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Evaluation of Heavy Metals Contamination in Soils and Vegetables Grown in Selected Irrigation Sites in Katsina State, Nigeria

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ABSTRACT: Prolonged consumption of vegetables grown in soils contaminated with heavy metals poses significant health risks in humans and animals. This study, therefore, investigated the levels of some heavy metals of biological importance, such as mercury, cadmium, chromium, iron and lead in soils and selected vegetables grown in irrigation sites in Katsina State, Nigeria, using Atomic Absorption Spectrometry after HNO_3/H_2O_2 digestion. The findings revealed that the heavy metals were detected at varying levels, notably, Pb (0.98±0.00 mg/kg to 4.01±0.80 mg/kg) and Cd (0.001±0.00 mg/kg to 0.022±0.00 mg/kg) were present in all the soil samples at levels exceeding those recommended by Food and Agriculture Organization. The highest concentrations for Pb (1.81±0.03 mg/kg to 4.01±0.80 mg/kg) and Fe (8.01±1.24 mg/kg to 12.61±2.06 mg/kg) were observed in the vegetables grown in 'Kofar Sauri' irrigation site, while the lowest levels for Hg (0.001±0.0 mg/kg) and Cd (0.004±0.00 mg/kg to 0.021±0.00 mg/kg) were found in the vegetables grown around 'Ajiwa' dam site. Mercury (Hg) was however, not detected in most of the vegetable samples. Therefore, identification of contamination sources, sustainable agricultural practices and stringent regulatory measures are necessary to mitigate heavy metals contamination of foods and ensure food safety and healthy living.

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Anthropogenic activities, such as irrigation, application of fertilizers, pesticides and herbicides release heavy metals into the soil, whilst mobility and solubility off the heavy metals in the soil leads to their bioaccumulation in the plants**.** Irrigation is a common practice in urban and sub-urban centers in Katsina State, Nigeria in which water is supplied to soils to meet the plants' water needs, overcome drought and improve its yields, and most often, it's associated with the use of municipal sewage and wastewater. The sewage and wastewater are often contaminated with heavy metals in various forms and at different levels, because they usually contain both industrial effluents and domestic wastewater. Thus, vegetables grown through irrigation with the contaminated sewage and wastewater may bioaccumulate potentially toxic heavy metals with unfavorable effects on growth of the plants and health of its consumers (Apollos *et al.,* 2016). Heavy metals are those metals that fall within the d-block of the periodic table and whose atomic numbers are greater than 20. The heavy metals could be categorized into two groups namely, essential and

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non-essential, based on their roles in living systems. Metals like Iron, Zinc Manganese, Nickle and Copper enhances growth, development and other physiological functions in living organisms, and are therefore, classified as essential heavy metals, while metals such as Lead, Cadmium and Arsenic, do not have any known biological function, and are often toxic to living organisms. These are classified as non-essential heavy metals (Paul and John, 2014). Soils contaminated with heavy metals are potential environmental hazards of great concern worldwide, as they can affect crop quality and cause toxicity in humans either through direct exposure to the soils or through entry of the heavy metals into the food chain (Margenat *et al*., 2019). The heavy metals are continuously present in the ecosytem because of the intense use of their compounds in industrial applications, and are very detrimental owing to their non-biodegradability, long half-lives and bioaccumulation potentials in different body organs. Most heavy metals are toxic due to their solubility in water. Even low concentrations of heavy metals can have deleterious effects to humans and animals since there is no established mechanism for their removal or clearance from the body (Hochwimmer *et al*., 2020). The non- biodegradable nature of the heavy metals leads to their accumulation and toxicity in organisms. The heavy metals exert toxicity by one of two mechanisms: they either act as antagonists to the essential metals by substituting the metals required by the body, or by directly causing damage to the tissues. Some of their adverse effects on human health includes oxidative stress, infertility, erectile dysfunction, renal dysfunction, cancer and central nervous system damage. The toxicity of the heavy metals has been a global challenge for a long time (Vigneri *et al*., 2017). Vegetable plants are important component of human diet and provide good sources of vitamins, minerals, fiber and are good source of antioxidants in the human body (Maitera *et al*., 2019). However, consumption of heavy metals contaminated vegetables, may cause serious health risks to humans, as they may accumulate in various organs of the body, including liver, kidney and lungs, causing disruptions to numerous biochemical and physiological processes, leading to cardiovascular, kidney, bone and other diseases (Singh *et al.,* 2018). Even though, several adverse effects of the heavy metals are known, exposure of humans and animals to heavy metals is increasing at an alarming rate, particularly in developing countries and in most parts of the world. Due to the understanding of nutritional significance of the vegetables, their consumption in the study area is very high, as the communities presumed vegetables to be 100% safe. Hence, evaluation of heavy metals contents of soils in the irrigation sites and their bioaccumulation in vegetables is very crucial for ensuring food safety and healthy living. The present study, therefore, aims to assess the irrigated soils and the grown vegetables, including spinach, cabbage and lettuce of heavy metals contamination levels, including mercury, cadmium, chromium, lead and iron, in the selected irrigation sites in Katsina State, Nigeria.

MATERIALS AND METHODS

The reagents and chemicals used in this research work were of analytical quality grade. Standard equipment/apparatus were equally used.

Study Area: This work was carried out in Katsina State, Nigeria, located at latitude 12º 15º and longitude 7º 30º east. Katsina State share borders with Kaduna, Zamfara, Jigawa, Kano States and Maradi State of Niger Republic. The region is mainly populated by the Hausa and Fulani tribes. Large portion of the population in the state are involved in subsistence agricultural practices, such as, livestock production, food and cash crops etc, which happens all year round owing to irrigation practices along rivers and dams.

Collection and Preparation of the Sample: Three (3) vegetable samples were collected from the irrigation sites of Kofar Marusa, Kofar Sauri and Ajiwa dam sites weekly for the period of three (3) random weeks and designated as A, B and C respectively. All the samples have been washed with distilled water to remove dust and microorganisms, and then followed with air drying in an electric oven at 60º for 24hrs. The dry samples were pulverized into powder using a ceramic coated grinder (WHO, 2000). The powdered samples were stored in a clean polythene bag until needed for digestion.

*Ashing of the Samples: E*xactly 5g from each powered sample was measured and transferred into a weighed crucible in a muffle furnace at temperature of 500°C and ashed for 4hrs. The ashed samples were then placed in a desiccator to cool, after which the weight of the ash was measured and recorded. The ashing was done to reduce the possibility of interference with organic matter, which was therefore, burnt off, leaving only the inorganic matter.

Sample Digestion: The weighed ash was placed in a beaker and 20cm^3 of HNO_3/H_2O_2 solution in the ratio of 2:1 was added. The mixture was then placed on a heating mantle and heated in a fume hood until nearly dried. The contents were cooled and 20cm^3 of distilled water was then added and filtered using whattman filter paper No. 42 and 0.45μm Millipore filter paper and then transferred into a 25mL volumetric flask with the addition of distilled water. This was then taken to the Atomic Absorption Spectrophotometre for the analysis.

Analysis of the Samples: Flame Atomic Absorption Spectrophotometer (Buck Scientific, 210 VGF) was used in the analysis. The parameters were set according to the specifications in the manufacturer's protocol, including lamp current and fuel system of air/acetylene flame. The machine had a picking meter that indicated when the optimum conditions have been realized, i.e. an automatic optimization.

Statistical Evaluation: The data obtained in this work were evaluated using mean and standard deviation.

RESULTS AND DISCUSSION

The results of the heavy metals evaluation in the soils and the selected vegetables grown in the irrigation sites in Katsina State are presented in Table 1 and Table 2 respectively. From the findings, the heavy metals were detected at varying levels, notably, Pb (0.98±0.00 to 4.01±0.80 mg/kg) and Cd (0.001±0.00 to 0.022±0.00 mg/kg) were found in all the samples at levels higher than those recommended by the Food and Agriculture Organization. The highest concentrations for Pb (1.81±0.03 to 4.01±0.80 mg/kg) and Fe (8.01±1.24 to 12.61±2.06 mg/kg) were observed in the vegetables grown in 'Kofar Sauri' irrigation site, while the lowest levels for Hg (0.001±0.0 mg/kg) and Cd (0.004±0.00 to 0.021±0.00 mg/kg) were found in the vegetables from Ajiwa dam irrigation site. Mercury was however, not detected in most of the vegetable samples.

The detection of soils contamination with heavy metals can be achieved through many conventional analytical methods, including spectroscopic, separation and electrochemical techniques. From the results presented above, Fe and Pb had the highest concentrations among all samples. Fe is non-toxic in small amounts as because it is an essential element that participates in many biochemical processes. However, Fe overload due to prolonged consumption can cause several pathological conditions. Pb is toxic and has no known biochemical function in human and animal systems. The observed amounts could be from the frequent applications of nitrogenous fertilizers and manures to the farmlands. Pb-based materials, such as batteries present in the irrigation water can also be a contributing factor. The level of Pb detected in these samples could also be associated with vehicle emissions owing to the heavy traffic density in Katsina, which can change the natural composition of the soils (Kumar *et al.*, 2019). It is, therefore, imperative to regulate the persistent increase in the concentration of heavy metals in the environment.

Table 1: The heavy metals contents in soils from the irrigation sites in Katsina state

Location	Hg (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Pb (mg/kg)
K/Sauri	0.003±0.0	0.022±0.00	1.383±0.10	13.08±0.80	2.91±0.01
K/Marusa	ND	0.012±0.00	2.013±0.02	11.96±1.01	1.76±0.00
Ajiwa Dam	0.002±0.0	0.021±0.00	ND	12.71±0.06	2.56±0.01

Values are expressed as mean ± Standard Deviation of three replicates. ND= Not detected (n=3).

Table 2: The heavy metals contents in vegetables grown in the irrigation sites in Katsina state

Location		Hg (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Pb (mg/kg)
K/Sauri	Spinach	ND	0.003±0.00	0.092±0.00	8.01±1.24	2.18±0.04
	Cabbage	0.001±0.0	0.010±0.00	0.271±0.00	10.01±2.00	1.81±0.03
	Lettuce	ND	0.001±0.00	0.046±0.00	9.06±0.06	2.01±0.01
K/Marusa	Spinach	ND	0.001±0.00	1.264±0.01	8.32±1.32	0.98±0.00
	Cabbage	ND	0.003±0.00	0.161±0.00	10.27±1.09	1.04±0.03
	Lettuce	ND	0.001±0.00	0.17±0.00	6.00±0.08	1.22±0.00
Ajiwa	Spinach	0.001±0.0	0.012±0.00	ND	9.30±0.10	0.99±0.00
	Cabbage	ND	0.010±0.00	ND	10.01±0.09	1.09±0.02
	Lettuce	ND	0.004±0.00	ND	8.26±1.32	1.82±0.02

Values are expressed as mean ± Standard Deviation of three replicates. ND= Not detected (n =3).

Evidences indicated that consumption of even small amounts of Pb could be implicated in brain damage and behavioral perturbations in children, as well as oxidative stress and related complications in adults (Mapanda *et al*., 2005). The results of the present study, reveals Cd concentration level from 0.001±0.00 to 0.022±0.00 mg/kg from both soils and vegetables, this is in proximity with the findings of Armaya'u *et al*. (2020) who reported the values of 0.0336 mg/dL and of 0.0182 mg/dL as the highest and lowest values respectively, from Lambun Sarki sampling points. The reference sample of his report has a value of 0.0054 mg/dL while the WHO/FEPA permissible limit of Cd in soil is 0.0030 mg/L. This clearly shows that the concentration of Cd in all the sampled sites is higher when compared to the reference area and the maximum permissible limit. This could be associated with effluents of steel rolling industry and wastes from the metal works that are discharged into the sewage water and used for irrigation around the farmlands. The prolonged consumption of Cd in foods could be implicated in the postmenopausal breast cancer in women and possible kidney damage (Sanusi and Aminu, 2017). The Cr level obtained is higher when compared to the WHO daily recommended limits. This is contrary to the value of 0.0091 mg/dL and the highest value of 0.0123 mg/dL reported by Armaya'u *et al*. (2020) in the study area, which were also higher than that of the reference area (0.0088 mg/L). The high Cr concentration could be due to the metallurgical processes occurring around the sites and the possible deposition of materials containing Cr, such as paints, cement, papers, rubbers, etc. in the farmyard manure. Cr contamination could cause hepatotoxicity, lung damage, cancer, abnormal thyroid artery and polycythaemia problems (Martin and Griswold, 2009).

Conclusion: The findings of this study suggest possible serious implications associated with prolonged exposure to the heavy metals, through consumption of the heavy metals contaminated vegetables, which could accumulate in organs and cause toxicity and adverse health effects. This informed the need for identification of contamination sources, sustainable agricultural practices and stringent regulatory measures to mitigate the heavy metals contamination of vegetables and foods to ensure food safety and healthy living.

Declaration of Conflict of Interest: The authors declare no conflict of interest

Data Availability Statement: Data for this research are available upon request from the corresponding author.

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