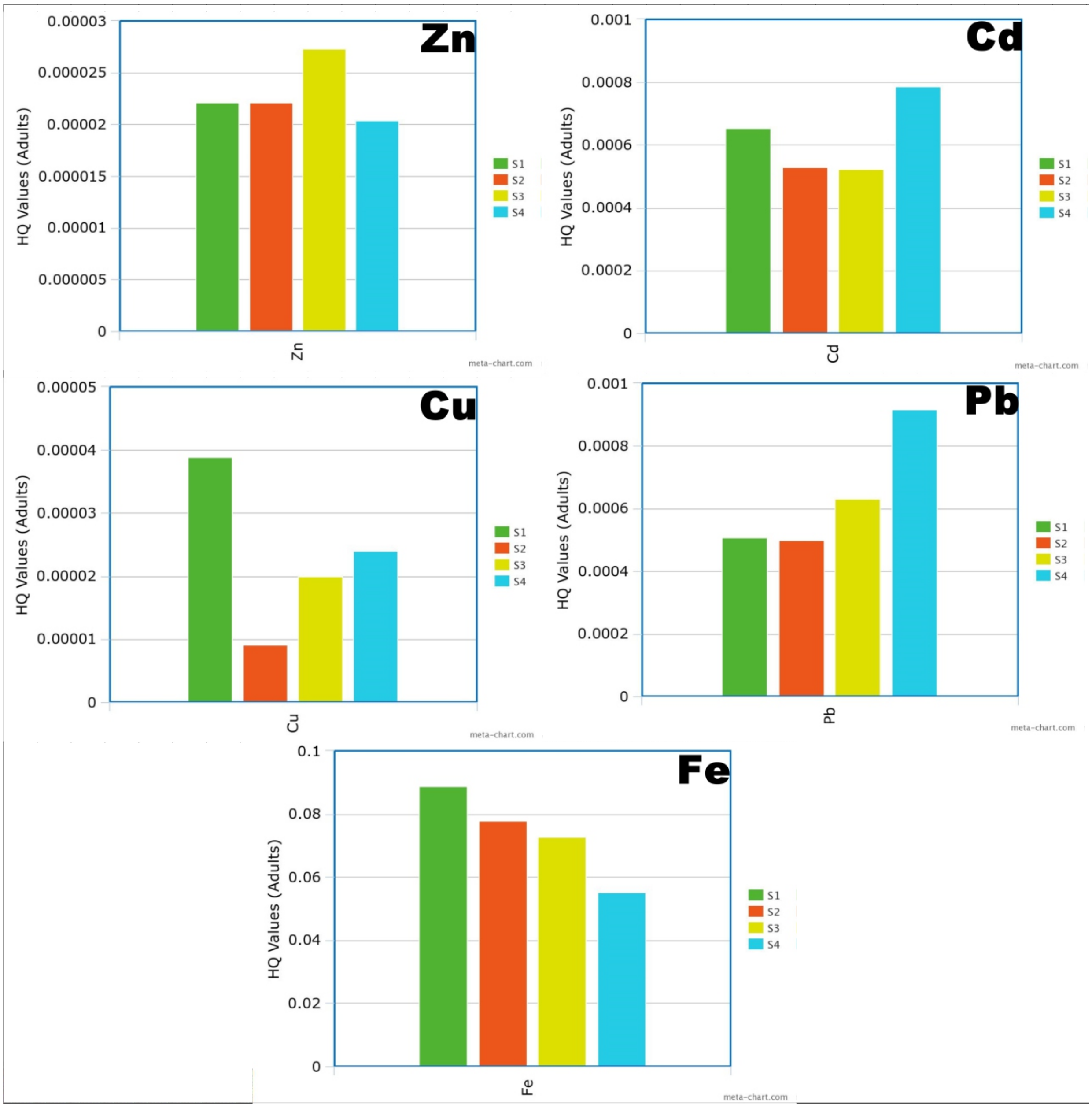

Figure 6: Hazard Quotient (HQ) values of heavy metals for non-cancerous health risk for adults in paddy soils of 4 different sampling areas.

Table 4: Targeted Health Quotient (THQ) for heavy metals in paddy rice grain

		THQ Zn	**THQ Cd**	**THQ Cu**	**THQ Pb**	**THQ Fe**
Adult	Plant 1	3.14E-3	9.43E-2	1.01E-1	1.71E-4	1.58E+0
	Plant 2	3.03E-2	2.23E-1	2.31E-2	3.18E-4	1.40E+0
	Plant 3	4.86E-3	2.23E-1	6.02E-3	2.69E-4	9.17E-1
	Plant 4	5.14E-3	2.22E-1	3.71E-3	3.43E-4	1.22E+0
	Plant 5	6.86E-3	2.57E-1	3.24E-3	1.47E-4	1.83E+0
Children	Plant 1	4.85E-3	4.85E-4	1.94E-2	6.17E-4	1.63E-1
	Plant 2	4.67E-2	1.15E-3	4.41E-3	1.15E-3	1.44E-1
	Plant 3	7.49E-3	1.15E-3	1.15E-3	9.70E-4	9.43E-2
	Plant 4	7.94E-3	1.15E-3	7.05E-4	1.23E-3	1.25E-1
	Plant 5	1.06E-2	1.32E-3	6.17E-4	5.29E-4	1.89E-1

DISCUSSION

In this study, it was determined that heavy metal concentrations in paddy soils of the study region were greater than those detected in the control sample but lower than the USEPA's (2002) recommended limits (Table 1). Zn, Cd, Cu, and Pb concentrations in paddy soils in this region were lower than those reported by Zhong *et al.* (2010) in China, Satpathy *et al.* (2014) in India, and Machiwa (2010) in Tanzania, which are comparable studies conducted in other regions of the world. While Cu levels were greater than those published by the same study, Zn, Pb, and Fe in the soil samples were below those reported in paddy soils of Bangladesh by Halim *et al.* (2014). Paddy soils in this area have greater organic matter content (OMC) than soils in Tanzania as reported by Machiwa (2010) (Table 1). The quantities of Zn, Cd, Cu, Pb, and Fe in the roots, shoots, and grains of paddy rice plants were lower than those detected in the soils (Figure 2). It was found that the amount of metals in the local rice grains was lower than the FAO/WHO recommended level (Table 2). The results of this study's BAF indicated that heavy metals in the soils were not efficiently bioaccumulating in the plants since they were less than 1. (Figure 3). All of the metal's TF values were less than one, indicating that they were not properly transferred from the soil to the root (Figure 3).

According to Hakanson (1980), the contamination factor (CF) used in this study showed that the area's paddy soils were moderately to significantly contaminated by Zn, Cu, and Fe while they were moderately to very contaminated by Cu and Pb (Table 3). Furthermore, metals in paddy soils of this area posed moderate to extremely high degree of pollution as indicated by the contamination degree (CD) (Table 3). This claim was further supported by the pollutant load index, which uncovered that the presence of metals in the region is degrading the soil (Table 3). Anthropogenic activities that take place quite near to the region are blamed for polluting the paddy soils there. Household, industrial, and agricultural wastes produced in this region were easily swept down into the drainage system due to its low terrain in comparison to the nearby area. The research also revealed that the local paddy rice was polluted, particularly in sample PR2 (Figure 4), with Zn, whereas samples PR2, PR3, PR4, and PR5 were contaminated with Cd (Figure 4). Only sample PR1 was free of these metal contamination, maybe as a result of its great distance from suspected human sources. Zinc in plants may result in photosynthesis being reduced, reduced root development, and stunted growth (Kaur and Garg, 2021). Due to the excessive production of reactive oxygen species (ROS) caused by cadmium toxicity, plant membranes are damaged as well as cell organelles and macromolecules (Abbas *et al.*, 2017). Also, cadmium prevents plants from absorbing Fe and Zn, which results in leaf chlorosis (Xu *et al.*, 2017).

According to USEPA (2022), human health risk assessment (HHRA) of heavy metals in soils from this region showed that the metal's HQ for both adults and children were less than 1 for non-carcinogenic risk and less than 1E-4 for carcinogenic risk (Figures 5, 6 and 7). This demonstrated that oral consumption of heavy metals from local soils does not expose adults or children living in this location to any known carcinogenic or non-carcinogenic health hazards. However, the study found that youngsters may be more susceptible to infections than adults in the region since they had higher HQ values than adults (Adewumi *et al.*, 2020). Oral ingestion of Zn, Cd, Cu, and Pb found in paddy rice grains from the region may not have any non-carcinogenic health impacts on both adults and children, according to findings by the targeted health quotient (THQ) (Table 4). There are no non-carcinogenic health concerns that affect children in this region (Table 4). However, it was shown that consuming too much Fe from paddy rice grains from the region may be hazardous to adult's health over time. Fe consumption in excess can cause hematemesis, diarrhea, stomach discomfort, and nausea (Spanierman, 2021). It may also result in heart, kidney, lung, and hematologic system abnormalities as well as mitochondrial dysfunction (Spanierman, 2021).

CONCLUSIONS

This investigation assessed the level of pollution, absorption, and health concerns related to toxic metals in rice plants and paddy soils in the Ogbese region of southwest Nigeria. It was discovered that the levels of heavy metals in the paddy soils and rice plants in this region were lower than suggested limits and those found in comparable research worldwide. The study also showed that the area's soils were contaminated with heavy metals, and rice grains were primarily contaminated with Cd. The study also shown that heavy metals from soils were not efficiently absorbed by plant roots and entered plant systems. Also, the research uncovered that human activities have play significant role in the discharge of heavy metals into the soil in this region. Heavy metals in soils were assessed for their potential to cause cancer and other disorders that are not cancerous to humans, however as of the time of this study, neither of the conditions existed. The study also shown that high oral Fe consumption from the paddy rice might expose people in this region to non-carcinogenic health risks. To prevent their negative effects on the environment and public health, it is advised that human activities that might raise the amount of lethal metals in the paddy environment be limited.

Potential Conflict of Interest: There are no conflicts of interest for this work

Author contributions:
A.A.J.: Conceptualization, methodology, investigation, resources, writing - original draft presentation, writing – review and editing, visualization, supervision.
L.A.E.: Investigation, resources, writing - original draft preparation.

REFERENCES

Abbas, T., Rizwan, M., Ali, S., Adrees, M., Zia-ur-Rehman, M., Qayyum, M.F., Ok, Y.S. and Murtaza, G. 2017. Effect of biochar on alleviation of cadmium toxicity in wheat (*Triticum aestivum* L.) grown on Cd-contaminated saline soil. *Environmental Science and Pollution Research*, 25:25668–25680. doi.org/10.1007/s11356-017-8987-4

Adewumi, A.J., Anifowose, A.Y.B., Olabode, F.O. and Laniyan, T.A. 2018. Hydrogeochemical characterization and vulnerability assessment of shallow groundwater in Basement Complex Area, Southwest Nigeria. *Contemporary Trends in Geoscience,* 7(1):72-103. doi.org/10.2478/ctg-2018-0005

Adewumi, A.J., Laniyan, T.A. and Ikhane, P.R. 2021. Distribution, contamination, toxicity, and potential risk assessment of toxic metals in media from Arufu Pb–Zn–F mining area, northeast Nigeria. *Toxin Reviews*, 40(4):997-1018. doi.org/10.1080/15569543.2020.1815787

Adewumi, A.J. and Laniyan, T.A. 2020. Contamination, sources and risk assessments of metals in media from Anka artisanal gold mining area, Northwest Nigeria. *Science of the Total Environment*, 718:137235. doi.org/10.1016/j.scitotenv.2020.137235

Adewumi, A.J., Laniyan, T.A., Xiao, T., Liu, Y. and Ning, Z. 2020. Exposure of children to heavy metals from artisanal gold mining in Nigeria: Evidences from bio-monitoring of hairs and nails. *Acta Geochimica*, 39(4):451-470. doi.org/10.1007/s11631-019-00371-9

Akinbile, C.O. and Omoniyi, O. 2018. Quality assessment and classification of Ogbese River using water quality index (WQI) tool. *Sustainable Water Resources Management,* 4(4):1023-1030. 10.1007/s40899-018-0226-8

Bakers, A.J.M. and Brooks, R.R. 1989. Terrestrial higher plants which hyper accumulate metallic elements – a review of their distribution, ecology and phytochemistry. *Biorecovery,* 1:81-96.

Chien, L.C., Hung, T.C. and Choang, K.Y. 2002. Daily intake of TBT, Cu, Zn, Cd and As for fishermen in Taiwan. *Science of the Total Environment*, 285:177–185. doi.org/10.1016/s0048-9697(01)00916-0

Ghosh, M. and Singh, S.P. 2005. A comparative study of cadmium phytoextraction by accumulator and weed species. *Environmental Pollution*, 133:365–371. https://doi.org/10.1016/j.envpol.2004.05.015

Haider, F.U., Liqun, C., Coulter, J.A., Cheema, S.A., Wu, J., Zhang, R. and Farooq, M. 2021. Cadmium toxicity in plants: Impacts and remediation strategies. *Ecotoxicology and Environmental Safety*, 211:111887. doi.org/10.1016/j.ecoenv.2020.111887

Hakanson, L. (1980). An ecological risk index for aquatic pollution control, a sedimentological approach. *Water Resources*, 14:975–1001. doi.org/10.1016/0043-1354(80)90143-8

Halim, M.A., Majumder, R.K. and Zaman, M.N. 2015. Paddy soil heavy metal contamination and uptake in rice plants from the adjacent area of Barapukuria coal mine, northwest Bangladesh. *Arabian Journal of Geosciences*, 8(6):3391-3401. https://doi.org/10.1007/s12517-014-1480-1

John, F.T. 2012. Post-Harvest Handling of Rice Paddy and Its Effects on Paddy Quality: A Case Study of Olam Nigeria Outgrowers in Pategi Local Government Area of Kwara State, Nigeria. pp. 61. https://edepot.wur.nl/298425

Kaur, H., Garg, N. 2021. Zinc toxicity in plants: a review. *Planta* 253, 129. doi.org/10.1007/s00425-021-03642-z

Khai, H.V. and Yabe, M. 2013. Impact of industrial water pollution on rice production in Vietnam. International Perspectives on Water Quality Management and Pollution Control, 61-85. 10.5772/54279

Machiwa, J.F. 2010. Heavy metal levels in paddy soils and rice (Oryza sativa (L)) from wetlands of Lake Victoria Basin, Tanzania. *Tanzania Journal of Science*, 36:59-72

Moradi, A., Honarjoo, N., Najafi, P. and Fallahzade, J. 2015. A human health risk assessment of soil and crops contaminated by heavy metals in industrial regions, central Iran. *Human and Ecological Risk Assessment: an International Journal,* 22(1):153-167. doi.org/10.1080/10807039.2015.1056293

Nadal, M., Ferré-Huget, N. and Martí-Cid, R. 2008. Exposure to metals through the consumption of fish and seafood by population living near the Ebro River in Catalonia, Spain. *Health Risks Human Ecology Risk Assessment,* 14:780–795. doi.org/10.1080/10807030802235235

Obiora-Okeke, O.A., Adewumi, J.R. and Ojo, O.M. 2021. Impact of Climate Change on Runoff Prediction in Ogbese River Watershed. FUOYE Journal of Engineering and Technology, 6(4):2579-0625. dx.doi.org/10.46792/fuoyejet.v6i4.721

Satpathy, D., Reddy, M.V. and Dhal, S.P. 2014. Risk assessment of heavy metals contamination in paddy soil, plants, and grains (*Oryza sativa L.*) at the East Coast of India. *BioMed Research International*, 2014:545473. https://doi.org/10.1155/2014/545473

Spanierman, C.S. (2021). Iron Toxicity. Available at https://emedicine.medscape.com/article/815213-overview?reg=1#a5

Tomlinson, D.L., Wilson, J.G., Harris, C.R. and Jeffrey, D.W. 1980. Problems in the assessment of heavy-metal levels in estuaries and the formation of a pollution index. *Helgolander Meeresunters*, 33:566–575. doi.org/10.1007/BF02414780

USEPA. 2002. Supplemental guidance for developing soil screening levels for superfund sites. Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, D.C.

USEPA. 2022. Human Health Risk Assessment. Available at https://www.epa.gov/risk/human-health-risk-assessment

Xu, Z.M., Li, Q.S., Yang, P., Ye, H.J., Chen, Z.S., Guo, S.H., Wang, L.L., He, B.Y. and Zeng, E. Y. 2017. Impact of osmoregulation on the differences in Cd accumulation between two contrasting edible amaranth cultivars grown on Cd-polluted saline soils. Environmental Pollution, 224:89–97. https://doi.org/10.1016/j.envpol.2016.12.067

Zhong, L., Liu, L. and Yang, J. 2010. Assessment of heavy metals contamination of paddy soil in Xiangyin County, China. In Proceedings of the 19th World Congress of Soil Science: Soil solutions for a changing world, Brisbane, Australia, 1-6 August 2010. pp. 17-20

Zulkafflee, N.S., Redzuan, N.A.M., Hanafi, Z., Selamat, J., Ismail, M.S., Praveena, S.M. and Abdull Razis A.F. 2019. Heavy Metal in Paddy Soil and its Bioavailability in Rice Using In-Vitro Digestion Model for Health Risk Assessment. International Journal of Environmental Research and Public Health 16(4769), 1-12. 10.3390/ijerph16234769