

Health Risk Assessment of Heavy Metal Contamination in Natron (Kanwa) Consumed in Selected Local Government Areas, Northwestern Kebbi State, Nigeria

Authors Details

Shemishere B. Ufuoma^{1*}

Department of Biochemistry and Molecular Biology Federal University Birnin Kebbi,
Kebbi State.

Anyebe A. Daniel²

Department of Biochemistry and Molecular Biology Federal University Birnin Kebbi,
Kebbi State.

Liman U. Usman³

Department of Biochemistry and Molecular Biology Federal University Birnin Kebbi,
Kebbi State.

Erhovwosere Oghenevwede⁴

Department of Medical Biochemistry, University of Delta, Agbor, Delta State.

Aghayere Faith⁵

Department of Biochemistry, University of Benin, Benin City, Edo state.

Corresponding Author: *Shemishere B. Ufuoma*

ABSTRACT: The widespread consumption of Natron (“Kanwa”) in Northern Nigeria necessitates evaluation of its safety, particularly regarding heavy metal contamination. This study assessed the concentrations of selected heavy metals and associated health risks in Natron consumed across selected Local Government Areas (LGAs) in Northwestern Kebbi State, Nigeria. Three commonly consumed Natron varieties (*Balma*, *Kanwa Jarinrai*, and

Kanwa Tuwo) were collected from Bunza, Birnin Kebbi, Kalgo, and Jega LGAs and analyzed for cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr), and manganese (Mn). Health risk assessment was performed using Daily Intake of Metals (DIM) and Health Risk Index (HRI) for adults and children. Results revealed detectable concentrations of all investigated metals, with marked spatial variations across locations. Cadmium DIM values ranged from 0.0041–0.0134 mg/person/day, lead from 0.006–0.020 mg/person/day, chromium from 0.009–0.027 mg/person/day, and manganese from 0.013–0.054 mg/person/day. Higher DIM values were generally observed in Birnin Kebbi and Bunza compared to Kalgo and Jega. HRI analysis showed significant health concerns, as cadmium and chromium exceeded the safety threshold ($HRI > 1$) in all samples, with maximum values of 13.37 and 9.07, respectively. Lead also presented elevated HRI values of up to 5.82, indicating potential non-carcinogenic risks. Conversely, nickel and manganese recorded HRI values below 1, suggesting minimal immediate risk. These findings indicate that regular Natron consumption may pose serious long-term health risks, emphasizing the need for routine monitoring, public awareness, and regulatory control of heavy metal contamination in food additives.

Keywords: *Heavy Metals, Toxicity, Environmental Exposure, Risk Assessment, Food Contamination*

Introduction

Naturally occurring alkaline salts such as Natron (locally known as kanwa) are widely consumed across Northern Nigeria as food additives, tenderizers, and traditional remedies (1). While Natron contributes to culinary practices and cultural heritage, its geogenic origin raises concerns regarding contamination with potentially toxic heavy metals (2). Heavy metals such as manganese, chromium, lead, and cadmium are ubiquitous in the environment and may accumulate in mineral deposits through natural geological processes or anthropogenic activities (3, 4). Chronic dietary exposure to these metals, even at low concentrations, has been associated with adverse health outcomes including neurotoxicity, renal impairment, carcinogenicity, and developmental disorders (5, 6). Consequently, the safety of traditionally consumed mineral-based food additives has become an important subject within environmental health and toxicology.

Despite the widespread consumption of Natron in regions such as Kebbi State, there is limited comprehensive data on its heavy metal content and associated health risks. Previous studies on food contamination in Nigeria have largely focused on agricultural produce, water sources, and industrial pollutants, with comparatively little attention given to locally sourced mineral additives like Kanwa (7, 8). This represents a significant gap in public health knowledge, particularly as these substances are consumed regularly and sometimes in substantial quantities. Furthermore, the variability in sourcing, processing, and marketing of different Natron brands may contribute to inconsistent levels of contamination, thereby complicating risk assessment (9). The primary problem addressed in this study is the potential health risk posed by chronic exposure to heavy metals through the consumption of Natron (10). Given that regulatory oversight of locally marketed Natron is minimal, consumers may be unknowingly exposed to hazardous levels of toxic elements. Vulnerable populations, particularly children, are at increased risk due to their lower body weight and higher susceptibility to toxic insults (8). The absence of standardized safety limits and routine monitoring further exacerbates the potential for adverse health outcomes (6).

There is urgent need to generate empirical data on the concentration of heavy metals in commonly consumed Natron and to evaluate the associated health risks (11). Such data are essential for informing public health policies, guiding regulatory frameworks, and raising awareness among consumers. By focusing on multiple brands and sampling locations, this research provides a more representative assessment of exposure risks within the study area. The aim of this study is to assess the levels of selected heavy metals in three commonly consumed Natron brands and to evaluate their potential health risks among consumers in selected Local Government Areas of Kebbi State.

Materials and Methods

Study Areas

This study was conducted in four Local Government Areas (LGAs) namely; Birnin Kebbi, Kalgo, Jega, and Bunza allocated in Kebbi State, Northwestern Nigeria. Kebbi State lies between latitudes approximately 10°00'N and 13°15'N and longitudes 3°30'E and 6°02'E, within the Sudan–Sahel ecological zone. The region is characterized by a tropical continental climate, marked by two distinct seasons: a rainy season (May–October) and a

dry season (November–April). The vegetation is predominantly Sudan savannah, consisting of short grasses and scattered trees. The major economic activities in the study areas include agriculture, livestock rearing, and local trading, with widespread consumption of Natron (Kanwa) as a food additive and tenderizing agent.

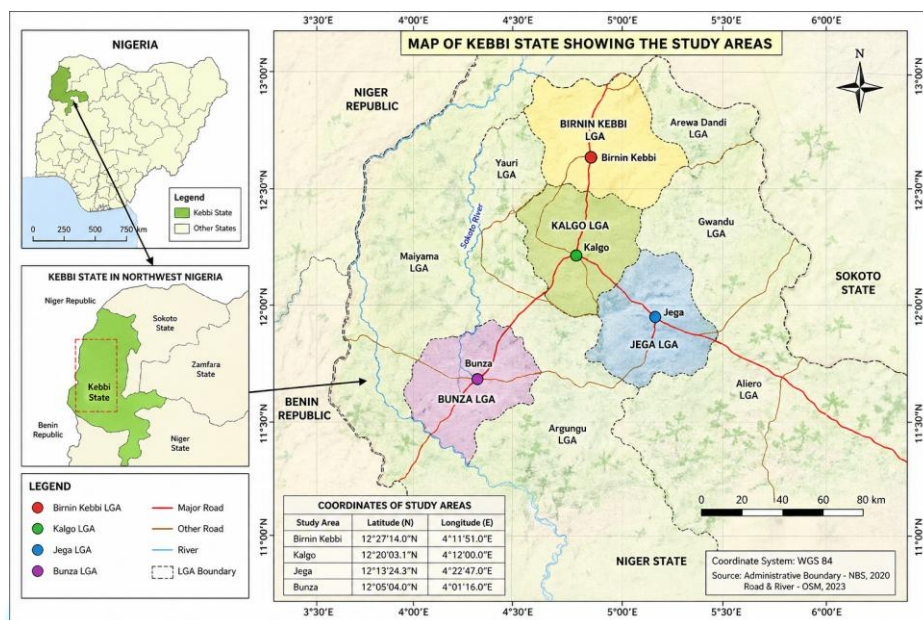


Figure1: Map showing the location and description of the Study Areas

Source of materials

The three study samples of Natron varieties (*Balma*, *Kanwa Jarirai*, and *Kanwa Tuwo*) were purchased from majors markets in the four selected LGAs of Kebbi-State, Nigeria.

Heavy Metals Analysis

Heavy metal analysis was carried out using Atomic Absorption Spectroscopy as previously described by Yahaya et al (12). Natron samples collected from the selected study areas were air-dried, homogenized, and ground into fine powder using a clean mortar and pestle. The powdered samples were sieved to obtain uniform particle size and stored in airtight containers prior to analysis. A wet acid digestion method was employed to extract heavy metals from the samples. Briefly, 1.0 g of each sample was accurately weighed into a digestion flask, followed by the addition of 10 mL of concentrated nitric acid (HNO_3). The mixture was heated on a hot plate at 120–150°C until initial digestion was achieved and brown fumes subsided. Subsequently, 2–3 mL of perchloric acid (HClO_4) was added, and heating continued until a clear solution was obtained. The digest was allowed to cool,

filtered using Whatman No. 1 filter paper, and quantitatively transferred into a 50 mL volumetric flask. The volume was made up to the mark with deionized water. The concentrations of lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), and manganese (Mn) in the Natron samples were then determined using the UNICAM atomic absorption spectrophotometer (model: 969).

Health Risk Assessment of the Heavy Metals in the Natron Samples

Using equations 1 and 2 below, the health risk of consuming the different Natron samples on a daily basis was determined from the Daily Intake of Metal (DIM) and Health Risk Index (HRI) of heavy metals in the Natron samples (13)

$$\text{DIM} = \frac{C_m \times I_r \times E_f \times E_d}{Bwt \times At}$$

Where:

DIM = Daily intake of heavy metals per kilogram of body weight; C_x = concentration of heavy metals in water; I_r = ingestion rate per unit time; E_f = exposure frequency; E_d = exposure duration; Bwt = body weight; At = the average time ($E_d \times E_f$). According to Yahaya et al (14), the standard values and units of the mentioned variables are as follows: E_f = 365 days/years; I_r = 2L/day; E_d = 55 years; Bwt = 65 kg; At = 20075 days.

$$\text{HRI} = \frac{\text{DIM}}{\text{RfD}}$$

Where:

DIM = Daily intake of Heavy metals; RfD = Reference dose of Heavy metals; Cadmium = 0.001, Lead = 0.0035, Nickel = 0.02, Manganese = 0.14, Chromium = 0.003.

RESULTS

Heavy Metal Contents

The results indicate the presence of five heavy metals—cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr), and manganese (Mn)—in all sampled natron varieties across Bunza, Birnin Kebbi, Kalgo, and Jega LGAs (Figures 1 to 5). The concentration levels (mg/kg) varied significantly across locations and sample types (Balma, K/Jarinrai, and K/Tuwo). Cadmium and lead were consistently detected in appreciable concentrations across all

locations, with relatively higher values observed in Birnin Kebbi and Bunza samples. This is of particular concern due to the known toxicity of these metals even at low concentrations. Chromium and manganese showed comparatively higher concentrations overall, especially in K/Tuwo samples, indicating possible geogenic or anthropogenic sources of contamination. Nickel concentrations were moderate but consistently present across all samples. Spatial variation suggests that contamination may be influenced by environmental factors such as soil composition, mining activities, or processing/storage practices. Importantly, the detected levels for Cd and Pb appear elevated when compared to typical permissible limits for food substances, indicating potential public health concerns.

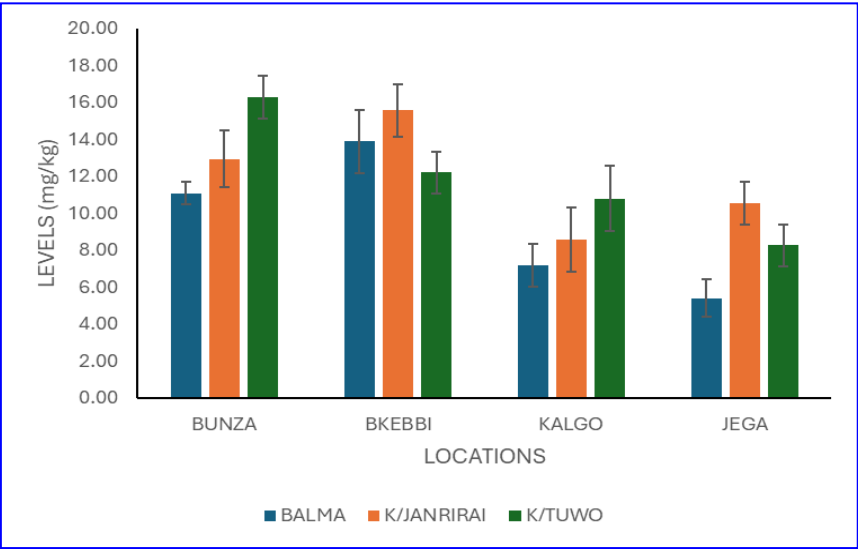


Figure 1: Cadmium content of three Natron varieties sold in selected LGA in Kebbi state

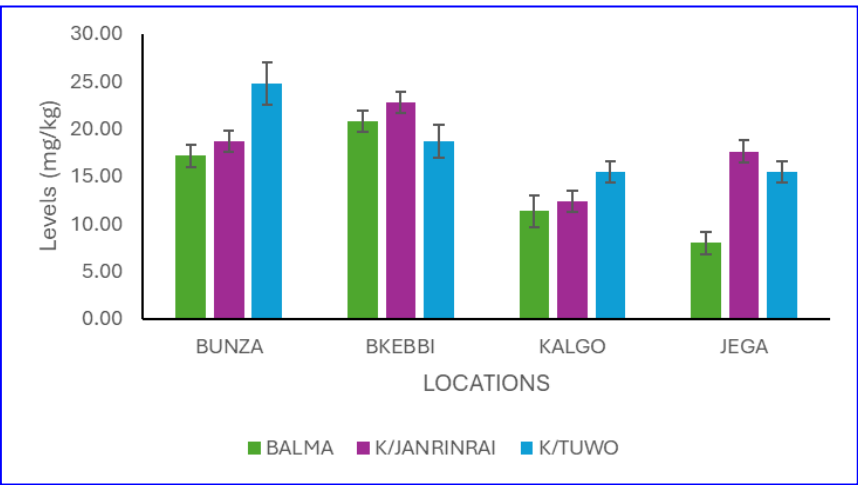


Figure 2: Lead content of three Natron varieties sold in selected LGA in Kebbi state

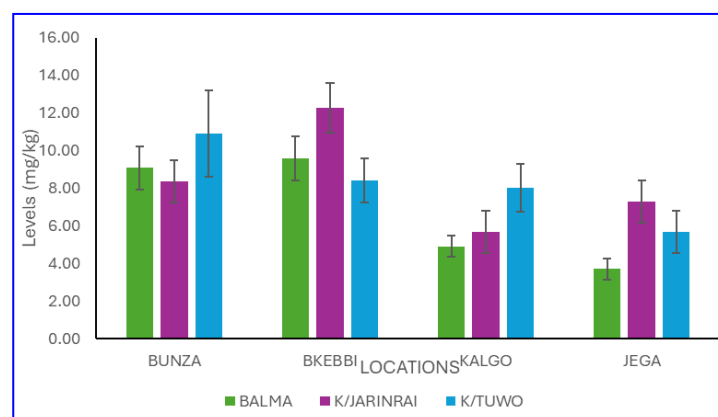


Figure 3: Nickel content of three Natron varieties sold in selected LGA in Kebbi state

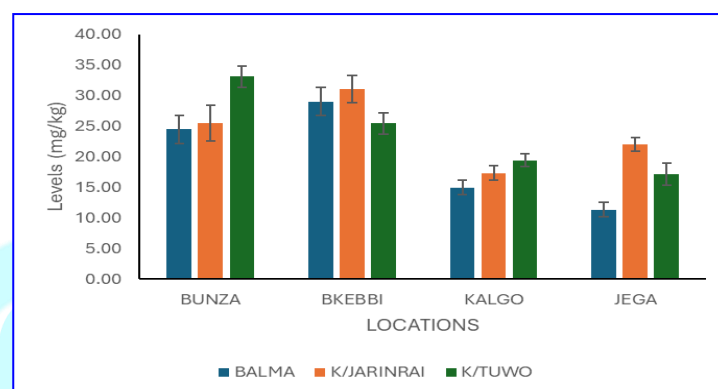


Figure 4: Chromium content of three Natron varieties sold in selected LGA in Kebbi state

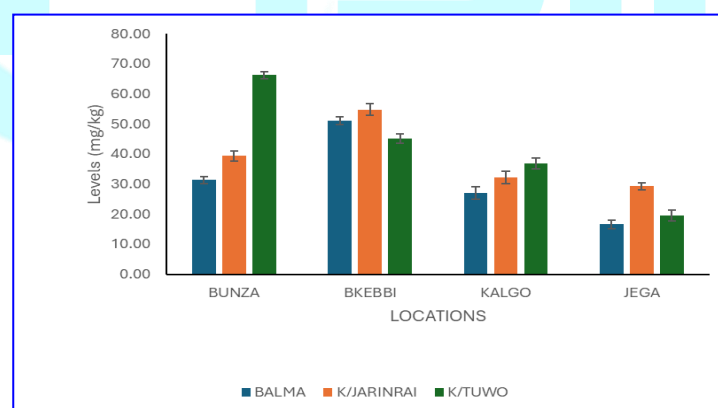


Figure 5: Manganese content of three Natron varieties sold in selected LGA in Kebbi state

Daily Intake of Metals (DIM)

The estimated daily intake of metals (mg/person/day) shows that exposure varies by age group (children vs. adults), location, and Natron type (Table 1 to 5). Across all metals, adults generally exhibited slightly higher DIM values than children, reflecting higher consumption rates. Among the metals, manganese and chromium recorded the highest

daily intake values, with Mn reaching up to 0.054 mg/person/day and Cr up to 0.027 mg/person/day in some locations. Lead and cadmium also showed notable intake levels, particularly in Birnin Kebbi and Bunza, where Pb intake reached up to 0.020 mg/person/day and Cd up to 0.0134 mg/person/day. Nickel had the lowest intake values across all metals, indicating relatively lower exposure risk from this element alone. However, cumulative exposure from multiple metals remains a concern. Overall, the DIM values suggest that regular consumption of Natron contributes significantly to dietary exposure to heavy metals, especially in areas with higher contamination levels.

Table 1: Daily Intake Rate of Cadmium (mg/person/day) in the Natron samples.

	BUNZA		BKEBBI		KALGO		JEGA	
	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT
BALMA	0.0085	0.0091	0.0107	0.0114	0.0055	0.0059	0.0041	0.0044
K/JAN	0.0099	0.0106	0.0119	0.0128	0.0066	0.0071	0.0081	0.0087
K/TUWO	0.0125	0.0134	0.0094	0.0100	0.0083	0.0089	0.0064	0.0068

Table 2: Daily Intake Rate of Lead (mg/person/day) in the Natron samples.

	BUNZA		BKEBBI		KALGO		JEGA	
	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT
BALMA	0.013	0.014	0.016	0.017	0.009	0.009	0.006	0.007
K/JAN	0.014	0.015	0.017	0.019	0.009	0.010	0.014	0.014
K/TUWO	0.019	0.020	0.014	0.015	0.012	0.013	0.012	0.013

Table 3: Daily Intake Rate of Nickel (mg/person/day) in the Natron samples.

	BUNZA		BKEBBI		KALGO		JEGA	
	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT
BALMA	0.0070	0.0075	0.0074	0.0079	0.0038	0.0040	0.0028	0.0030
K/JAN	0.0064	0.0069	0.0094	0.0101	0.0044	0.0047	0.0056	0.0060
K/TUWO	0.0084	0.0090	0.0065	0.0069	0.0061	0.0066	0.0044	0.0047

Table 4: Daily Intake Rate of Chromium (mg/person/day) in the Natron samples.

	BUNZA		BKEBBI		KALGO		JEGA	
	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT
BALMA	0.018	0.020	0.022	0.024	0.011	0.012	0.009	0.009
K/JARINRAI	0.018	0.021	0.024	0.026	0.013	0.014	0.017	0.018
K/TUWO	0.025	0.027	0.020	0.021	0.015	0.016	0.013	0.014

Table 5: Daily Intake Rate of Manganese(mg/person/day) in the Natron samples.

	BUNZA		BKEBBI		KALGO		JEGA	
	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT
BALMA	0.024	0.026	0.039	0.042	0.021	0.022	0.013	0.014
K/JARINRAI	0.030	0.032	0.042	0.045	0.025	0.026	0.022	0.024
K/TUWO	0.051	0.054	0.035	0.037	0.028	0.030	0.015	0.016

Health Risk Index (HRI)

The Health Risk Index (HRI) values provide insight into the potential non-carcinogenic health risks associated with natron consumption. An HRI value greater than 1 indicates a potential health risk. **Cadmium (Cd)** HRI values ranged from approximately 4.14 to 13.37 across all locations, far exceeding the safety threshold. This indicates a significant health risk for both children and adults, with the highest risk observed in Bunza and Birnin Kebbi. **Lead (Pb)** HRI values ranged from 1.76 to 5.82, also exceeding the safe limit in all cases. This suggests serious public health concern, particularly given lead's neurotoxic effects, especially in children. **Chromium (Cr)** HRI values ranged from 2.90 to 9.07, indicating substantial risk. The highest values were observed in Bunza samples, suggesting elevated exposure. **Nickel (Ni)** HRI values were below 1 (0.14–0.50) across all samples, indicating no immediate health risk from nickel alone. **Manganese (Mn)** HRI values ranged from 0.09 to 0.39, also below the threshold of concern, suggesting low risk.

Table 6: Health Risk Index of Cadmium in the Natron Samples

	BUNZA		BKEBBI		KALGO		JEGA	
	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT
BALMA	8.50	9.11	10.67	11.43	5.51	5.90	4.14	4.44
K/JAN	9.93	10.64	11.94	12.80	6.59	7.06	8.09	8.67
K/TUWO	12.48	13.37	9.36	10.03	8.27	8.86	6.35	6.81

Table 7: Health Risk Index of Lead in the Natron Samples

	BUNZA		BKEBBI		KALGO		JEGA	
	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT
BALMA	3.76	4.03	4.57	4.89	2.48	2.66	1.76	1.88
K/JAN	4.10	4.39	5.00	5.35	2.71	2.90	3.86	4.13
K/TUWO	5.43	5.82	4.09	4.39	3.38	3.63	3.38	3.62

Table 8: Health Risk Index of Nickel in the Natron Samples

	BUNZA		BKEBBI		KALGO		JEGA	
	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT
BALMA	0.35	0.37	0.37	0.39	0.19	0.20	0.14	0.15
K/JAN	0.32	0.34	0.47	0.50	0.22	0.23	0.28	0.30
K/TUWO	0.42	0.45	0.32	0.35	0.31	0.33	0.22	0.23

Table 9: Health Risk Index of Chromium in the Natron Samples

	BUNZA		BKEBBI		KALGO		JEGA	
	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT
BALMA	6.25	6.70	7.43	7.96	3.83	4.10	2.90	3.10
K/JARINRAI	6.52	6.99	7.94	8.51	4.43	4.74	5.64	6.05
K/TUWO	8.47	9.07	6.51	6.98	4.97	5.32	4.38	4.69

Table 10: Health Risk Index of Manganese in the Natron Samples

	BUNZA		BKEBBI		KALGO		JEGA	
	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT	CHILD	ADULT
BALMA	0.17	0.18	0.28	0.30	0.15	0.16	0.09	0.10
K/JARINRAI	0.22	0.23	0.30	0.32	0.18	0.19	0.16	0.17
K/TUWO	0.36	0.39	0.25	0.27	0.20	0.22	0.11	0.11

Discussion

The present study evaluated heavy metal contamination in Natron (Kanwa) consumed across selected Local Government Areas in Northwestern Kebbi State and assessed associated health risks. The findings revealed the presence of cadmium (Cd), lead (Pb),

chromium (Cr), nickel (Ni), and manganese (Mn), with considerable spatial variation across sampling locations. These results align with growing evidence that food substances in Nigeria are increasingly contaminated with heavy metals due to environmental pollution, poor handling practices, and geogenic factors (15, 16).

The elevated concentrations of cadmium and lead observed in this study are of significant toxicological concern. Both metals are non-essential and highly toxic even at low concentrations. Similar findings have been reported in Nigerian food systems, where Pb and Cd frequently exceed permissible limits in food products (17, 18). The relatively higher levels of chromium and manganese, particularly in certain Natron samples, may be attributed to natural mineral composition or environmental contamination during extraction and processing. Previous studies in Kebbi State and other parts of Nigeria have demonstrated that natural food additives and plant-derived products can accumulate heavy metals from contaminated soils and water sources (19). Furthermore, experimental studies have shown that consumption of contaminated Natron may induce biochemical and histopathological alterations, suggesting potential long-term toxicity (20).

The estimated daily intake (DIM) values indicate that both adults and children are exposed to measurable quantities of heavy metals through Natron consumption, with adults showing slightly higher exposure levels. Among the metals, manganese and chromium contributed the highest intake values, followed by lead and cadmium. Although the DIM values appear relatively low, chronic exposure to heavy metals—even at low levels—can result in bioaccumulation and adverse health outcomes over time (21). This is particularly concerning for toxic metals such as lead and cadmium, which have no biological function and tend to accumulate in vital organs. Similar studies have reported that dietary exposure through food additives and condiments significantly contributes to the total body burden of heavy metals in developing countries (22, 23).

The Health Risk Index (HRI) values obtained in this study provide a clearer indication of potential health risks. The HRI values for cadmium, lead, and chromium exceeded the safety threshold ($HRI > 1$) across all locations, indicating significant non-carcinogenic health risks for both children and adults. These findings are consistent with previous reports where hazard quotient values greater than unity were observed in contaminated food products, suggesting potential public health concerns (24, 25). In contrast, nickel and

manganese exhibited HRI values below 1, indicating relatively low immediate risk. However, cumulative exposure to multiple heavy metals may result in additive or synergistic toxic effects, even when individual metals are within acceptable limits (21). The elevated HRI values for cadmium and lead are particularly alarming given their established roles in causing nephrotoxicity, neurotoxicity, and developmental disorders. Chronic exposure to lead has been linked to cognitive impairment in children, while cadmium accumulation is associated with kidney damage and skeletal dysfunction (26). Chromium exposure also poses health concerns depending on its oxidation state, with hexavalent chromium (Cr^{6+}) being highly toxic and carcinogenic. The high HRI values observed for chromium in this study suggest potential long-term health implications for habitual consumers of Natron.

Overall, the results of this study indicate that regular consumption of Natron in the study areas may pose significant health risks due to elevated levels of toxic heavy metals. This supports the growing body of evidence that food contamination remains a critical public health issue in Nigeria and other developing countries (17, 16). Given the widespread use of Natron as a food additive in Northern Nigeria, there is an urgent need for regulatory intervention, routine monitoring, and public awareness campaigns. Establishing strict quality control measures and enforcing permissible limits for heavy metals in food products are essential steps toward reducing exposure and safeguarding public health.

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