Original Research Papers

Contamination and Pollution Risk Assessment of Heavy Metals in Rice Samples (*Oryza Sativa*) from Nasarawa West, Nigeria

Abstract

Aim: This study was undertaken to assess the heavy metals contamination level in rice grains (*Oryza sativa*) from Nasarawa West, Nigeria.

Study Design: To estimate the contamination factor, degree of Contamination and Pollution load index of rice samples from Nasarawa west using the world health organization/food and agricultural organization acceptable limits of some toxic Heavy Metals in Food as reference heavy metals concentration.

Place and Duration of study: Department physics, Nasarawa State University, Keffi, the research was carried out between September 2017 to April 2018.

Methodology: Fifteen (15) samples each were taken from various locations in Keffi, Kokona, Karu, Nasarawa, and Toto respectively. Samples were dried in an open air at an ambient temperature and analyzed using Energy Dispersive X – Ray Fluorescence (EDXRF) spectrometer (with brand name ECLIPSE Ш, model XR–100CR).

Results: The contamination factor of rice were samples from the study area were Zn < Cu < Ni < Cr < Pb < 1 indicating a 'low risk' of contamination with the value of Cd >> 6 presenting a very high contamination risk of Cd. The Pollution Load Index value observed in Nasarawa West were in order of NSW (0.0683) < KEF (0.0773) < TTO (0.0972) < KKN (0.0988) < KRU (0.1389) and are all less than unity (1), indicating that the rice samples were not polluted by Cd, Cu, Cr, Ni, Pb and Zn.

Conclusion: Findings from this will help in making policies and preferring solution to public health related issues and further studies may be important.

Keywords: Heavy Metals Mean Concentration, Contamination Level, Pollution Load Index.

1.0 INTRODUCTION

The resulting effects of human activities on the earth's surface are devastating to the global ecosystem and man [1]. Activities such as commerce, agriculture, industry, among others, have becomes a major source of concern to the world, in terms of their effects on the environment and human health. The human society today is faced with so many environmental problems, prominent among which is contamination and pollution. According to [2], contamination and pollution results from human activities and these affect the quality of air, water, land and food. Majority of rice consumers may in turn be exposed to the heavy metals [3]. Heavy metals could be released into the environment either through natural or anthropogenic sources [4]. Anthropogenic inputs are always associated with industrialization and agricultural activates deposition. Some of which include atmospheric deposition, waste disposal, waste incineration, urban effluent, traffic emission, application of fertilizer and long – term application of waste water in our agricultural lands [5]. The deposition of radionuclides and heavy metals in food crops such as rice which could be subsequently transferred to the edible portion of plants are key pathways in a large set of ecological and other surveys. This is one of the first steps in which heavy metals enters our biosphere and thus, the human food chains [6]. Heavy metals become toxic to the plants when it exceeds maximum acceptable limits [7]. Toxic heavy metals could be absorbed and then accumulated by plants which might eventually enter the human body through the normal food intake. Consumption of these foods is the major exposure pathway; with the exposure risk from ingestion exceeding risks from inhalation and dermal contacts [8]. A reduction in crop yield may results from the normal plant growth inhibited by high levels of heavy metal in the soil [9,10]. Exposure to heavy metal sources both from the soil and water may results in contamination of crops such as rice that are grown in submerged conditions.

Consumptions of food (e.g. rice) contaminated with heavy metals is closely related to the negative health impacts. Clear evidence has shown that human renal dysfunction is linked to contamination of rice with heavy metals [11, 12]. In view of the recognition of the adverse health implications of heavy metals toxicity, there is a need for up – to – date measures to be taken so as to overcome the potential food contamination in the study area, especially as agrochemical applications such as pesticides, herbicides and fertilizers are now the practice of the day in the study area.

2.0 MATERIALS AND METHOD

2.1 Materials

The following are the materials used in carrying out the research work:

Plastic containers, Rice Samples, Pestle, Mortar and a Sieve, Global Positioning System (GPS), XRF Spectrometry Machine, Tissue paper, Methylated spirit, Polythene bags, shovel.

2.2 METHOD

2.2.1 Study Area

Nasarawa west agricultural zone as the study area consisting of Keffi (KEF), Kokona (KKN), Karu (KRU), Nasarawa (NSW), and Toto (TTO) Local Government Areas is bordered by Federal Capital Territory, Abuja, Kogi State and Kaduna state respectively. The study area has an existing network of roads linking all rural areas and major towns. Nasarawa west being part of Nasarawa State dominated by guinea savannah vegetation has agriculture as the mainstay of its economy with the production of varieties of cash crops such as rice, groundnut, cassava, pepper, cowpea, sesame, sorghum, yam throughout the year by the populace that engage in subsistence farming. It also contains various minerals such as cassiterite, columbit, mica, granite, quartz, iron-ore, and bauxite which are mostly mined by artisanal miners. The Figure below shows the map of Nasarawa West as the study area.

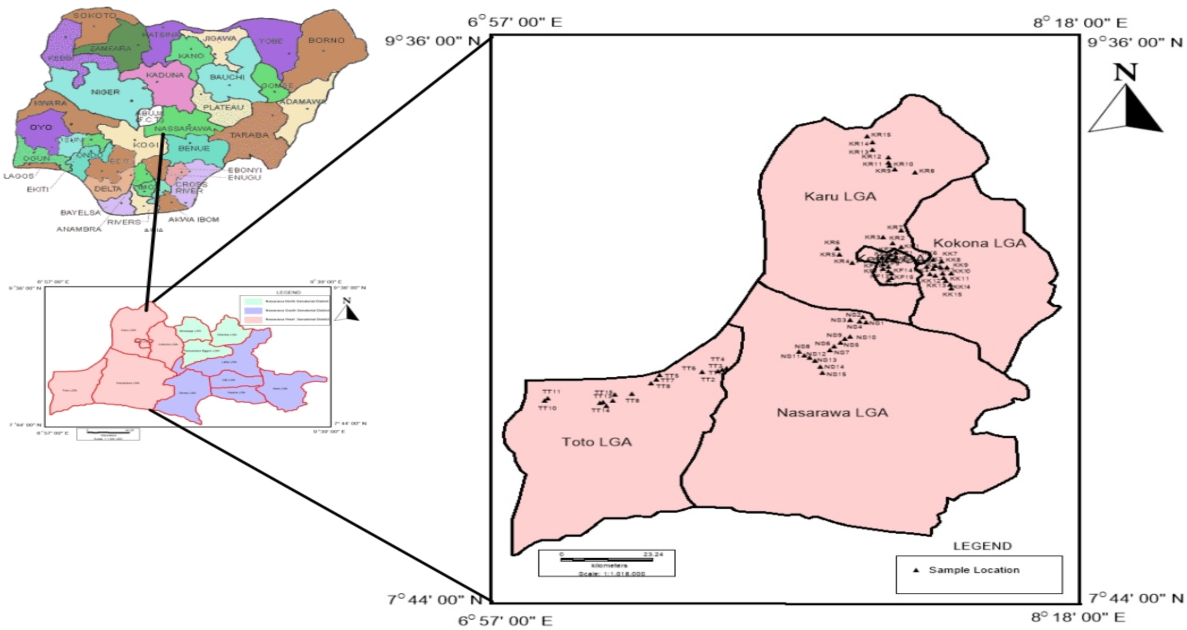

Figure 1: Map of the Study area

2.2.2 Samples Collection and Preparation

A total of Seventy five (75) samples were taken from various locations in Nasarawa West, Nigeria. Fifteen (15) samples were taken from each of the five Local Governments in the study area using a Global Positioning System (GPS) to obtain the coordinates of each location and the samples packaged in well labeled containers. The samples to be analyzed were dried in an open air at an ambient temperature, pulverized using agate mortar and pestle, and then sieved with a 2.00mm so as to obtain a uniform representative sample sizes. The samples were then pelletized, since it is a biological sample. A 0.8g samples by mass measured from each sample is pelletized with steel molds, pellets and a hydraulic press, using aluminum foil as the binder to hold the sample particles together after the removal from the molds.

2.2.3 Rice Samples Analysis

X – Ray Fluorescence (XRF) Spectrometry as a relatively non-destructive spectrometric procedure for analysis of food samples with little or no pre-treatment required was employed in this study. Representative samples were irradiated using the Energy Dispersive X – Ray Fluorescence (EDXRF) spectrometer (with brand name ECLIPSE Ш, model XR–100CR) supplied by AMTEK INC. MA; USA, with a high performance thermoelectrically cooled Si–PIN photodiode as an X – ray detector and a preamplifier at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile–Ife, Nigeria where the concentration of the heavy metals by mass were obtained.

2.2.4 Contamination Factor (CF)

Contamination factor (CF) is used to assess contamination level in relative to average concentration of the respective heavy metals in the environment i.e. foods to the measured reference values from previous study with similar geological origin or uncontaminated foods [13]. The mathematical expression (1) was used for calculating the Contamination Factor (CF) [14].

$$CF = \frac{C_m}{C_{ref}}$$

where, C_m= mean concentration of the heavy metal in the rice sample;

C_{ref} = reference concentration of the metal.

WHO/FAO standards for some toxic heavy metals in foods were taken as the reference concentration. The values are presented in Table 1 below.

Table 1: Acceptable Limits of some toxic Heavy Metals in Food by WHO/FAO.

Heavy Metals	Concentrations (μg/g) [15]
Cd	0.10
Cu	73.00
Cr	2.30
Ni	67.00
Pb	0.30
Zn	100.00

These metals are called micronutrients and are toxic when taken in excess of requirements.
Information about contamination factor is shown in table 2 below.

Table 2: Contamination Factor used to assess food contamination

Contamination Factor	Low risk	Moderate risk	Considerable High risk	Very high risk
CF	CF < 1	1 ≤ CF< 3	3 ≤ CF < 6	CF ≥ 6

[16, 17]

2.2.4 Contamination Degree (CD)

Contamination degree (CD) is sometimes known as degree of contamination. Cd is the sum of all contamination factors, which provides information about total contamination in a particular sampling location [18, 19] and it is shown in Table 3 below.

Contamination degree is often expressed as:

$$CD = \Sigma CF_{Cd} + CF_{Cr} + CF_{Cu} + CF_{Cu} + CF_{Ni} + CF_{Pb} + CF_{Zn} \qquad (2)$$

Where, CF_{Cd}, CF_{Cr}, CF_{Cu}, CF_{Ni}, CF_{Pb} and CF_{Zn} were the contamination factors for Cadmium, Chromium, Copper, Nickel, Lead and Zinc respectively [17, 20].

Table 3: Contamination Degree used to assess food contamination

Contamination Degree	Low risk	Moderate risk	Considerable High risk	Very high risk
CD	CF < 8	8 ≤ CD< 16	16 ≤ CD < 32	CD ≥ 32

[13, 16, 17]

2.2.5 Pollution Load Index (PLI)

The basis of determining the pollution load is to estimate the extent of heavy metals pollution in rice samples in comparison to its reference acceptable limits in foods by WHO/FAO. Pollution load index (PLI) gives information about the toxicity of heavy metals in each respective sample locations in the study area [19, 21, 22] and it is shown in Table 4 below.

The expression (3) was used for calculating the pollution load index (PLI) base on the toxic heavy metals detected with a view of determining the suitability of rice for human consumption [14].

$$PLI = (CF_1 \times CF_2 \times CF_3 \times CF_4 \ldots \ldots \ldots \times CF_n)^{1/n} \quad (3)$$

where, n=number of metals considered in the study;

CF_i = Contamination Factor for each individual metal.

Table 4: Pollution Load Index used for assessing food pollution

Pollution Load Index	No Pollution	Moderate Pollution	Heavy Pollution	Extremely Heavy Pollution
PLI	PLI < 1	1 < PLI < 2	2 < PLI < 3	PLI > 3

[13, 14, 16, 17]

3.0 RESULTS AND DISCUSSION

3.1 Mean Concentrations of Heavy metals in Rice Samples from Nasarawa West Agricultural Zones

The mean concentrations of cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) (Chukwuma, 2014) were estimated in rice samples from Keffi, Kokona, Karu, Nasarawa and Toto of Nasarawa West agricultural zone. Table 5 shows that the results of the mean concentrations of heavy metals in rice samples from Keffi (KEF) were in the decreasing order of Cd > Ni > Cu > Zn > Pb > Cr with each heavy metal having the mean value of Cd (29.521µg/g), Ni (0.349µg/g), Cu (0.287µg/g), Zn (0.215µg/g), Pb (0.157µg/g) and Cr (0.060µg/g) respectively. In Kokona (KKN), it is observed that the mean concentrations of heavy metals in rice samples were in the increasing order of Cr < Pb < Zn < Cu < Ni < Cd with the value of Cr (0.097µg/g), Pb (0.181µg/g), Zn (0.252µg/g), Cu (0.341µg/g), Ni (0.420µg/g) and Cd (33.477µg/g) respectively.

It is shown in table 5 below that the mean concentrations of heavy metals in rice samples from Karu (KRU) were in the order of Cr < Pb < Zn < Cu < Ni < Cd with Cr (0.172µg/g) presenting the lowest value followed by Pb (0.268µg/g), Zn (0.380µg/g), Cu (0.531µg/g), Ni (0.648µg/g) and Cd (40.183µg/g) respectively.

The observed mean concentrations of heavy metals in rice samples from Nasarawa (NSW) were in the order of Cr < Pb < Zn < Cu < Ni < Cd with the respective value of 0.085µg/g, 0.123µg/g, 0.179µg/g, 0.241µg/g, 0.293µg/g and 25.919µg/g.

The mean concentrations of heavy metals in rice samples from Toto (TTO) were in order of Cr < Pb < Zn < Cu < Ni < Cd with the value of Cr (0.146µg/g), Pb (0.168µg/g), Zn (0.262µg/g), Cu (0.340µg/g), Ni (0.410µg/g) and Cd (31.749µg/g) respectively.

It is observed that Cd has it highest mean concentration value of 40.183µg/g in rice samples from Karu (KRU) with the lowest value of 25.919µg/g in rice samples from Nasarawa (NSW) and this is corroborated by the study carried by [23].

Table 5: Mean Concentrations of Heavy metals in Rice Samples from Nasarawa West

S/N	Sample ID	Sample Size	Cd (µg/g)	Cr (µg/g)	Cu (µg/g)	Ni (µg/g)	Pb (µg/g)	Zn (µg/g)
1	KEF	15	29.521	0.060	0.287	0.349	0.157	0.215
2	KKN	15	33.477	0.097	0.341	0.420	0.181	0.252
3	KRU	15	40.183	0.172	0.531	0.648	0.268	0.380
4	NSW	15	25.919	0.085	0.241	0.293	0.123	0.179
5	TTO	15	31.749	0.146	0.340	0.410	0.168	0.262

NOTE: KEF – KEFFI, KKN – KOKONA, KRU – KARU, NSW – NASARAWA, TTO – TOTO, ID – Identity

3.2 Contamination Factor, Contamination degree and pollution Load Index of Heavy metals in Rice Samples from Nasarawa West Agricultural Zones

Contamination Factor (CF) which is used in assessing the level of contamination of heavy metals in rice samples from Keffi (KEF) is in the order of Zn < Cu < Ni < Cr < Pb < 1 indicating ‘low risk of contamination’ while Cd >> 6 indicating ‘a very high risk of contamination by Cadmium’ [16, 17].

In Kokona (KKN), Table 6 shows that risk level is in the order of Zn < Cu < Ni < Cr < Pb < 1 indicating that the contamination of these heavy metals is at ‘low risk’ while the CF value of Cd >> 6 indicating that the rice samples were highly contaminated with cadmium.

In Karu (KRU), the CF value shows that Zn < Cu < Ni < Cr < Pb < 1 indicating a ‘low risk’ of contamination by these heavy metals. But the rice samples presented a very high contamination risk of Cd indicating that the value of Cd >> 6.

Rice samples from Nasarawa (NSW) shows that contamination level of Zn < Cu < Ni < Cr < Pb < 1 indicating ‘low risk’ of of contamination by these heavy metals while the samples presented a very high risk of contamination by Cd with the value of Cd >> 6.

It is observed from Toto (TTO) that the rice samples presented the contamination level of heavy metals in the order of Zn < Cu < Ni < Cr < Pb < 1 indicating ‘low risk’ of contamination while the value of Cd >> 6 presenting a very high risk of contamination by Cadmium.

The **Degree of Contamination** by heavy metals in rice samples from KEF, KKN, KRU, NSW and TTO were 295.7705, 334.8254, 402.8188, 259.6464 and 318.1269 respectively.

The **Pollution Load Index** value observed in Nasarawa West were in order of NSW (0.0683) < KEF (0.0773) < TTO (0.0972) < KKN (0.0988) < KRU (0.1389) and are all less than unity (1), indicating that the rice samples were not polluted by Cd, Cu, Cr, Ni, Pb and Zn.

Table 6: Contamination factors (CF), Degree of Contamination (CD), and Pollution Load Index (PLI) of some Heavy metals in Nasarawa West Using WHO/FAO Standard.

Sample ID	Contamination factor (CF)						Degree of Contamination (CD) [20]		Pollution Load Index (PLI)	
	Cd	Cu ($x10^{-3}$)	Cr	Ni ($x10^{-3}$)	Pb	Zn ($x10^{-3}$)				
KEF	295.21	3.8784	0.0260	5.2089	0.5233	2.1500	295.7705	Very high risk	0.0773	Unpolluted

KKN	334.77	4.6712	0.0422	6.2687	0.6033	2.5200	334.8254	Very high risk	0.0988	Unpolluted
KRU	401.83	7.2739	0.0748	9.6716	0.8933	3.8000	402.8188	Very high risk	0.1389	Unpolluted
NSW	259.19	3.3014	0.0369	4.3731	0.4100	1.7900	259.6464	Very high risk	0.0683	Unpolluted
TTO	317.49	4.6575	0.0635	6.1194	0.5600	2.6200	318.1269	Very high risk	0.0972	Unpolluted

4.0 Conclusion

The high concentration and contamination levels presented by Cd in rice samples from the study area, may arise from the leaching of the top soils and rocks into the rice fields, and the modern practice of application of mineral fertilizers which is a great concern. This is an indication of potential health risk among the exposed population. The value of the pollution load index in Nasarawa west were all less than unity (1), indicating that the rice samples were not polluted by Cd, Cu, Cr, Ni, Pb and Zn.

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