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Seasonal Monitoring of Heavy Metals Contamination of Selected Fruits and Vegetables from Kaura Namoda, Central Market, Zamfara, Nigeria

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Abstract **- Fruits and vegetables are a primary source of human exposure to heavy metals, as most are consumed raw without undergoing any processing. This research aims to determine the seasonal concentrations of heavy metals-lead (Pb), chromium (Cr), cadmium (Cd), nickel (Ni), copper (Cu), and cobalt (Co)-in onions, spinach, lettuce, and cucumbers obtained from Kaura Namoda, Zamfara State. Samples were collected every four months (quarterly) from the same vendor. Acid digestion techniques and atomic absorption spectroscopy (A.A.S.) were used for sample preparation and analysis. The results show a significant difference in the seasonal concentrations of heavy metals in the selected fruits and vegetables, as determined using ANOVA ($P < 0.05$). Spinach, lettuce, and cucumber had Pb concentrations of 0.08 mg/kg in Q1; lettuce had 0.017 mg/kg in Q3; and cucumber had Pb concentrations of 0.18 mg/kg in Q4, 0.17 mg/kg in Q3, and 0.13 mg/kg in Q4. Spinach, lettuce, and cucumber appear to be more vulnerable in both dry and wet seasons. In conclusion, there should be continued monitoring and awareness campaigns regarding the potential sources of these heavy metals, such as illegal mining activities, improper use of agrochemicals, and inadequate waste disposal, to support effective management and policy development.**

Keywords: **Heavy Metals, Fruit, Vegetables, Atomic Absorption Spectrophotometer, Kaura Namoda**

I. INTRODUCTION

Healthy fruits and vegetables are those that are free from all forms of contamination, such as pesticide residues and heavy metals. Therefore, such fruits and vegetables provide essential minerals and vital vitamins that the body requires for growth and development in both adults and children [1]. Fruits and vegetables are identified as a source of human exposure to heavy metals because they absorb these metals from the soil and water, either through irrigation or runoff [2]. This makes fruits and vegetables that are mostly eaten raw, without processing, a vector for human exposure to toxic heavy metals [3]. The contamination levels of these heavy metals may vary due to seasonal variations and other factors, such as harmattan winds, rainfall, irrigation sources, and humidity levels occurring during both dry and wet seasons [4]. The safety of food from heavy metals has become a global concern due to the toxicity and bioaccumulation of these metals when they enter the food chain [5]. Heavy metals are not biodegradable like other organic pollutants; therefore, they are stored in the vital organs of humans and can result in various disorders [6], [7], including renal failure, cardiovascular disorders, and cancer [8]. The sources of heavy metal contamination in fruits and vegetables have been identified by various researchers worldwide, mainly from human and industrial waste [9], [10]. Zamfara State, one of the north-west states of Nigeria, has a history of lead poisoning outbreaks due to human activities such as illegal gold mining, which is associated with other heavy metals. These activities may have led to the contamination of soil, water, and even dust, which in turn bioaccumulate in humans [11].

Previous researchers [12], [13], [14], [15] have focused on assessing heavy metal concentrations in fruit and vegetable samples in Nigeria, but limited data are available on the seasonal variation of heavy metals in these products, particularly from Zamfara State. The aim of the present study is to monitor the seasonal variation in the concentrations of heavy metals (Pb, Cd, Cr, Ni, and Co) in selected fruits and vegetables-onion, spinach, lettuce, cucumber, and pineapple-obtained from Kaura Namoda central market.

II. METHODOLOGY

A. Samples collection

The fruit and vegetable samples (onion, spinach, lettuce, cucumber, and pineapple) were obtained from the Kaura Namoda central market. They were purchased randomly from the same fruit and vegetable vendors in December 2024, and in March, June, and September 2025 (quarterly). Each sample was kept in a polyethylene bag and transported to the Chemistry Laboratory, Federal Polytechnic.

B. Samples Preparation and Digestion

All the reagents and chemicals used were of analytical grade and used as purchased. All the samples were cleaned with running tap water and then rinsed with distilled water. This was carried out to ensure quality control. The edible parts of each sample were peeled and oven-dried, with constant weighing at intervals, until the moisture was completely removed.

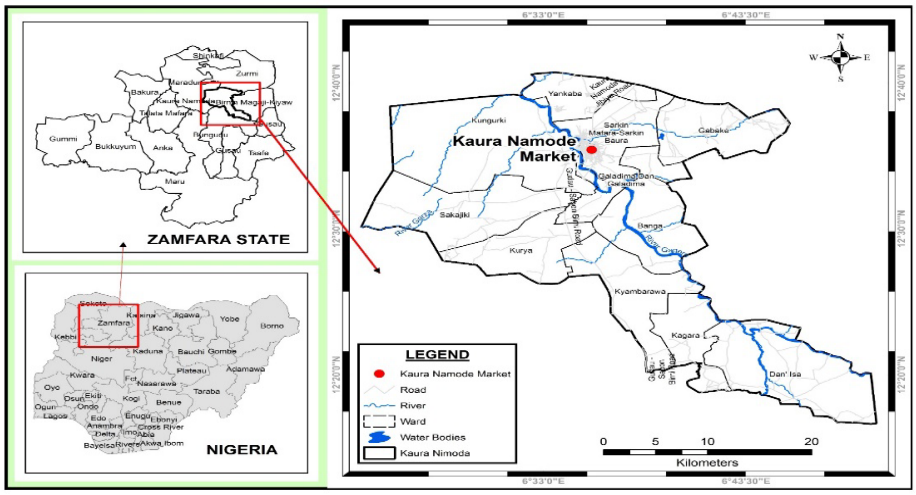

Fig.1 Map Showing Kaura Namoda Central Market

TABLE I CONCENTRATIONS OF HEAVY METALS (MG/KG) IN FRUIT AND VEGETABLE SAMPLES TABULATED IN MEAN ± STANDARD DEVIATION ACROSS QUARTERS

Sample	Quarters	Pb	Cr	Cd	Ni	Cu	Co
Onion	Q1	0.000±0.00	0.005 ±0.001	0.002 ±0.001	0.233±0.008	0.025±0.005	0.031±0.008
	Q2	0.000±0.00	0.00±0.00	0.00±0.00	0.144±0.001	0.000±0.00	0.000±0.00
	Q3	0.027±0.005	0.014±0.008	0.335±0.032	0.148±0.006	0.245±0.046	0.030±0.008
	Q4	0.107±0.001	0.005±0.001	0.007±0.001	0.132±0.049	0.214±0.001	0.044±0.009
Spinach	Q1	0.08±0.004	0.00±0.00	0.046±0.004	0. 153±0.005	0.097±0.041	0.017±0.001
	Q2	0.00±0.00	0.012±0.001	0.002±0.001	0.142±0.001	0.213±0.001	0.00±0.00
	Q3	0.007±0.002	0.00±0.00	0.00±0.00	0.232±0.002	0.134±0.002	0.00±0.00
	Q4	0.05±0.004	0.003±0.004	0.021±0.001	0.211±0.002	0.101±0.001	0.011±0.001
Lettuce	Q1	0.016±0.004	0.023±0.002	0.023±0.002	0.172±0.001	0.431±0.002	0.015±0.001
	Q2	0.021 ± 0.002	0.031±0.001	0.031±0.002	0.412± 0.001	0.71 ±0.002	0.251±0.002
	Q3	0.017±0.002	0.014±0.003	0.035±0.032	0.048±0.004	0.055±0.006	0.140±0.004
	Q4	0.007±0.001	0.005±0.002	0.007±0.001	0.032±0.009	0.024±0.001	0.064±0.003
Cucumber	Q1	0.18±0.001	0.00±0.00	0.46±0.004	0. 13±0.004	0.47±0.042	0.17±0.002
	Q2	0.00±0.00	0.12±0.002	0.02±0.001	0.42±0.002	0.13±0.002	0.00±0.00
	Q3	0.17±0.003	0.00±0.00	0.00±0.00	0.32±0.002	0.34±0.001	0.00±0.00
	Q4	0.13±0.003	0.23±0.001	0.21±0.001	0.11±0.002	0.11±0.001	0.11±0.002
Pineapple	Q1	0.000±0.00	0.205 ±0.001	0.112 ±0.001	0.223±0.007	0.035±0.005	0.051±0.002
	Q2	0.000±0.00	0.00±0.00	0.00±0.00	0.154±0.002	0.000±0.00	0.000±0.00
	Q3	0.037±0.005	0.114±0.008	0.235±0.032	0.248±0.004	0.255±0.046	0.040±0.004
	Q4	0.207±0.001	0.105±0.001	0.017±0.001	0.232±0.009	0.224±0.001	0.054±0.005

Key: Pb = lead, Cd = Cadmium, Cr = Chromium, Ni = Nickel, Cu Copper, Co = Cobalt. Q1-Q4 = Quarterly

Each sample was then ground to obtain a powder. The acid digestion technique was adopted using concentrated hydrochloric acid (HCl) and nitric acid (HNO_3) at a ratio of 3:1 [16]. The digestion was carried out using a hot plate with a regulated temperature of 120 °C for 5 hours in order to obtain a clear digest [17]. The solution was filtered with the aid of filter paper into a clean beaker. Deionized water was added thereafter. The Atomic Absorption Spectrophotometer (AAS) was calibrated (quality assurance) before carrying out the analysis to determine the concentration of the selected heavy metals.

C. Data Analysis

The experiment was carried out in triplicate for each element and thereafter expressed as mean ± standard deviation in order to ensure accuracy and precision. The data obtained from each quarter were also analyzed using statistical tools, specifically analysis of variance (ANOVA), and a test for the significant difference ($p < 0.05$) in the concentration of heavy metals in the selected fruit and vegetable samples from each quarter.

III. DISCUSSION

From Table I above, the order of heavy metals accumulated in the vegetables and fruit is consistently spinach > onion > lettuce > cucumber > pineapple. The seasonal variation of the heavy metals' concentration in the fruit samples ($p < 0.05$) shows a significant difference among the quarters. From the results obtained, the highest concentration of heavy metals was recorded in Q1, followed by Q4, and was at its lowest in Q3. On the other hand, the Pb levels in spinach during the first quarter, Q1, and Q4 are 0.08 mg/kg and 0.05 mg/kg, respectively. These values are higher than the FAO/WHO permissible limit of 0.3 mg/kg, while the other heavy metal concentrations are within the permissible limit.

However, the results, as shown in Table I, indicate that the fruits and vegetables obtained from Kaura Namoda show seasonally significant variation in the concentration of heavy metals. The higher heavy metal levels recorded in the spinach samples may be a result of the large surface area of its leaves, which may absorb heavy metals from dust and aerosols, and the plant structure may favor the accumulation of these metals [18]. On the other hand, the lower concentration of heavy metals in pineapple may be a result of its lower efficiency for absorption.

The peak concentrations observed in this study, in Q1 and Q4, can be attributed to irrigation sources, where harvested water is used for the irrigation of these fruits and vegetables. Additionally, the deposition of atmospheric particles is more pronounced during harmattan, when contaminated dust can travel long distances, either from a mining site or other anthropogenic activities [19]. The trend of heavy metals in the seasonal variation indicates a lower concentration in Q3, the rainy season. This may be a result of heavy rainfall, which can dilute or wash away deposited contaminants such as heavy metals.

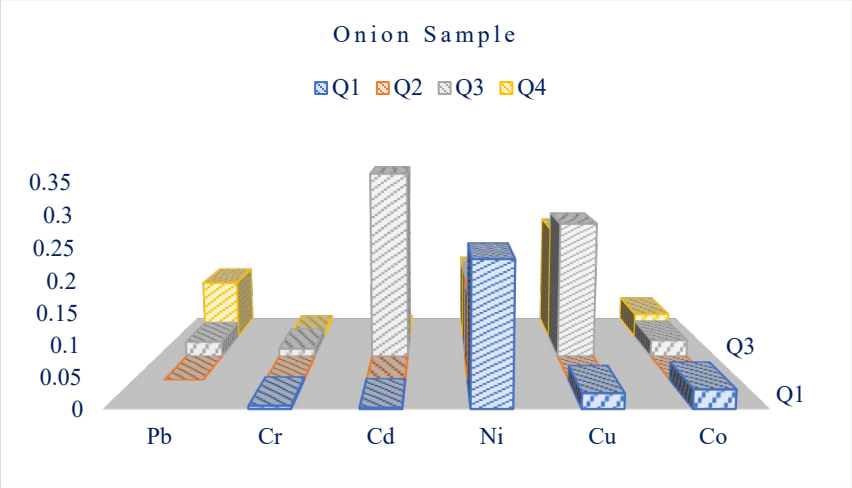

Fig.2 Heavy Metal Concentration in Onion Samples in Each Quarter (Q1,2,3,4)

Figure 2 shows the level of heavy metal concentration in onion samples within each quarter (Q1, Q2, Q3, Q4) from the graph above. Cd concentration was highest in the third quarter (Q3), followed by Cu in the same quarter. In another trend, Ni shows a higher concentration in the first quarter, while Pb, Cr, and Cd are almost undetected in the same quarters. This variation in heavy metal concentration across the quarters can be attributed to human activities and heavy rainfall, which may cause the metals to leach into the soil and accumulate in the groundwater [20]. On the other hand, irrigation with harvested water may be the source of the higher concentration of Ni in the first quarter, because heavy metal concentrations in this quarter tend to accumulate in the topsoil and can only be spread by the wind, while fruits and vegetables were not planted in that quarter except through irrigation [20].

Figure 3 shows the occurrence of heavy metals in the spinach samples based on each quarter (Q1, Q2, Q3, Q4). From the graph, the trend of heavy metal concentrations in each quarter is illustrated. Cr and Ni tend to have higher concentrations in all quarters, while the concentration of Co is very low in all quarters. The higher levels of Cr, Cd, and Ni in the first quarter (dry season) can be attributed to the fact that spinach is always available in this season, mainly through irrigation, because in the dry season, plants generally have inadequate water for their physiological development [9]; therefore, nutrient and other chemical absorption tends to be slow. On the other hand, during the wet season, chemical absorption by the plant tends to be higher because soil solubility increases the mobility of micronutrients such as Ni; therefore, the absorption capacity of the plant increases [21].

Figure 4 shows the selected heavy metal concentrations in lettuce across the different quarters. From the graph, Cr and Ni show higher concentrations in the first quarter, while the Pb concentration is zero. In the second quarter, all the heavy metals are below the detection level. On the other hand, Cd, Ni, and Cu show higher concentrations in the third quarter; in this quarter, the rainfall density is reduced, causing soil particles and organic matter to become more concentrated, which results in higher plant absorption [20].

The heavy metal concentrations in cucumber and pineapple are presented in Table II. All the heavy metals, namely Pb, Cr, Cd, Ni, Cu, and Co, were detected in the first quarter, except for Cr, Pb, and Co, which were not detected in Q2. In Q3, only Pb, Ni, and Cu were detected. All the heavy metals were detected in Q4. In all the seasons, Q1 shows Pb at 0.18 mg/kg and Cu at 0.17 mg/kg. In Q3, higher concentrations of 0.35 mg/kg and 0.34 mg/kg were observed for Ni and Cu, respectively. In pineapple samples, Pb was not detected in Q1 and Q2 but was detected in Q3 and Q4 with concentrations of 0.037 mg/kg and 0.207 mg/kg, respectively. All the heavy metals were detected in Q3 and Q4, with concentrations of 0.223 mg/kg, 0.254 mg/kg, 0.248 mg/kg, and 0.234 mg/kg for Q1, Q2, Q3, and Q4, respectively. Statistically, analysis of variance (ANOVA) at $p < 0.05$ shows a significant difference in the concentration of heavy metals in the fruit and vegetable samples across each quarter.

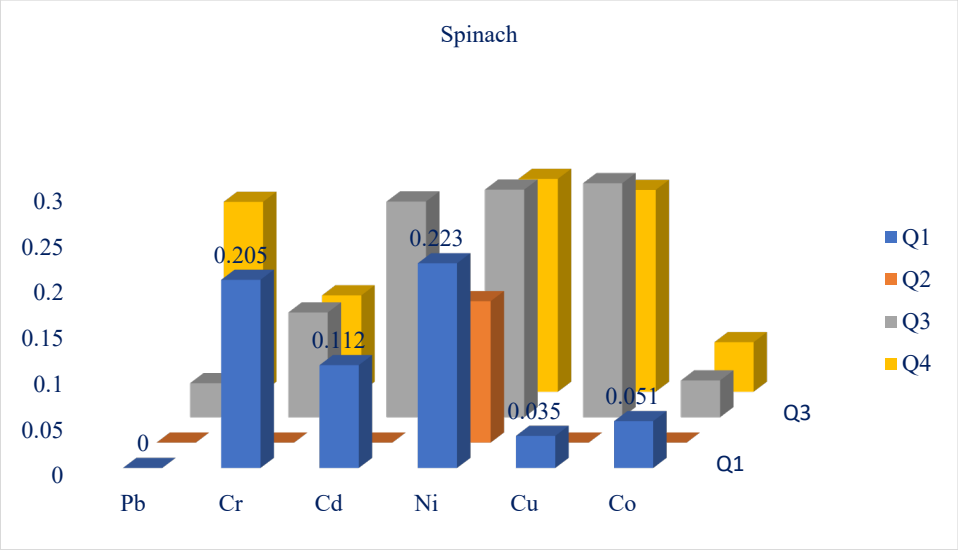

Fig.3 Heavy Metal Concentration in Spinach Samples in Each Quarter (Q1, Q2, Q3, Q4)

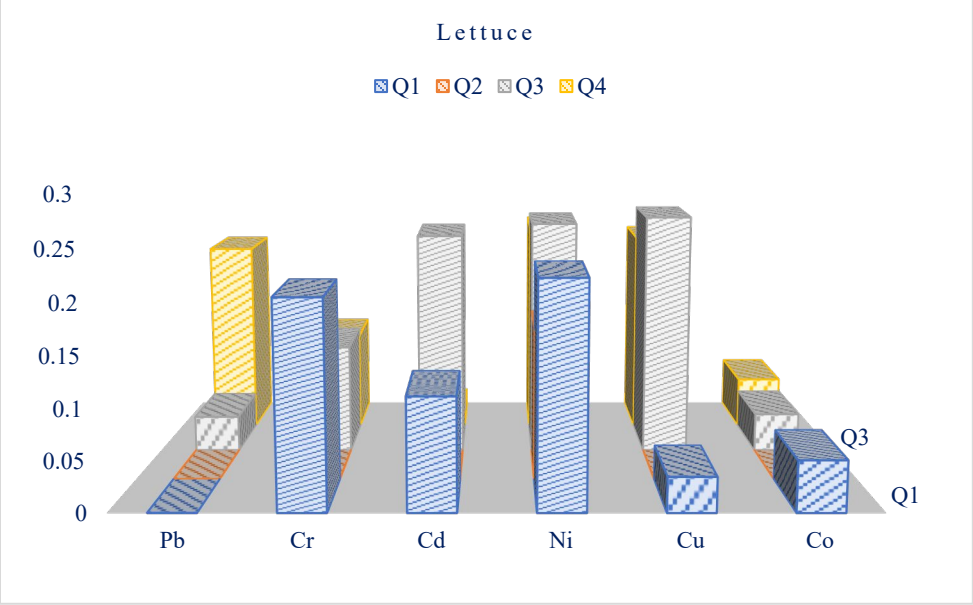

Fig.4 Heavy Metals Concentration in Lettuce Samples in Each Quarter (Q1,2,3,4)

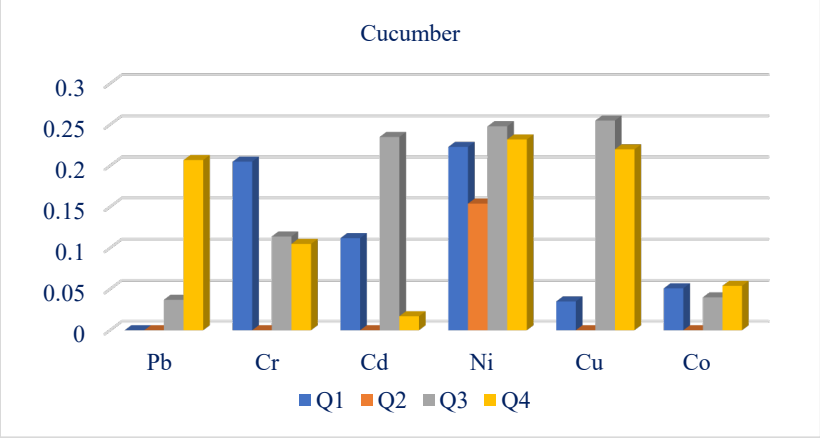

Fig.5 Show the Heavy Metal Concentration in Cucumber and Pineapple Samples in Each Quarter (Q1,2,3,4)

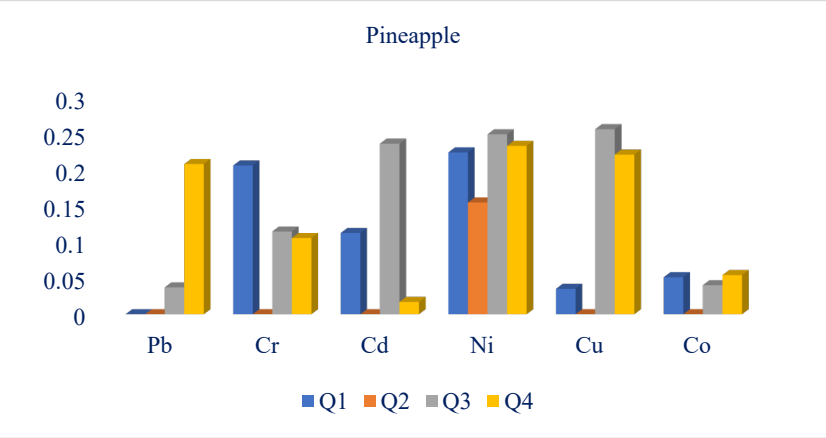

Fig.6 Show the Heavy Metal Concentration in Cucumber and Pineapple Samples in Each Quarter (Q1,2,3,4)

IV. CONCLUSION

The present research provides data on the seasonal concentration of heavy metals in selected fruits and vegetables from Kaura Namoda, Zamfara State. Spinach, lettuce, and cucumber showed Pb concentrations of 0.08 mg/kg in Q1; lettuce had 0.017 mg/kg in Q3, and cucumber had Pb concentrations of 0.18 mg/kg in Q4, 0.17 mg/kg in Q3, and 0.13 mg/kg in Q4. This indicates that spinach, lettuce, and cucumber are more vulnerable in both dry and wet seasons. There is a significant difference in the heavy metal concentrations in the selected fruit and vegetable samples from Kaura Namoda, Zamfara State, across the seasons. Therefore, continued monitoring and sensitization regarding the suspected sources of these heavy metals, such as illegal mining, discriminatory use of agrochemicals, and improper waste disposal, are necessary for adequate management and policy development.

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Declaration of Conflicting

The authors declare no potential conflicts of interest with respect to the research, authorship and /or publication of this article.

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Use of Artificial Intelligence (AI) - Assisted Technology for Manuscript Preparation

The authors confirm that no AI-assisted technologies were used in the preparation or writing of the manuscript, and no images were altered using AI.

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