ABUAD INTERNATIONAL JOURNAL OF NATURAL AND APPLIED SCIENCES
ISSN: 2955-1021
AIJNAS Volume 5, Issue 1, 2025 pp 10-18
https://doi.org/10.53982/aijnas.2025.0501.02-j

https://journals.abuad.edu.ng/index.php/aijnas

AIJNAS

Assessment of Heavy Metals and Phytochemicals in Soil and Rice Samples Cultivated in a Selected Agricultural Region of Nigeria

Erhuen E*., Ojo A. A., Onasanya A. A. and Adewole E.
Department of Chemical Sciences, College of Sciences, Afe Babalola University, Ado-Ekiti, Ekiti State, Nigeria

Abstract
Rice is a staple food consumed daily by millions of Nigerians, making the safety of its cultivation critical to public health. Given the potential for bioaccumulation and toxicity, the presence of heavy metal residues in rice poses serious health risks, necessitating a thorough assessment of both heavy metals and phytochemicals in rice and the soils where it is cultivated across selected agricultural regions of Nigeria. This study assesses the concentrations of heavy metals and phytochemicals in soil and rice samples (parboiled and paddy) collected from Abuja and Kogi State in Nigeria. Determination of Pb, Cr, Zn, Cd, Mn, Fe, Ni and Cu in soil and rice samples was analyzed Using AAS Buck Scientific 211 AAS VGP, while the Determination of essential elements (Ca, Na, K and Mg) in soil and rice samples was done Using flame photometry (Jenway Digital Flame Photometer, PFP7 Model). The most prevalent essential and heavy metals are calcium (32.25±0.354), magnesium (14.292±0.008), and zinc (28.167±0.004), and the results showed that paddy rice had higher amounts of these elements than parboiled rice. Some metals exhibited bioaccumulation tendencies, with bioaccumulation values surpassing 1, particularly zinc and cadmium. Phytochemical analysis was carried out using High Performance Liquid Chromatography (HPLC) with the highest flavonoid component, Apigenin (0.2632 mg/g) in paddy rice obtained from Kogi State, while rice samples obtained from Abuja, had Protocatechuic acid (0.9076 mg/g) and Ferulic acid (0.97 mg/g) as the highest phenolic components. Higher amounts of phytochemicals, which are advantageous for their antioxidant qualities, were retained in parboiled rice, suggesting that conventional parboiling techniques can aid in the retention of substances that promote health. For adults, the Hazard Index (HI) values of the metals were all less than 1, indicating low health risk while the HI value for the children in both locations was greater than 1 indicating potential adverse health effects. In order to guarantee food safety, the results highlight the necessity of routinely checking rice for pollutants and encouraging safer farming methods.
Keywords: *Heavy metals, soil, rice, phytochemicals*

INTRODUCTION

Environmental contamination from heavy metals residues, are having an increasing impact on agricultural production (Alengebawy *et al*., 2021). Due to its ability to bioaccumulate toxic and non-toxic substances from soil and water, rice (Oryza sativa), a staple food for more than half of the population of the world, is especially vulnerable to these environmental pollutants (Uddin *et al*., 2021). While its phytochemical content poses possible health advantages depending on growth and processing conditions, the possibility that rice could become a medium of human exposure to heavy metals raises serious concerns about food safety (Tan *et al*., 2020). Lead (Pb), cadmium (Cd), mercury (Hg), nickel (Ni), copper (Cu) and arsenic (As) are examples of heavy metals, which are non-biodegradable and persistent toxic substances in the environment (Uddin *et al*., 2021). They can build up in water, and soil, and bioaccumulate in crops, thereby contaminating the food chain. The main causes of heavy metal contamination in agricultural soils include mining, industrial operations, use of inorganic fertilizers in the farms, and inappropriate waste disposal (Mitra *et al*., 2022 and Jin *et al*., 2020). Rice plants are especially vulnerable to bioaccumulate heavy metals from the surrounding soil and water because of the special growth environment they experience in flooded paddy fields (Liu *et al*. 2021). These metals cannot be removed once they have been taken up by plants, and when rice is consumed by humans, they may then bioaccumulate in the body (Mitra *et al*., 2021). Dietary consumption is the main method by which the general public is exposed to heavy metals, and in nations where rice is a staple food, it is a major source (Tan *et al*., 2020). Numerous detrimental health effects have been connected to extended exposure to heavy metals. Exposure to arsenic is linked to skin lesions, cancer, and cardiovascular disease, whereas exposure to cadmium can cause kidney damage and osteoporosis (Zaynab *et al*., 2022). Mercury damages the nervous system, and lead exposure can cause developmental problems and neurological abnormalities in children (Zaynab *et al*., 2022).

Plants naturally contain substances called phytochemicals, which are of interest due to possible health benefits. These bioactive substances include phenolics, flavonoids, and saponins (Biondi *et al*., 2021). They have anti-inflammatory, anti-cancer, and cardiovascular protective qualities in addition to acting as antioxidants (Guan *et al*., 2021). Depending on variables including rice type, soil composition, and production practises, the amount of phytochemicals in rice can vary greatly, which can have varying effects on human health (Tan et al.,2020). Whereas oxidative stress resulting from accumulation of free radicals is linked to a number of chronic illnesses, however, the main health benefits of phytochemicals come from their capacity to combat these free radicals and lessen oxidative stress. (Tan et al., 2020, Sen et al., 2020). Flavonoids are known to improve vascular function and prevent heart disease, while phenolic compounds have anti-inflammatory properties that may help treat illnesses like arthritis (Sen *et al*., 2020). Furthermore, by preventing tumour growth and encouraging cancer cell death, some phytochemicals found in rice are thought to offer protection against specific types of cancer (Fatchiyah *et al*., 2020). However, certain rice cultivars contain saponins, which might function as anti-nutrients by preventing the absorption of nutrients and possibly causing gastrointestinal distress when ingested in excess (Yu et al., 2020). This study assesses the concentrations of heavy metals and phytochemicals in *parboiled and paddy rice collected from the Federal Capital Territory (Abuja) and Kogi State in Nigeria* and their respective soil samples.

MATERIALS AND METHODS

Study area

This study was carried out using samples that were collected from Abuja, the Federal Capital City of Nigeria and Kogi State which shares a boundary with the capital city. Both locations are home to rice cultivation and are part of the middle-belt region of Nigeria.

Sampling

Upland rice samples and soils were collected from rice field in Kwali, Abuja and Ibaji in Kogi State. Using a soil auger, soil samples were taken between 0 and 15 cm below the surface. After being wrapped in black polythene, the samples were brought to the laboratory. Following air drying and pulverisation with a mortar and pestle, they were sieved through a 2 mm mesh screen before analysis.

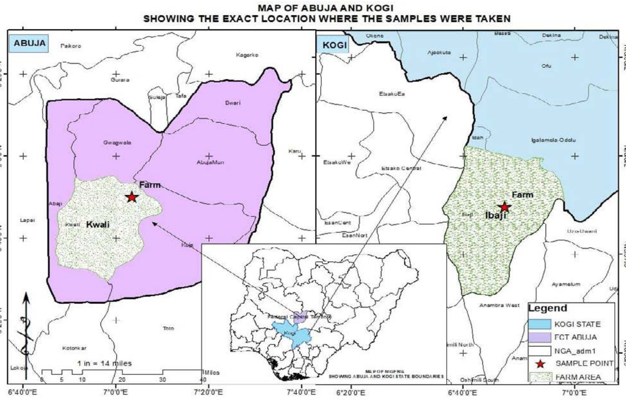

Figure 1: Map of the study area showing sampling locations.

Analytical procedures

Heavy metals in soil and rice

2g each of rice and soil samples were wet digested by the addition of 20 mL of HNO_3:$HClO_4$ (5:1) mixture to obtain a clear solution. The digested samples were cooled, filtered and transferred to 25 mL volumetric flask and distilled water was made to mark, and the metal concentrations were determined using an atomic absorption spectrophotometer (AAS) (Buck 211) (Howe *et al*.,2005).

Essential Metal Contents in rice

2g of rice samples were wet digested by the addition of 20 mL of HNO_3:$HClO_4$ (5:1) mixture to obtain a clear solution. The digested samples were cooled, filtered and transferred to 25mL volumetric flask and distilled water was made to mark, and the metal concentrations were determined using flame photometry (Jenway Digital Flame Photometer, PFP7 Model), to identify Ca, K, Mg, and Na, which are the essential metals found in rice and soil samples (Tilahun *et al*., 2015).

Health risk assessment

Bioaccumulation factor

The bioaccumulation factor (BAF) refers to the ratio of contaminant concentration in grains to that of the soil. The BAF were determined as follows:

$$BAF = \frac{C_R}{C_S}$$

Where C_R is the concentration of contaminant in rice and C_S is the concentration of the same contaminant in the soil (Zhang *et al*. 2010).

Bioaccumulation factor is rated as follows: BAF < 1 - low bioaccumulation; 1 to 10 - moderate bioaccumulation; 10 to 100 - high bioaccumulation; and >100 - very high bioaccumulation.

Non-carcinogenic health risk for heavy metals

The health risk associated with heavy metals was determined as shown below. The average daily dose was determined as follows:

$$ADD = \frac{C\ x\ IR\ x\ EF\ x\ ED}{BW\ x\ AT}$$

Where: ADD is the average daily dose (mg/kg-day); C is the concentration (mg/l); IR is the intake rate (I/day) = 70 kg/day; EF is the frequency of exposure (day/year) = 365 days/year; ED is the duration of exposure (year) = 70 years; BW is the bodyweight (kg) = 70 kg; and AT is the averaging time (day) = 25,550 days (Olaleye *et al.* 2022).

$$HQ = \frac{ADD}{RfD}$$

$$HI = HQ_1 + HQ_2 + \cdots + HQ_n$$

Where: HQ is the hazard quotient; HI is the hazard index and Rfd is the reference dose for each metal. The individual metal toxicity responses (dose response) are 1.0×10^{-3} for Cd, 3.0×10^{-3} for Cr, 3.5×10^{-3} for Pb, 1.4×10^{-2} for Mn, 7.0×10^{-1} for Fe, 3.0×10^{-1} for Zn, 4.2×10^{-2} for Cu and 2.0×10^{-2} for Ni, all in mg/kg/day as the Oral Reference Dose (RFD) (USEPA IRIS, 2011 and Wongsasuluk *et al.* 2014).

HQ > 1 indicates unacceptable risk of non-carcinogenic health effects, and HQ < 1 indicates that the risk level is acceptable. Also, HI > 1 indicates unacceptable risk of non-carcinogenic health effects, and HI < 1 indicates that the risk level is acceptable.

Phytochemicals in Rice

1g of powdered rice samples was placed in 10 mL of distilled water for 4 hours. After that, the mixture was filtered. Tests for the identification of tannins and phenolic chemicals, the lead acetate test for flavonoids, the foam test for saponins, and Mayer and Wager's test for alkaloids were all performed on the filtrate. The sole phytochemical found in the samples, total phenols and flavonoids, were then measured using spectrophotometry and high-performance liquid chromatography. The results of the analyses were recorded in mg/g (Harborne, 1973; Obadoni, 2001; Olajire et al., 2011; Sathish et al., 2024).

Statistical analysis

The data obtained from all the analyses for this study were entered into Microsoft Excel spreadsheets and analysed using descriptive and inferential tests (paired samples t-tests). Data presentation was done using charts and labelled appropriately.

RESULTS

Essential and Heavy Metal Element Concentrations

The concentrations of essential elements (Ca, K, Mg and Na) in soil and rice samples were determined and shown in Table 1 and Figure 2. The essential metal contents in Abuja ranged from 8.450 mg/kg (Na) to 17.700 mg/kg (Ca) in soil, 12.369 mg/Kg and 12.813 mg/Kg (Mg) to 29.400 mg/Kg and 27.550 mg/Kg (Ca) in both paddy and parboiled respectively. In Kogi, parboiled rice had the highest value in Potassium (K), 29.600 mg/Kg when compared with soil and paddy samples. All heavy metals were below standard values, with Zinc having the highest value in soil, paddy and parboiled samples from both Abuja and Kogi. The elements with the highest concentrations were Ca, Zn and Mg in that order. The concentrations of heavy metals in soil and paddy rice from Abuja and Kogi were significantly different at p<0.05, while those of parboiled rice were not.

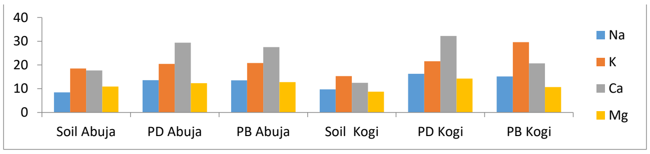

Figure 2: Essential Metal content in rice and soil from Abuja (Kwali) and Kogi State (Ibaji)

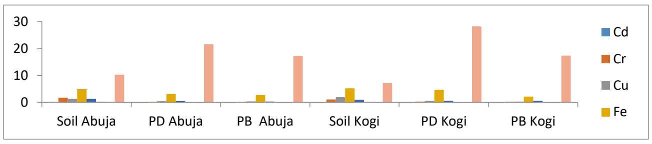

Figure 3: Heavy Metal content in rice and soil from Abuja (Kwali) and Kogi State (Ibaji)

Table 1: Determination of Essential and Heavy Metal Content (mg/kg) in Soil, Parboiled and Paddy Rice collected from Kwali in Abuja and Ibaji in Kogi State.

S/N	Element	Soil Abuja	PD Abuja	PB Abuja	Soil Kogi	PD Kogi	PB Kogi	WHO/FAO (Mg/Kg) (Soil)	WHO/FAO (Mg/Kg) (Rice)
1	Na	8.450 ±0.045	13.600 ±0.08	13.550 ±0.245	9.700 ±0.08	16.250 ±0.005	15.150 ±0.005		
2	K	18.500 ±0.08	20.450 ±0.045	20.850 ±0.02	15.300 ±0.02	21.550 ±0.0068	29.600 ±0.02		
3	Ca	17.700 ±0.283	29.400 ±0.141	27.550 ±0.5	12.450 ±0.212	32.250 ±0.354	20.650 ±0.212	-	-
4	Mg	10..950 ±0.004	12.369 ±0.006	12.813 ±0.004	8.757 ±0.004	14.292 ±0.008	10.728 ±0.003	-	-
5	Cd	0.153 ±0.004	0.046 ±0.002	0.0175 ±0.004	0.0107 ±0.004	0.026 ±0.001	0.006 ±0.002	3	0.02
6	Cr	1.744 ±0.002	0.173 ±0.006	0.130 ±0.003	1.072 ±0.002	0.296 ±0.001	0.208 ±0.003	100	5
7	Cu	1.271 ±0.002	0.428 ±0.002	0.313 ±0.045	1.946 ±0.001	0.519 ±0.006	0.293 ±0.004	100	40
8	Fe	4.898 ±0.004	3.127 ±0.004	2.714 ±0.004	5.217 ±0.006	4.613 ±0.008	2.085 ±0.002	-	450
9	Mn	1.281 ±0.076	0.478 ±0.006	0.251 ±0.005	0.906 ±0.002	0.547 ±0.006	0.509 ±0.004	2000	500
10	Ni	0.212 ±0.004	0.068 ±0.003	0.054 ±0.008	0.174 ±0.006	0.102 ±0.002	0.086 ±0.003	100	1.5
11	Pb	0.210 ±0.006	0.022 ±0.003	0.014 ±0.001	0.107 ±0.002	0.069 ±0.002	0.012 ±0.001	60	0.30
12	Zn	10.256 ±0.009	21.529 ±0.006	17.254 ±0.008	7.136 ±0.001	28.167 ±0.004	17.357 ±0.009	300	60

PD: Paddy, *PB: Parboiled.*

Phytochemicals in rice

The concentrations of flavonoids and phenolic compounds in the rice samples from Abuja are shown in Figures 4 and 5. The concentrations of flavonoids in paddy rice ranged from 0.2mg/g (Naringenin) to 0.262mg/g (Apigenin), while phenolic compounds ranged from 0.168mg/g (Feruloyl aldaric acid) to 0.97mg/g (Ferulic acid). For parboiled rice, flavonoids ranged from 0.1939mg/g (Quercetin) to 0.249mg/g (Apigenin), while phenolic compounds ranged from 0.1247mg/g (Feruloyl aldaric acid) to 0.9706mg/g (Protocatechuic acid).

The concentrations of flavonoids and phenolic compounds in the rice samples from Kogi are shown in Figures 6 and 7. The concentrations of flavonoids in paddy rice ranged from 0.2127mg/g (Naringenin) to 0.2632mg/g (Apigenin), while phenolic compounds ranged from 0.1619mg/g (Feruloyl aldaric acid) to 0.9687mg/g (Ferulic acid). For parboiled rice, flavonoids ranged from 0.2043mg/g (Quercetin) to 0.2373mg/g (Apigenin), while phenolic compounds ranged from 0.1463mg/g (Feruloyl aldaric acid) to 0.9456mg/g (Protocatechuic acid). The concentrations of flavonoids in paddy rice from Abuja and Kogi were significantly different at $p<0.05$, while those of flavonoids in parboiled rice and phenolic compounds in paddy and parboiled rice were not significantly different.

Table 2: Qualitative Phytochemical Analysis in rice

Sample	Paddy Abuja	Parboiled Abuja	Paddy Kogi	Parboiled Kogi
Phenols	++	++	++	++
Flavonoids	++	++	++	++
Terpenoids	-	-	-	-
Alkaloid	+	+	-	-
Steroids	-	-	-	-

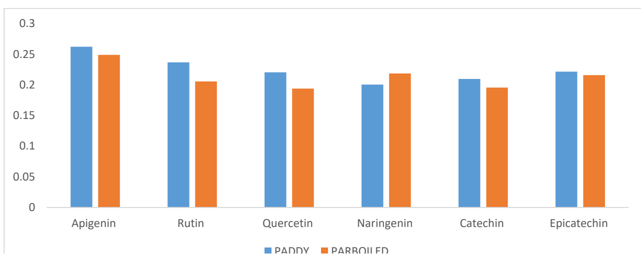

Figure 4: Flavonoids in rice samples from Abuja (Kwali).

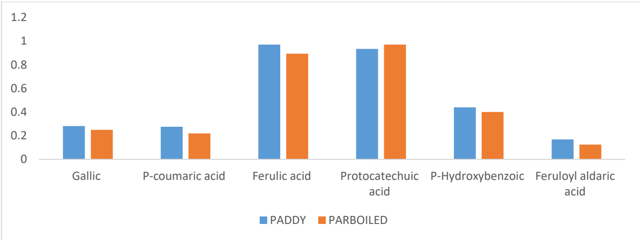

Figure 5: Phenolics in rice samples from Abuja (Kwali)

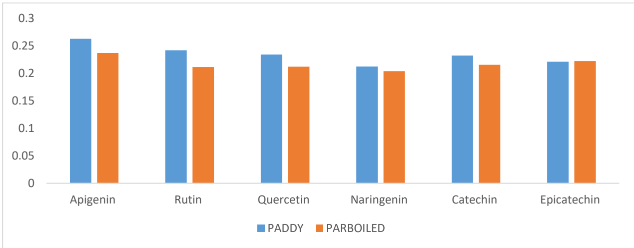

Figure 6: Flavonoids in rice samples from Kogi State (Ibaji)

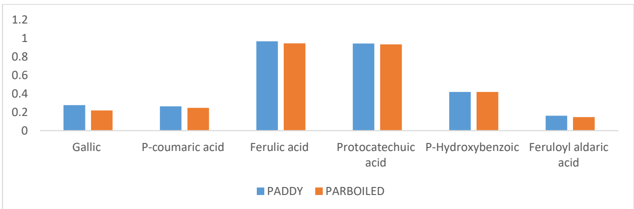

Figure 7: Phenolics in rice samples from Kogi State (Ibaji)

Health risk assessment

Bioaccumulation factor

The bioaccumulation factor (BAF) values determined during this study are presented in Table 3. For Abuja, BAF values were less than 1 except for Zn in paddy rice and, Cd and Cr in parboiled rice. For Kogi, the values of BAF were all less than 1 with the exception of Zn and Cd in paddy rice, and Zn in parboiled rice.

Table 3: Bioaccumulation factor for heavy metals in rice

Element	Paddy Abuja	Parboiled Abuja	Paddy Kogi	Parboiled Kogi
Cd	0.301	1.556	2.429	0.561
Cr	0.099	1.170	0.276	0.194
Cu	0.337	0.114	0.267	0.151
Fe	0.638	0.074	0.884	0.399
Mn	0.373	0.246	0.604	0.561
Ni	0.321	0.554	0.586	0.494
Pb	0.105	0.196	0.645	0.112
Zn	2.099	0.255	3.947	2.432

Non-carcinogenic risk for heavy metals

The non-carcinogenic risk indices, which refer to the potential for adverse health effects that are not related to cancer, are calculated for heavy metals in soil and rice and are presented in Table 4 to 7. The Hazard Quotient (HQ) values for children in Abuja are less than 1 except for Cd and Cr in soil. However, the HI values for rice and soil exceeded 1, indicating a potential risk of non-carcinogenic impacts. For adults, individual HQ values are less than one except for Cr in soil. The HI values for rice are less than 1 indicating no risk to health, however, that of soil exceeds 1. The individual HQ values of metals in Ibaji (Kogi State) for children are less than 1 except for Cr in soil, however, the HI values calculated for soil and rice exceed 1, pointing to possible adverse health impacts. For adults, the individual HQ values of the metals were all less than 1, indicating low health risk while the HI value for the soil was greater than 1 indicating potential adverse health effects.

Table 4: Non-carcinogenic risk from heavy metals in rice for children (Abuja)

Element	**Average Daily Dose (ADD)**		**Hazard Quotient**		
	Paddy Abuja	**Parboiled Abuja**	**Soil**	**Paddy Abuja**	**Parboiled Abuja**
Cd	0.0003	0.0001	1.8	0.6	0.2
Cr	0.001	0.0008	3.67	0.33	0.27
Cu	0.003	0.002	0.17	0.07	0.05
Fe	0.019	0.016	0.42	0.03	0.02
Mn	0.003	0.002	0.57	0.21	0.14
Ni	0.0004	0.0003	0.05	0.02	0.02
Pb	0.0001	0.00008	0.29	0.03	0.02
Zn	0.130	0.104	0.21	0.43	0.35
Hazard Index =			7.18	1.72	1.07

Table 5: Non-carcinogenic risk from heavy metals in rice for adults (Abuja)

Element	ADD		Hazard Quotient		
	Paddy Abuja	**Parboiled Abuja**	**Soil**	**Paddy Abuja**	**Parboiled Abuja**
Cd	0.000123	0.0000471	0.822	0.246	0.0942
Cr	0.000465	0.00035	1.563	0.155	0.1167
Cu	0.0011523	0.0008426	0.08145	0.02744	0.02006
Fe	0.0008418	0.007306	0.1884	0.001203	0.01043
Mn	0.001286	0.000675	0.24628	0.091857	0.048214
Ni	0.0001830	0.0001453	0.02854	0.00915	0.007265
Pb	0.0005923	0.00003769	0.16143	0.16923	0.010769
Zn	0.05796	0.04645	0.09203	0.1932	0.15483
Hazard Index =			3.18	0.89	0.52

Table 6: Non-carcinogenic risk from heavy metals in rice for children (Kogi State)

Element	ADD		Hazard Quotient		
	Paddy Kogi	**Parboiled Kogi**	**Soil**	**Paddy Kogi**	**Parboiled Kogi**
Cd	0.0001	0.00004	0.12	0.2	0.08
Cr	0.002	0.001	2	0.67	0.33
Cu	0.003	0.002	0.29	0.07	0.05
Fe	0.028	0.013	0.45	0.04	0.02
Mn	0.003	0.003	0.36	0.21	0.21
Ni	0.0006	0.0005	0.05	0.03	0.03
Pb	0.0004	0.00007	0.17	0.11	0.02
Zn	0.170	0.105	0.14	0.57	0.35
Hazard Index =			3.58	1.9	1.07

Table 7: Non-carcinogenic risk from heavy metals in rice for adults (Kogi State)

Element	**ADD**		**Hazard Quotient**		
	Paddy Kogi	**Parboiled Kogi**	**Soil**	**Paddy Kogi**	**Parboiled Kogi**
Cd	0.00007	0.00001615	0.0576	0.14	0.0323
Cr	0.000796	0.00056	0.962	0.2653	0.1867
Cu	0.001397	0.0007888	0.1247	0.03326	0.01878
Fe	0.01242	0.005613	0.20066	0.01774	0.008018
Mn	0.001472	0.001370	0.17421	0.10514	0.09785
Ni	0.0002746	0.0002315	0.02342	0.01373	0.011575
Pb	0.0001857	0.00003230	0.082285	0.05306	0.009228
Zn	0.07583	0.04673	0.06404	0.25277	0.15577
Hazard Index =			1.689	0.88	0.52

DISCUSSION

There is notable variation in the metal concentrations in rice and soil between the two sites. The highest amounts of any mineral content are found in calcium (Ca), which ranges from 17.7 mg/kg in Abuja soil to 32.25 mg/kg in paddy rice from Kogi. Previous studies have recorded similar concentrations of metals to those in this study (Wang et al., 2023, Tariq et al., 2021, Al-Hugail et al., 2022) Due to variation in underlying geology or agricultural vpractices, the differing soil mineral contents of the two locations may be reflected in this high Ca abundance (Kukusamude et al., 2021). Abuja soil has significantly higher levels of Cd, Cr, Mn, Pb, and Zn**.** Kogi **soil** has more Cu and Fe. These differences suggest regional variation in geological composition or contamination sources (e.g., fertilizers, industrial activities). Localized sources of metal pollution, possibly brought on by adjacent industrial operations or agricultural inputs (Tariq et al., 2021), are suggested by the substantial difference in heavy metal levels in soil and paddy rice between Abuja and Kogi, as shown by p-values less than 0.05. Parboiling may lessen heavy metal levels in rice, as seen by the reduced concentrations in parboiled rice. The removal of the husk, which can have greater metal concentrations absorbed from the soil, could be the cause of this (Goh *et al*., 2024; Gupta *et al*., 2023).

Soil in Abuja generally has higher total metal concentrations, but Rice (PD especially) from Kogi tends to accumulate more Cd, Cr, Cu, Zn, and Pb, showing greater bioaccumulation efficiency. These variations highlight the complex interaction of environment, rice variety, and processing in determining final metal content. The ability of rice to bioaccumulate specific metals from soil is shown by the bioaccumulation factor (BAF) values, particularly for zinc (Zn) and cadmium (Cd). Some BAF values are more than 1, suggesting that the rice plant is more likely to concentrate metals in edible sections than in soil. This agrees with previous investigations (Usman *et al*., 2020, Leonard *et al*., 2023). Given its vital role as a vitamin, the frequent bioaccumulation of zinc is noteworthy, yet elevated amounts may be harmful to health (Aziz *et al*., 2023). Long-term exposure to cadmium, a hazardous and non-essential metal, is especially concerning because it has been linked to kidney impairment and bone demineralization (Zaynab *et al*., 2022). Hence, rice is a possible route for heavy metal exposure to humans, as indicated by the higher BAF values for Zn and Cd in paddy rice from both locations.

The profiles of flavonoid and phenolic compounds in rice are consistent between Abuja and Kogi, with the highest quantities linked to apigenin and protocatechuic acid. Similar phytochemical profiles are reported in other studies (Yu *et al*., 2022; Yu *et al*., 2021; Chen *et al*., 2022). The relative variations in phytochemical compositions between the two locations could be due to genetic variations in rice cultivars or environmental effects on phytochemical production (Bagchi *et al*., 2021). These compounds improve the nutritional profile of rice by providing anti-inflammatory, antioxidant, and perhaps anticancer effects (Shahidi *et al*., 2022). The fact that these compounds are still present in parboiled rice after processing is noteworthy because it shows that Nigerian traditional parboiling techniques preserve important bioactive components (Bagchi *et al*., 2021). In contrast to paddy rice, parboiled rice has somewhat lower quantities of flavonoids and phenolics, which suggests slight processing losses (Bagchi et al., 2021; Shahidi *et al*., 2022). Though the levels of the phytochemicals in this study are considered beneficial to the health of humans, however, excessive intake may be harmful, especially in populations that consume large amounts of rice (Biondi *et al*., 2021; Sen *et al*., 2020).

Hazard quotient (HQ) values for specific metals (apart from Cd and Cr in soil) that are less than 1 indicate no immediate threat to the health of humans from isolated exposure in both children and adults. This is similar to findings in other studies (Kukusamude *et al*., 2021; Huda *et al*., 2024; Almutari *et al*., 2021). However, the cumulative non-carcinogenic risk, especially for children, is indicated by the hazard index (HI) values for rice and soil in the two studied areas, which are greater than 1 (Zulkafflee *et al*., 2020). This is consistent with the idea that young people are more susceptible to exposure to toxins (Zaynab *et al*., 2022). However, BAF values below 1 for the majority of residues in rice point to limited transfer from soil to rice.

CONCLUSION

The quantities of heavy metals and phytochemicals in rice and soil from Abuja and Kogi differ significantly, according to this study. According to the results, paddy rice has higher amounts of heavy metals than parboiled rice. Metals like zinc and cadmium exhibit bioaccumulation tendencies, though the amount of Zinc in rice from Abuja and Kogi is safe for human consumption because Zn is an essential nutrient, unlike cadmium, which could be harmful to health, particularly for young people. For adults, the Hazard Index values of the metals were all less than 1, indicating low health risk while the HI value for the children in both locations was greater than 1 indicating potential adverse health effects. These results highlight how crucial it is to regularly monitor heavy metal levels in our rice farms, as heavy metal pollution is a cause for concern to the health of humans via the food chain. To improve food safety and safeguard public health, this study emphasises the necessity of raising consumer knowledge and promoting safer farming methods.

ACKNOWLEDGMENT

I wish to acknowledge my supervisors, Professor Abiodun Ojo, Professor Amos Onasanya and Professor Ezekiel Adewole who designed the work and for their guidance through the course of this study

REFERENCES

Alengebawy, A., Abdelkhalek, S. T., Qureshi, S. R., and Wang, M. Q. (2021). Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications. *Toxics*, *9*(3), 42.

Al-Huqail, A. A., Kumar, P., Eid, E. M., Adelodun, B., Abou Fayssal, S., Singh, J., and Širić, I. (2022). Risk assessment of heavy metals contamination in soil and two rice (Oryza sativa L.) varieties irrigated with paper mill effluent. *Agriculture*, *12*(11), 1864.

Almutairi, M., Alsaleem, T., Jeperel, H., Alsamti, M., and Alowaifeer, A. M. (2021). Determination of inorganic arsenic, heavy metals, pesticides and mycotoxins in Indian rice (Oryza sativa) and a probabilistic dietary risk assessment for the population of Saudi Arabia. *Regulatory toxicology and pharmacology*, *125*, 104986.

Aziz, R. A., Yiwen, M., Saleh, M., Salleh, M. N., Gopinath, S. C., Giap, S. G. E., and Gobinath, R. (2023). Bioaccumulation and translocation of heavy metals in paddy (Oryza sativa L.) and soil in different land use practices. *Sustainability*, *15*(18), 13426.

Bagchi, T. B., Chattopadhyay, K., Sivashankari, M., Roy, S., Kumar, A., Biswas, T., and Pal, S. (2021). Effect of different processing technologies on phenolic acids, flavonoids and other antioxidants content in pigmented rice. *Journal of Cereal Science*, *100*, 103263.

Biondi, F., Balducci, F., Capocasa, F., Visciglio, M., Mei, E., Vagnoni, M., and Mazzoni, L. (2021). Environmental conditions and agronomical factors influencing the levels of phytochemicals in Brassica vegetables responsible for nutritional and sensorial properties. *Applied Sciences*, *11*(4), 1927.

Chen, X., Yang, Y., Yang, X., Zhu, G., Lu, X., Jia, F., and Wu, X. (2022). Investigation of flavonoid components and their associated antioxidant capacity in different pigmented rice varieties. *Food Research International*, *161*, 111726.

Fatchiyah, F., Sari, D. R. T., Safitri, A., and Cairns, J. R. (2020). Phytochemical compound and nutritional value in black rice from Java Island, Indonesia. *Systematic Reviews in Pharmacy*, *11*(7), 414-421.

Goh, N. C., Noor, N. S., Mohamed, R., Tualeka, A. R., Zabidi, M. A., and Aziz, M. Y. (2024). Health risk assessment of metal contamination in Malaysian rice (Oryza sativa): The impact of parboiling on toxic metal reduction prior to cooking. *International Journal of Food Science and Technology*.

Guan, R., Van Le, Q., Yang, H., Zhang, D., Gu, H., Yang, Y., and Peng, W. (2021). A review of dietary phytochemicals and their relation to oxidative stress and human diseases. *Chemosphere*, *271*, 129499.

Gupta, A., Tiwari, R. K., Agnihotri, R., Padalia, K., Mishra, S., and Dwivedi, S. (2023). A critical analysis of various post-harvest arsenic removal treatments of rice and their impact on public health due to nutrient loss. *Environmental Monitoring and Assessment*, *195*(9), 1073.

Harborne, J. B. (1973). Phytochemical methods: *A guide to modern techniques of plant analysis*. Chapman and Hall Ltd, London.; Pp. 279.

Howe, A., Hoo Fung, L., Lalor, G., Rattray, R., Vutchkov, M., 2005. Elemental composition of Jamaican foods. 1: A survey of five food crop categories. Environmental Geochemistry and Health 27, 19–30.

Huda, M. N., Harun-Ur-Rashid, M., Hosen, A., Akter, M., Islam, M. M., Emon, S. Z., and Ismail, M. (2024). A potential toxicological risk assessment of heavy metals and pesticides in irrigated rice cultivars near industrial areas of Dhaka, Bangladesh. *Environmental Monitoring and Assessment*, *196*(9), 794.

Jin, M., Yuan, H., Liu, B., Peng, J., Xu, L., and Yang, D. (2020). Review of the distribution and detection methods of heavy metals in the environment. *Analytical methods*, *12*(48), 5747-5766.

Kukusamude, C., Sricharoen, P., Limchoowong, N., and Kongsri, S. (2021). Heavy metals and probabilistic risk assessment via rice consumption in Thailand. *Food Chemistry*, *334*, 127402.

Leonard, L. S., and Riwa, E. G. (2023). Bioaccumulation of trace elements in paddy soil, paddy plants and rice grains from irrigation schemes, Morogoro-Tanzania. *Ethiopian Journal of Science and Technology*, *16*(1), 29-49.

Liu, S., Shi, J., Wang, J., Dai, Y., Li, H., Li, J., and Zhang, P. (2021). Interactions between microplastics and heavy metals in aquatic environments: a review. *Frontiers in microbiology*, *12*, 652520.

Mitra, S., Chakraborty, A. J., Tareq, A. M., Emran, T. B., Nainu, F., Khusro, A., and Simal-Gandara, J. (2022). Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity. *Journal of King Saud University-Science*, *34*(3), 101865.

Obadoni, B.O. and Ochuko, P.O. (2001) Phytochemical Studies and Comparative Efficacy of the Crude Extracts of Some Homeostatic Plants in Edo and Delta States of Nigeria. Global Journal of Pure and Applied Science, 8, 203-208.

Olajire A.A and Azeez L. (2011). Total antioxidant activity, phenolic, flavonoid and ascorbic acid contents of Nigerian vegetables. *African Journal of Food Science and Technology.*

2011; 2(2)022-029

Olaleye, A. A., Adubiaro, H. O., Dauda A. and Adamu, Y. A. (2022). "Impact of Heavy Metals Toxicity on Children and Adults from Local Rice Varieties of Northern Nigeria," *Pak. J. Anal. Environ. Chem.* Vol. 23, No. 2 (2022) 205 – 214.

Sathish, K. R. and Anburaj, G. (2024). Phytochemical Screening by, UV and FTIR, HPLC Analysis of *Capparis zeylanica* Leaf Extracts. *Research journal of Agricultural sciences*, 15(03), 843-847.

Sen, S., Chakraborty, R., and Kalita, P. (2020). Rice-not just a staple food: A comprehensive review on its phytochemicals and therapeutic potential. *Trends in Food Science and Technology*, *97*, 265-285.

Shahidi, F., Danielski, R., Rhein, S. O., Meisel, L. A., Fuentes, J., Speisky, H., and de Camargo, A. C. (2022). Wheat and rice beyond phenolic acids: Genetics, identification database, antioxidant properties, and potential health effects. *Plants*, *11*(23), 3283.

Tan, B. L., and Norhaizan, M. E. (2020). *Rice by-products: Phytochemicals and food products application*. Springer International Publishing.

Tariq, F., Wang, X., Saleem, M. H., Khan, Z. I., Ahmad, K., Saleem Malik, I., and Ali, S. (2021). Risk assessment of heavy metals in basmati rice: Implications for public health. *Sustainability*, *13*(15), 8513.

Tilahun Belayneh, Zemene Atnafu, Alle Madhusudhan (2015). Determinations of the level of essential and non-essential metals in rice and soil samples. International Journal of Modern Chemistry and Applied Science 2015, 2(1), 65-72.

Uddin, M. M., Zakeel, M. C. M., Zavahir, J. S., Marikar, F. M., and Jahan, I. (2021). Heavy metal accumulation in rice and aquatic plants used as human food: A general review. *Toxics*, *9*(12), 360.

USEPA IRIS (US Environmental Protection Agency's Integrated Risk Information System). (2011). http://www.epa.gov/iris/.

Usman, B., Ahmad, A., Jibrin, N. A., Gaya, E. A., and Jibrin, M. (2020). Bioaccumulation and human health risk of heavy metals from pesticides in some crops grown in Plateau State, Nigeria. In *Biology and Life Sciences Forum* (Vol. 4, No. 1, p. 12). MDPI.

Wang, C. C., Zhang, Q. C., Yan, C. A., Tang, G. Y., Zhang, M. Y., Ma, L. Q., and Xiang, P. (2023). Heavy metal (loid) s in agriculture soils, rice, and wheat across China: Status assessment and spatiotemporal analysis. *Science of The Total Environment*, *882*, 163361.

Wongsasuluk, P., Chotpantarat, S., Siriwong, W., and Robson, M. (2014). "Heavy metal contamination and human health risk assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand," Environ Geochem Health. 2014;36:169–82.

Yu, X., Chu, M., Chu, C., Du, Y., Shi, J., Liu, X., and Yan, N. (2020). Wild rice (Zizania spp.): A review of its nutritional constituents, phytochemicals, antioxidant activities, and health-promoting effects. *Food Chemistry*, *331*, 127293.

Yu, X., Yang, T., Qi, Q., Du, Y., Shi, J., Liu, X., and Yan, N. (2021). Comparison of the contents of phenolic compounds including flavonoids and antioxidant activity of rice (Oryza sativa) and Chinese wild rice (Zizania latifolia). *Food Chemistry*, *344*, 128600.

Zaynab, M., Al-Yahyai, R., Ameen, A., Sharif, Y., Ali, L., Fatima, M., and Li, S. (2022). Health and environmental effects of heavy metals. *Journal of King Saud University-Science, 34*(1), 101653.

Zhang, H., Feng, X. B., and Larssen, T. (2010). “Bioaccumulation of methylmercury versus inorganic mercury in rice (Oryza sativa L.) grain,” Environ. Sci. Technol. **2010**, 44, 4499–4504.

Zulkafflee, N. S., Redzuan, N. A. M., Selamat, J., Ismail, M. R., Praveena, S. M., and Razis, A. F. A. (2020). Evaluation of heavy metal contamination in paddy plants at the northern region of Malaysia using ICPMS and its risk assessment. *Plants*, *10*(1), 3.