

Assessment of Essential and Non-Essential Metals in Commonly Consumed Grains in Kogi State, North Central, Nigeria

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Abstract

This study assessed the concentration of essential and non-essential metals in commonly consumed grains in Kogi State, Nigeria. Four (4) grains; rice (*Oryza sativa*), maize (*Zea mays*), millet (*Panicum miliaceum*) and beans (*Phaseolus vulgaris*) were collected from major sale points in selected Local Governments Areas (LGAs) across the three Senatorial Districts of Kogi State, Nigeria. The concentrations of the metals (Zn, Cu, Mn, Fe, Pb, Cd and Cr) were analyzed using an Atomic Absorption Spectrometer (AAS solar 969 Unican series) and subsequently compared to the FAO/WHO MPLs (Maximum Permissible Limits). Results of the analysis showed that the essential and non-essential metals were detected in the grains (rice, maize, millet and beans) sourced from the three (3) senatorial districts of Kogi State in varying concentrations. All the essential metals were present in the grains at concentrations below their MPLs while some of the non-essential metals were present at concentrations above their MPLs. The major contaminant of rice and millet was Cd. Cd was detected in rice and millet samples in a number of LGAs across the Senatorial Districts at concentrations above their PMLs. Pb was also present in rice and millet samples from some LGAs at concentrations above its MPL. For maize and bean samples, Cd and Pb were the only metals detected in one LGA in Kogi West Senatorial District at concentrations above their MPLs. The other non-essential metal assessed- Cr was not detected in majority of the grains but below its MPL in samples where it was detected. Cd and Pb therefore, are the major contaminants of grains consumed in Kogi State as revealed by this study. Accumulation of these non-essential metal is a major public health concern. We therefore, recommend regular monitoring of grains and other foods sold within Kogi State and Nigeria at large.

Introduction

Heavy metals are divided into two categories namely; essential and non-essential heavy metals. Iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), cobalt (Co), nickel (Ni), molybdenum (Mo) and selenium (Se) belong to the essential category. They are known by this name because living things need them in trace amounts for essential metabolic processes. Many of them operate as cofactors that are crucial for both functional and structural aspects of many types of life. However, when certain essential metals are present in organisms above a specific level, it leads to detrimental physiological effects. The non-essential heavy metals, many of which have no known advantages for biological systems are poisonous even in little amounts. The non-essential heavy metals include lead (Pb), chromium (Cr), cadmium (Cd), and mercury (Hg) (Tchounwou *et al.*, 2012). Increasing evidence suggests that the most threatening heavy metals of human health are Pb, Cd and Hg [1]. It has been reported that Cd exposure may cause organ damage, including kidney damage and possibly also bone defects and fractures [2, 3]. Pb and Hg are also highly neurotoxic and they also affect other organ systems adversely.

Heavy metal contamination is a major environmental health challenge and is potentially dangerous because of bioaccumulation through the food chain [4], which arises from rapid industrial growth, advances in the use of agricultural chemicals, and the urbanizing activities of man. This has led to the dispersion of heavy metals in the environment, resulting in the impaired health of the population, mainly

by the ingestion of food crops contaminated by these harmful elements [5]. In many regions of Nigeria, some heavy metals have been reportedly added to the soil through chemical fertilizer application [6]. Heavy metal emissions from other sources, such as worn automobile tires and brake linings, roofs, and food remnants in residences, as well as other domestic byproducts, such as refuse, have also been identified [7, 8]. Heavy metals emanating from anthropogenic sources are more dangerous because of their instability and solubility, which leads to a high bioavailability [9]. In the Itakpe iron ore mining site of Kogi State, heavy metal concentrations in crops were reportedly higher than those grown on control soil even though the observed concentrations of heavy metals were below the WHO/FAO limit for food [10]. The presence of zinc and copper in plants and the higher level of metals observed in the mining site indicate that agrochemicals and mining contribute to high levels of heavy metals in the environment.

With the many adverse effects on man and other animals due to heavy metal contamination of crops, a need exists to regularly monitor food crops for the presence of these metals. This study was aimed at assessing selected essential and non-essential levels in some commonly consumed grains (rice, maize, millet and beans) in the three Senatorial Districts of Kogi State, North Central, Nigeria. The findings of this study may provide insights into the metal accumulation factor of grains sold in Kogi State and potential human health risks through the consumption of these grains.

Materials and Methods

Sample collection

Four (4) commonly consumed grains; rice (*Oryza sativa*), maize (*Zea mays*), millet (*Panicum miliaceum*) and beans (*Phaseolus vulgaris*) were collected from major sale points in the following Local Governments Areas (LGAs) representing the three Senatorial Districts of Kogi State, North Central, Nigeria;

Kogi East Senatorial District- Ibaji LGA (L1), Idah LGA (L2), Ofu LGA (L3), Dekina LGA (L4), Olamaboro LGA (L5), Bassa LGA (L6).

Kogi Central Senatorial District- Ajaokuta LGA (L1), Okene LGA (L2), Adavi LGA (L3), Ogorimagongo LGA (L4).

Kogi West Senatorial District- Lokoja LGA (L1), Kabba Bunu LGA (L2), Yagba East LGA (L3), Ijumu LGA (L4).

Samples were collected in triplicates in polythene bags from each of the locations and labeled properly and taken to the laboratory for appropriate analysis.

Sample preparation for determination of essential and non-essential metals concentration

The sample were washed with distilled water and deionized water, sun dried and ground in to uniform powder using electrical blender. The sample were then sieved through a 2mm nylon sieve and 0.5g of

each of the dried samples was weighed in to 50ml platinum crucibles. The crucibles were then placed in a muffle furnace operating at 500 C and the samples were allowed to ash for 3 hours. The ashed samples in each crucible were then digested by mixing them with 5ml of 10% (v/v) nitric acid (HNO₃), 5ml of 20% (v/v) Perchloric Acid (HClO₄) and 2ml of 10% (v/v) Sulphuric acid (H₂SO₄) at 100 C on a hot plate for two hours in a fume cupboard. The resulting solution was left to cool for twelve hours and then transferred to 250ml flasks, after which they were diluted with 88ml of distilled water to make it up to 100 ml mark. the content of each flask was filtered with Whatman No.1 filter paper in to appropriate sample bottles and then stored for subsequent analysis.

Determination of essential and non-essential metals concentration

The concentration of elements was carried out using an Atomic Absorption Spectrometer (AAS solar 969 Unican series) [12].

The concentration of the metals detected in the grains was subsequently compared with FAO/WHO MPLs [13].

Statistical Analysis

Descriptive statistics (mean and standard error) was used to analyze results obtained for different heavy metals in each grain. All analyses were performed using GraphPad prism 10 software..

Results

Essential and Non-Essential Metals Concentration in Rice (*Oryza sativa*) from different Local Government Areas of Kogi East Senatorial District

The results of the essential and non-essential metals in the rice samples from the different LGAs under Kogi East Senatorial District are presented in Table 1. Cu, Pb, Zn, Mn and Fe were detected in the rice samples from all the LGAs in varying proportions. Cr was detected in only 2 LGAs- Ibaji and Idah LGAs while Cd was detected in only 3 LGAs- Ofu, Dekina and Olamaboro LGAs. Cu concentrations detected in Idah (0.30 ± 0.02) and Ibaji (0.27 ± 0.01) LGAs were above its MPL (0.20 mg/kg). However, Cd concentration was below this stipulated level in the rice samples from the other LGAs. All the other metals detected were at concentrations below their MPLs.

Table 1

Essential and Non-Essential Metals Concentration in Rice (*Oryza sativa*) from different Local Government Areas of Kogi East Senatorial District

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4	L5	L6
Copper, Cu	73.00	0.67 ± 0.01	0.59 ± 0.01	0.60 ± 0.00	0.63 ± 0.01	0.65 ± 0.01	0.60 ± 0.01
Lead, Pb	0.30	0.27 ± 0.00	0.27 ± 0.01	0.19 ± 0.00	0.25 ± 0.01	0.28 ± 0.02	0.31 ± 0.02
Zinc, Zn	100.00	0.80 ± 0.01	0.93 ± 0.03	0.80 ± 0.02	0.62 ± 0.04	0.69 ± 0.01	0.63 ± 0.02
Chromium, Cr	30.00	ND	ND	0.91 ± 0.02	0.75 ± 0.03	0.75 ± 0.03	0.70 ± 0.03
Cadmium, Cd	0.20	0.30 ± 0.02*	0.27 ± 0.01*	ND	ND	ND	ND
Manganese, Mn	500.00	4.23 ± 0.78	5.02 ± 0.98	3.28 ± 0.45	5.23 ± 0.99	5.18 ± 0.86	4.85 ± 0.81
Iron, Fe	425.00	4.11 ± 0.23	6.57 ± 0.88	5.09 ± 1.21	3.78 ± 0.85	3.44 ± 0.52	3.33 ± 0.76

Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND), Ibaji LGA (L1), Idah LGA (L2), Ofu LGA (L3), Dekina LGA (L4), Olamaboro LGA (L5), Bassa LGA (L6), Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL

Essential and Non-Essential Metals Concentration in Maize (*Zea mays*) from different Local Government Areas of Kogi East Senatorial District

Cu, Pb, Zn, Mn and Fe were detected in the maize samples from all the different LGAs under Kogi East Senatorial District in varying proportions. All but Pb were detected at concentrations below their MPLs. In Ofu LGA, Pb was found to be above its MPL (0.30 mg/kg). Cr and Cd were not detected in the rice sample from any of the LGA (Table 2).

Table 2
Essential and Non-Essential Metals Concentration in Maize (*Zea mays*) from different Local Government Areas of Kogi East Senatorial District

Essential/ Non-Essential metals (mg/kg))	MPLs	L1	L2	L3	L4	L5	L6
Copper, Cu	73.00	0.56 ± 0.01	0.75 ± 0.02	0.046 ± 0.01	0.068 ± 0.01	0.071 ± 0.01	0.070 ± 0.002
Lead, Pb	0.30	0.28 ± 0.02	0.20 ± 0.01	0.31 ± 0.01*	0.22 ± 0.02	0.40 ± 0.01	0.35 ± 0.01
Zinc, Zn	100.00	0.78 ± 0.01	0.93 ± 0.04	0.72 ± 0.02	0.95 ± 0.04	0.88 ± 0.01	0.95 ± 0.01
Chromium, Cr	30.00	ND	ND	ND	ND	ND	ND
Cadmium, Cd	0.20	ND	ND	ND	ND	ND	ND
Manganese, Mn	500.00	0.99 ± 0.05	0.84 ± 0.03	1.28 ± 0.19	1.32 ± 0.18	1.56 ± 0.25	1.48 ± 0.27
Iron, Fe	425.00	1.23 ± 0.19	1.27 ± 0.11	2.78 ± 0.19	2.22 ± 0.21	2.18 ± 0.46	2.39 ± 0.28

*Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND), Ibaji LGA (L1), Idah LGA (L2), Ofu LGA (L3), Dekina LGA (L4), Olamaboro LGA (L5), Bassa LGA (L6), Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL*

Essential and Non-Essential Metals Concentration in Millet (*Panicum miliaceum*) from different Local Government Areas of Kogi East Senatorial District

Table 3 shows the heavy metals and trace elements detected in the millet samples from the different LGAs under Kogi East Senatorial District are presented. Cu, Pb, Zn, Mn and Fe were detected in the millet samples from all the LGAs in varying proportions. Cr and Cd were detected in rice samples from only Ofu and Dekina LGAs. Cd in the rice samples from these two LGAs were above its MPL (0.20 mg/kg). All the other metals detected were at concentrations below their MPLs.

Table 3

Essential and Non-Essential Metals Concentration in Millet (*Panicum miliaceum*) from different Local Government Areas of Kogi East Senatorial District

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4	L5	L6
Copper, Cu	73.00	1.11 ± 0.15	0.92 ± 0.12	0.85 ± 0.19	1.20 ± 0.09	1.32 ± 0.02	0.99 ± 0.07
Lead, Pb	0.30	0.23 ± 0.01	0.17 ± 0.00	0.19 ± 0.01	0.21 ± 0.03	0.11 ± 0.05	0.32 ± 0.02
Zinc, Zn	100.00	0.68 ± 0.03	0.62 ± 0.02	0.70 ± 0.04	0.69 ± 0.05	0.50 ± 0.02	0.56 ± 0.01
Chromium, Cr	30.00	ND	ND	1.46 ± 0.09	0.95 ± 0.06	ND	ND
Cadmium, Cd	0.20	ND	ND	0.35 ± 0.00*	0.20 ± 0.02*	ND	ND
Manganese, Mn	500.00	3.08 ± 0.26	4.22 ± 0.47	5.02 ± 0.45	3.21 ± 0.32	3.48 ± 0.45	3.40 ± 0.32
Iron, Fe	425.00	2.06 ± 0.13	5.22 ± 0.23	2.51 ± 0.95	4.21 ± 0.58	4.01 ± 0.87	3.34 ± 0.44

Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND), Ibaji LGA (L1), Idah LGA (L2), Ofu LGA (L3), Dekina LGA (L4), Olamaboro LGA (L5), Bassa LGA (L6), Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL

Essential and Non-Essential Metals Concentration in Beans (*Phaseolus vulgaris*) from different Local Government Areas of Kogi East Senatorial District

Essential and Non-Essential metals detected in the bean samples from the different are presented in Table 4. Cu, Zn, Mn and Fe were all detected in the bean samples from all the LGAs at concentrations below their MPLs. Pb, Cr and Cd were not detected in the bean samples from all the LGAs.

Table 4

Essential and Non-Essential *Metals* Concentration in Beans (*Phaseolus vulgaris*) from different Local Government Areas of Kogi East Senatorial District

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4	L5	L6
Copper, Cu	73.00	0.85 ± 0.01	0.91 ± 0.01	0.88 ± 0.09	0.56 ± 0.02	0.48 ± 0.04	0.52 ± 0.01
Lead, Pb	0.30	ND	ND	ND	ND	ND	ND
Zinc, Zn	100.00	0.86 ± 0.03	0.45 ± 0.01	0.70 ± 0.05	0.66 ± 0.02	0.72 ± 0.08	0.51 ± 0.02
Chromium, Cr	30.00	ND	ND	ND	ND	ND	ND
Cadmium, Cd	0.20	ND	ND	ND	ND	ND	ND
Manganese, Mn	500.00	5.23 ± 0.67	5.05 ± 0.89	4.92 ± 0.73	3.37 ± 0.28	3.50 ± 0.26	3.36 ± 0.41
Iron, Fe	425.00	3.65 ± 0.54	4.28 ± 0.56	3.11 ± 0.68	4.36 ± 0.47	4.11 ± 0.33	3.28 ± 0.42

Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND), Ibaji LGA (L1), Idah LGA (L2), Ofu LGA (L3), Dekina LGA (L4), Olamaboro LGA (L5), Bassa LGA (L6), Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL

Essential and Non-Essential Metals Concentration in Rice (*Oryza sativa*) from different Local Government Areas of Kogi Central Senatorial District

The results of essential and non-essential metals detected in the rice samples from the different LGAs representing Kogi Central Senatorial District in this study are presented in Table 5. Cu, Zn, Mn and Fe were detected in the rice samples from all the LGAs at concentrations below their MPLs. Cr was detected in samples from only Adavi LGA at a concentration below its MPL. Cd was present in concentrations above its MPL in Ajaokuta, Okene and Ogorimagongo LGAs but below its MPL in samples from Adavi LGA. Pb was equally present in rice samples from Ogorimagongo at a concentration (0.35 ± 0.01 mg/kg) above its MPL (0.30 mg/kg) but below its MPL in samples from the other 3 LGAs (Table 5).

Table 5

Essential and Non-Essential Metals Concentration in Rice (Oryza sativa) from different Local Government Areas of Kogi Central Senatorial District

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4
Copper, Cu	73.00	0.91 ± 0.01	0.89 ± 0.03	0.53 ± 0.01	0.66 ± 0.02
Lead, Pb	0.30	0.10 ± 0.00	0.17 ± 0.01	0.21 ± 0.02	0.35 ± 0.01*
Zinc, Zn	100.00	0.53 ± 0.01	0.63 ± 0.001	0.75 ± 0.02	0.65 ± 0.01
Chromium, Cr	30.00	ND	ND	0.58 ± 0.00	ND
Cadmium, Cd	0.20	0.25 ± 0.00*	0.31 ± 0.01*	0.15 ± 0.01	0.33 ± 0.02*
Manganese, Mn	500.00	1.45 ± 0.12	2.88 ± 0.31	2.23 ± 0.25	1.21 ± 0.14
Iron, Fe	425.00	12.15 ± 1.21	15.07 ± 2.21	10.33 ± 2.01	10.84 ± 1.02

*Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND Ajaokuta LGA (L1), Okene LGA (L2), Adavi LGA (L3), Ogorimagongo LGA (L4), Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL*

Essential and Non-Essential Metals Concentration in Maize (Zea mays) from different Local Government Areas of Kogi Central Senatorial District

In the Central Senatorial District, the tested Essential and Non-essential were detected in the bean samples from all the LGAs in concentrations below their MPLs. Only Cr and Cd were not detected (Table 6).

Table 6

*Essential and Non-Essential Metals Concentration in Maize (*Zea mays*) from different Local Government Areas of Kogi Central Senatorial District*

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4
Copper, Cu	73.00	0.46 ± 0.01	0.58 ± 0.01	0.30 ± 0.00	0.60 ± 0.01
Lead, Pb	0.30	0.20 ± 0.00	0.25 ± 0.01	0.18 ± 0.00	0.28 ± 0.01
Zinc, Zn	100.00	0.67 ± 0.01	0.60 ± 0.00	0.72 ± 0.02	0.61 ± 0.01
Chromium, Cr	30.00	ND	ND	ND	ND
Cadmium, Cd	0.20	ND	ND	ND	ND
Manganese, Mn	500.00	2.31 ± 0.21	4.21 ± 0.87	2.23 ± 0.21	3.26 ± 0.23
Iron, Fe	425.00	18.23 ± 2.56	10.08 ± 1.34	11.03 ± 1.34	16.22 ± 1.25

*Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND Ajaokuta LGA (L1), Okene LGA (L2), Adavi LGA (L3), Ogorimagongo LGA (L4), Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL*

Essential and Non-Essential Metals Concentration in Millet (*Panicum miliaceum*) from different Local Government Areas of Kogi Central Senatorial District

The results of the Essential and Non-essential metals detected in the millet samples from the different LGAs are presented in Table 7. Cu, Zn, Mn and Fe were detected in the millet samples from all the LGAs at concentrations below their MPLs. Cr was detected in samples from all but Adavi LGA at concentration below its MPL. Cd was present in concentrations above its MPL in Ajaokuta but not detected in other LGAs. Pb was equally present in rice samples from Ajaokuta and Ogorimagongo at concentrations above its MPL (0.30 mg/kg) but below its MPL in samples from Okene and Adavi LGAs (Table 7).

Table 7

Essential and Non-Essential Metals Concentration in Millet (*Panicum miliaceum*) from different Local Government Areas of Kogi Central Senatorial District

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4
Copper, Cu	73.00	1.23 ± 0.12	0.93 ± 0.09	0.57 ± 0.04	0.98 ± 0.05
Lead, Pb	0.30	0.40 ± 0.06*	0.28 ± 0.02	0.24 ± 0.03	0.35 ± 0.01*
Zinc, Zn	100.00	0.80 ± 0.09	0.69 ± 0.04	0.70 ± 0.05	0.61 ± 0.02
Chromium, Cr	30.00	ND	1.26 ± 0.02	1.20 ± 0.01	0.99 ± 0.01
Cadmium, Cd	0.20	0.31 ± 0.00*	ND	ND	ND
Manganese, Mn	500.00	1.45 ± 0.09	1.24 ± 0.04	3.56 ± 0.08	1.37 ± 0.05
Iron, Fe	425.00	10.21 ± 1.04	19.52 ± 2.23	10.35 ± 2.11	12.62 ± 3.11

Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND Ajaokuta LGA (L1), Okene LGA (L2), Adavi LGA (L3), Ogorimagongo LGA (L4), Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL

Essential and Non-Essential Metals and Trace Elements Concentration in Beans (*Phaseolus vulgaris*) from different Local Government Areas of Kogi Central Senatorial District

The tested Essential and Non-essential metals were detected in the bean samples from all the LGAs at concentrations below their MPLs. Only Cr and Cd were not detected (Table 8).

Table 8
Essential and Non-Essential Metals Concentration in Beans (*Phaseolus vulgaris*) from different Local Government Areas of Kogi Central Senatorial District

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4
Copper, Cu	73.00	0.88 ± 0.03	0.93 ± 0.02	1.55 ± 0.06	1.05 ± 0.06
Lead, Pb	0.30	0.15 ± 0.00	0.21 ± 0.01	0.19 ± 0.01	0.16 ± 0.01
Zinc, Zn	100.00	0.88 ± 0.01	1.59 ± 0.02	0.90 ± 0.02	1.33 ± 0.07
Chromium, Cr	30.00	ND	ND	ND	ND
Cadmium, Cd	0.20	ND	ND	ND	ND
Manganese, Mn	500.00	0.90 ± 0.02	0.89 ± 0.04	1.05 ± 0.06	0.92 ± 0.01
Iron, Fe	425.00	5.41 ± 0.87	4.03 ± 0.81	2.75 ± 0.33	3.45 ± 0.78

Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND Ajaokuta LGA (L1), Okene LGA (L2), Adavi LGA (L3), Ogorimagongo LGA (L4), Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL

Essential and Non-Essential Metals Concentration in Rice (*Oryza sativa*) from different Local Government Areas of Kogi West Senatorial District

Table 9 shows the result of the heavy metals detected in the rice samples from the LGAs. Cu, Zn, Mn and Fe were detected at concentrations below their MPLs. Pb, Cr and Cd were not detected (Table 9).

Table 9
Essential and Non-Essential Metals Concentration in Rice (*Oryza sativa*) from different Local Government Areas of Kogi West Senatorial District

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4
Copper, Cu	73.00	2.43 ± 0.28	1.22 ± 0.09	1.53 ± 0.08	0.99 ± 0.04
Lead, Pb	0.30	ND	ND	ND	ND
Zinc, Zn	100.00	0.92 ± 0.08	0.60 ± 0.02	0.57 ± 0.04	0.78 ± 0.03
Chromium, Cr	30.00	ND	ND	ND	ND
Cadmium, Cd	0.20	ND	ND	ND	ND
Manganese, Mn	500.00	4.35 ± 0.78	6.44 ± 0.38	4.23 ± 0.04	5.06 ± 0.04
Iron, Fe	425.00	6.21 ± 0.76	7.74 ± 1.23	5.45 ± 0.77	4.89 ± 0.91

*Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND), Lokoja LGA (L1), Kabba Bunu LGA (L2), Yagba East LGA (L3), Ijumu LGA (L4), Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL*

Essential and Non-Essential Metals Concentration in Maize (*Zea mays*) from different Local Government Areas of Kogi West Senatorial District

The results of the detected Essential and Non-essential metals in the maize samples from the different LGAs are presented in Table 10. Cu, Zn, Mn and Fe were detected in the maize samples from all the LGAs at concentrations below their MPLs. Pb concentrations detected in Kabba Bunu LGA (0.34 ± 0.02) was above its MPL (0.30 mg/kg). However, in Yagba West LGA, Pb concentration was below its MPL. Cr and Cd were not detected in the maize samples from all the LGAs (Table 10).

Table 10
Essential and Non-Essential Metals *Concentration* in Maize (*Zea mays*) from different Local Government Areas of Kogi West Senatorial District

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4
Copper, Cu	73.00	0.56 ± 0.07	0.73 ± 0.01	0.76 ± 0.01	0.61 ± 0.02
Lead, Pb	0.30	ND	$0.34 \pm 0.02^*$	0.23 ± 0.00	ND
Zinc, Zn	100.00	1.26 ± 0.02	1.23 ± 0.01	0.98 ± 0.04	1.65 ± 0.09
Chromium, Cr	30.00	ND	ND	ND	ND
Cadmium, Cd	0.20	ND	ND	ND	ND
Manganese, Mn	500.00	4.33 ± 0.35	4.35 ± 0.52	4.06 ± 0.67	5.39 ± 0.19
Iron, Fe	425.00	1.34 ± 0.45	3.21 ± 0.37	2.45 ± 0.26	4.83 ± 0.78

*Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND), Lokoja LGA (L1), Kabba Bunu LGA (L2), Yagba East LGA (L3), Ijumu LGA (L4) Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL*

Essential and Non-Essential Metals Concentration in Millet (*Panicum miliaceum*) from different Local Government Areas of Kogi West Senatorial District

Table 11 shows the results of the detected Essential and Non-essential metals in the millet samples from the different LGAs under Kogi West Senatorial District. Cu, Mn and Fe were detected in the millet samples from all the LGAs in varying proportions. Cr was detected in 3 LGAs- Kabba Bunu, Yagba West and Ijumu LGAs while Cd was detected in only 2 LGAs- Lokoja and Kabba Bunu LGAs. In these two LGAs, Cd was present in the millet samples at concentrations, (0.49 ± 0.02 and 0.32 ± 0.01 mg/kg respectively) above its MPL (0.20 mg/kg). Pb was not detected in the samples from all the LGAs.

Table 11

Essential and Non-Essential Metals Concentration in Millet (*Panicum miliaceum*) from different Local Government Areas of Kogi West Senatorial District

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4
Copper, Cu	73.00	1.25 ± 0.31	0.99 ± 0.26	0.83 ± 0.04	0.48 ± 0.01
Lead, Pb	0.30	ND	ND	ND	ND
Zinc, Zn	100.00	0.56 ± 0.01	0.68 ± 0.05	0.70 ± 0.08	0.65 ± 0.03
Chromium, Cr	30.00	ND	2.31 ± 0.14	2.51 ± 0.45	1.33 ± 0.21
Cadmium, Cd	0.20	0.49 ± 0.02*	0.32 ± 0.01*	ND	ND
Manganese, Mn	500.00	4.28 ± 0.44	6.28 ± 0.91	4.24 ± 0.21	0.36 ± 0.18
Iron, Fe	425.00	5.41 ± 0.32	4.32 ± 0.35	3.71 ± 0.45	6.81 ± 0.27

*Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND), Lokoja LGA (L1), Kabba Bunu LGA (L2), Yagba East LGA (L3), Ijumu LGA (L4) Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL*

Essential and Non-Essential Metals Concentration in Beans (*Phaseolus vulgaris*) from different Local Government Areas of Kogi West Senatorial District

Cu, Zn, Mn and Fe were detected in the bean samples from all the LGAs at concentrations below their MPLs. Cd was detected in samples from only Lokoja LGA and at a concentration above its MPL. Pb and Cr were not detected in the samples from all the LGAs (Table 12).

Table 12

Essential and Non-Essential Metals Concentration in Beans (*Phaseolus vulgaris*) from different Local Government Areas of Kogi West Senatorial District

Essential/ Non-Essential metals (mg/kg)	MPLs	L1	L2	L3	L4
Copper, Cu	73.00	0.77 ± 0.06	0.81 ± 0.04	0.76 ± 0.1	0.065 ± 0.05
Lead, Pb	0.30	ND	ND	ND	ND
Zinc, Zn	100.00	0.99 ± 0.08	0.76 ± 0.08	0.72 ± 0.06	0.68 ± 0.04
Chromium, Cr	30.00	ND	ND	ND	ND
Cadmium, Cd	0.20	0.50 ± 0.02*	ND	ND	ND
Manganese, Mn	500.00	5.28 ± 0.43	7.00 ± 0.48	4.15 ± 0.42	6.32 ± 0.18
Iron, Fe	425.00	2.46 ± 0.36	6.44 ± 0.73	3.56 ± 0.36	7.83 ± 0.56

Values for Essential and Non-Essential Metals concentration were expressed as mean of triplicate determinations; Not Detected (ND), Lokoja LGA (L1), Kabba Bunu LGA (L2), Yagba East LGA (L3), Ijumu LGA (L4) Maximum Permissible Limit (MPLs) (FAO/WHO, 2016), * Exceeded MPL

Discussion

In this study, we observed that the essential and non-essential metals were detected in the grains (rice, maize, millet and beans) sourced from the three senatorial districts of Kogi State in varying concentrations. All the essential metals were present in the grains at concentrations below their MPLs while some of the non-essential metals were present at concentrations above their MPLs. The major contaminant of rice and millet was Cd. Cd was detected in rice and millet samples in a number of LGAs across the Senatorial Districts in concentrations above their PMLs. Pb was also present in rice and millet samples from some LGAs in concentrations above its MPL. For maize and bean samples, Cd and Pb were the only two metals detected in just one LGA in Kogi West Senatorial District at concentrations above their PMLs. The other non-essential metal assessed- Cr was not detected in majority of the grains' samples but below its PML in samples where it was detected. Cd and Pb therefore, were the 2 major contaminants of grains consumed in Kogi State as revealed by this study.

The most important sources of Cd contaminations of soils are phosphate fertilizers, sewage sludge amendments and industrial discharge. The concentration of Cd in the grain crops grown on contaminated soils can be very high depending on the nature and the proximity of the source of contamination. Chronic exposure to the Cd can lead to kidney disorders as the kidneys and liver store about 50 to 85% of Cd in the body with 30 to 60% being stored in the kidneys [14]. The other diseases caused by Cd exposure include; anemia, emphysema, anosmia (loss of sense and smell), cardiovascular

diseases, renal problems, and hypertension [15]. Cd has no known biological functions in the body but it interferes with some essential function of Zn, thereby inhibiting enzyme reactions and nutrient utilization. It catalyzes oxidation reactions, generating free-radical tissue damage [16]. Zinc, an essential trace element is more toxic in salt form than in elemental form. Its ingestion causes gastrointestinal toxicity, pulmonary toxicity, nephrotoxicity and neurotoxicity [13]. Though there has been paucity of information on reported carcinogenicity by oral route, most classifications are based on occupational exposure to Cd with inhalation as the primary route of exposure.

Soil (through the use of fertilizers) and atmospheric dust fall are the direct sources of Pb contamination in grain crops. Studies have shown that Pb has the ability to impair the synthesis of heme by inhibiting the activity of δ -aminolaevulinic dehydratase which is an important enzyme in heme biosynthesis pathway. Pb poisoning is also known to cause developmental problems such as impaired cognitive function, behavioral disorder, stunted growth, and impaired hearing [17]. Pb can also interfere with calcium metabolism, both directly and by interfering with vitamin D metabolism; it concentrated largely in bones in animals and humans and interferes with the normal maturation of erythroid elements in the bone marrow [18]. Adverse effects have been observed in children at blood lead levels ranging from 12 to 120 $\mu\text{g/l}$. Pb is toxic to both the central and peripheral nervous systems, inducing subencephalopathic neurological and behavioral effects. Other effects include epidemiological effects (blood lead level of 30 $\mu\text{g/l}$), intelligence quotient deficits of about four points in children due to prenatal/postnatal exposure to lead (blood lead level ranging from 11 to 33 $\mu\text{g/l}$), headache, irritability, constipation, weight loss, fatigue, hypertension, miscarriages, stillbirths, and renal tumors [19]. However, there is evidence from studies in humans that adverse neurotoxic effects other than cancer may occur at very low concentrations of lead, and that a guideline value derived on this basis would also be protective for carcinogenic effects [20].

Conclusion

Cd and Pb are the major contaminant of grains especially rice as revealed by this study. Cd and Pb were detected in concentrations above the FAO/WHO MPLs. Ingestion of the grains with high concentration of these metals can result in acute toxicological effects. Other essential and non-essential metals were detected in concentrations that are not sufficient to cause acute toxicological effects. However, chronic ingestion of this low concentration of the metals can lead to chronic diseases and death. We therefore, recommend regular monitoring of grains and other foods sold within Kogi State and Nigeria at large.

Declarations

Data Availability

Dr. Precious A. Idakwoji is the curator of the data set and are available on request.

Conflicts of Interest

The authors declare that they have no conflicting interests.

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Not applicable

Supplementary Materials

Not applicable.

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Figures

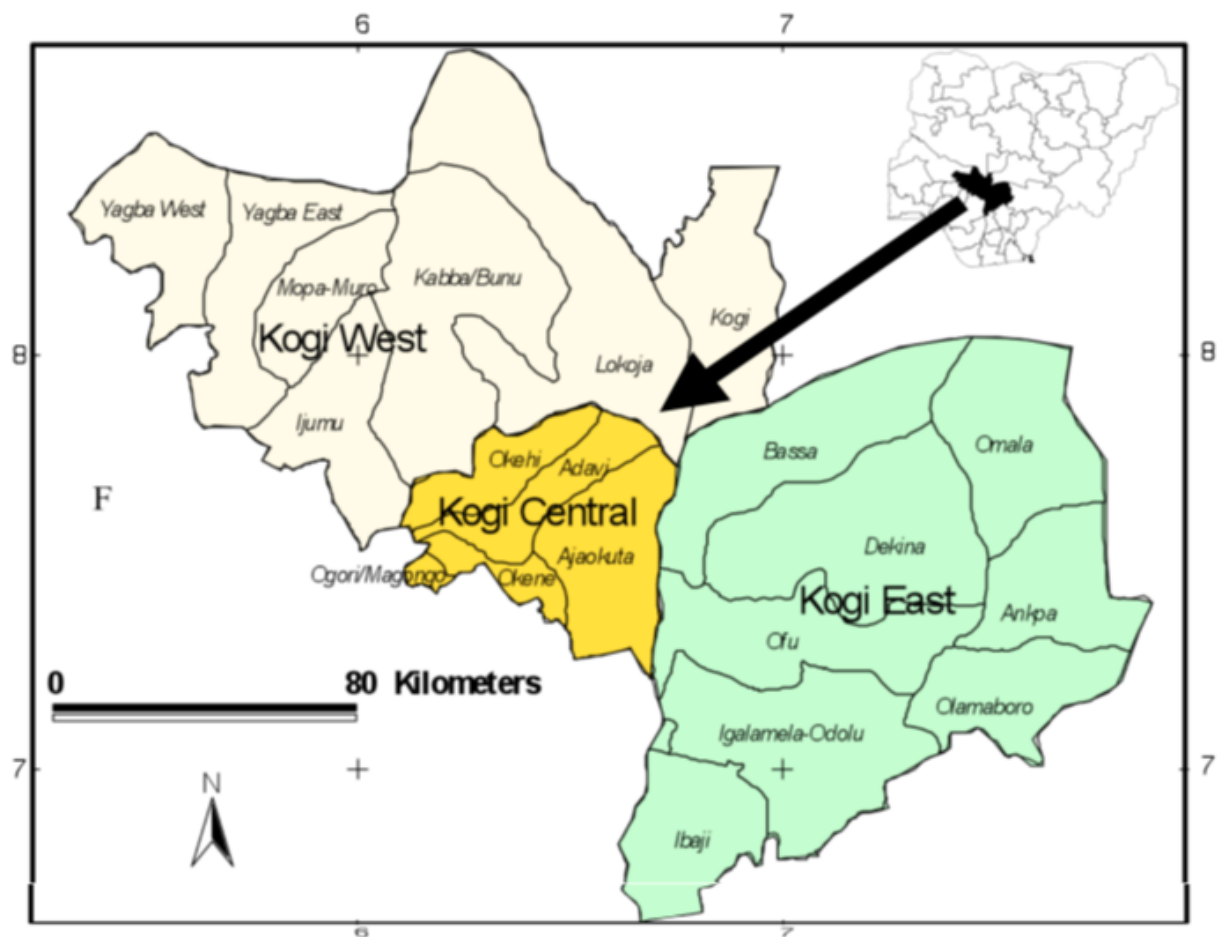


Figure 1

Senatorial Districts and Local Government Areas in Kogi state. (Source: Babatimehin *et al.* [11])