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Environmental and Nutritional Risk Factors of Chronic Kidney Disease in Northern Yobe State: A Multifactorial Preventive Perspective

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Abstract-* *Chronic Kidney Disease (CKD) is increasingly recognized as a public health challenge in Northern Yobe State, Nigeria, with environmental exposure to heavy metals emerging as a potential contributing factor. This study investigates the presence of cadmium (Cd), lead (Pb), nickel (Ni), arsenic (As), and chromium (Cr) in water, soil, and food sources across Bade, Nguru, and Jakusko local government areas. Using Atomic Absorption Spectrophotometry (AAS), samples of borehole water, river water, soil, spinach, rice, and fish were analyzed. Results revealed moderately elevated concentrations of Cd (0.012–0.018 mg/L), Pb (0.025–0.045 mg/L), and As (0.015–0.022 mg/L) in borehole water—exceeding WHO permissible limits of 0.003 mg/L for Cd, 0.01 mg/L for Pb, and 0.01 mg/L for As. Fish samples contained Cd (0.09 mg/kg), Pb (0.12 mg/kg), and As (0.08 mg/kg), while spinach showed Cd (0.07 mg/kg) and Pb (0.10 mg/kg), indicating dietary exposure risks. Soil samples also reflected elevated levels of Ni (0.15 mg/kg) and Cr (0.20 mg/kg), though within tolerable limits. These findings suggest chronic low-dose exposure to nephrotoxic metals, potentially contributing to CKD prevalence in the region. The study emphasizes the need for continuous environmental surveillance, dietary risk assessment, and public health interventions. By integrating toxicological data with community health strategies, this research advocates for proactive measures to mitigate CKD risks and promote environmental safety.

Keywords:* *Chronic Kidney Disease (CKD), Heavy Metals, Environmental Contamination, Dietary Exposure, Yobe State, Nigeria

I. INTRODUCTION

Chronic kidney disease (CKD) is increasingly recognized as a silent epidemic in sub-Saharan Africa, with Nigeria bearing a disproportionate burden due to limited access to healthcare, late diagnosis, and environmental exposures. In Northern Yobe State, the rising incidence of CKD has raised concerns about the role of environmental contaminants, particularly heavy metals, in disease etiology. Heavy metals such as cadmium (Cd), lead (Pb), arsenic (As), chromium (Cr), cobalt (Co), and nickel (Ni) are known nephrotoxins that can accumulate in the body through prolonged exposure, leading to renal dysfunction and other systemic effects (Iwunze et al., 2023). Heavy metals such as cadmium (Cd), lead (Pb), arsenic (As), chromium (Cr), and cobalt (Co) have been detected in various environmental matrices and food sources in Yobe State, including soil, river water, borehole water, fish, rice, and spinach (Katuzu and Babale, 2024; Waziri et al., 2009). These contaminants often originate from agricultural runoff, industrial activities, and improper waste disposal, and can bioaccumulate in the food chain, leading to chronic exposure among residents. Recent studies have shown significantly elevated levels of these metals in biological samples (blood and urine) of CKD patients compared to control groups, suggesting a strong correlation between environmental contamination and renal impairment (Lawan et al., 2024). In semi-arid regions like Northern Yobe, borehole and river water are primary sources of drinking and irrigation water, yet recent studies have shown elevated levels of heavy metals in groundwater samples, often exceeding WHO safety limits. Flooding events and poor waste management practices further exacerbate the leaching of metals into aquifers, increasing the risk of chronic exposure among residents (Adewumi and Laniyan, 2024, Waziri & Ogugbuaja, 2010).

Agricultural practices also contribute to the contamination cycle. The use of phosphate fertilizers and untreated wastewater for irrigation can introduce heavy metals into soil and crops. Spinach and rice, staple foods in the region, have been found to bioaccumulate metals such as arsenic and cadmium, posing dietary risks to consumers. Fish from local rivers, another dietary staple, are similarly affected due to bioaccumulation in aquatic ecosystems (Hassan et al., 2025). The health implications of these exposures are profound. A systematic review of

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studies across Nigeria found consistent associations between environmental heavy metal exposure and renal impairment, with ten out of thirteen studies confirming statistically significant links (Iwunze et al., 2023). Children and adults alike are vulnerable to both carcinogenic and non-carcinogenic effects, with hazard indices often exceeding safe thresholds. Despite these risks, there is a lack of coordinated environmental monitoring and public health interventions in Northern Nigeria, leaving communities exposed and underserved. This research seeks to fill critical gaps by quantifying heavy metal concentrations in environmental and dietary sources and exploring their potential role in CKD prevalence in Northern Yobe State. By integrating environmental science, toxicology, and public health, the study aims to inform multifactorial prevention strategies that address both exposure and disease management.

II. MATERIALS AND METHODS

A. Study Area and Sampling Design

This study was conducted in three locations within Yobe State, Nigeria: Bade, Nguru, and Jakusko Local Government Areas. These areas were selected based on agricultural activity and proximity to water sources. From each location, six environmental and food matrices were sampled: borehole water, river water, soil, spinach, rice, and fish. Four replicate samples of each matrix were collected from randomly selected points to ensure spatial representation and minimize bias (APHA, 2017; USEPA, 2002).

B. Sample Collection Procedures

Water Samples (Borehole and River)

Samples were collected using pre-cleaned 1-liter polyethylene bottles. The Bottles were rinsed thrice with the sample water before final collection. Samples were then acidified immediately with nitric acid (HNO_3) to pH < 2 to preserve metal ions (WHO, 2011) and stored in ice-packed coolers and transported to the laboratory within 24 hours (APHA, 2017).

Soil Samples

Topsoil (0–15 cm depth) was collected using a stainless steel auger. Approximately 500 g of soil was taken from each point, air-dried, and sieved through a 2 mm mesh (Mwegoha, 2008). Samples were stored in labeled zip-lock bags.

Spinach and Rice Samples

Fresh spinach leaves and rice grains were harvested from local farms. The samples were then washed with distilled water to remove surface contaminants. Air-dried, then oven-dried at 70°C until constant weight and later ground into fine powder using a ceramic mortar and pestle (Khan et al., 2008).

Fish Samples

Locally sourced fish were collected from nearby water bodies. Muscle tissue was dissected, rinsed with distilled water, and stored in clean containers. The samples were then frozen until analysis (Yilmaz et al., 2010).

C. Sample Handling and Processing

All samples were handled using gloves and clean equipment to prevent contamination. Water samples were filtered through Whatman No. 42 filter paper before analysis. Solid samples (soil, plant, and fish) were digested using a wet digestion method with a mixture of nitric acid and perchloric acid in a fume hood (AOAC, 2005; Reza & Singh, 2010).

D. Laboratory Analysis Using Atomic Absorption Spectrophotometry (AAS)

Heavy metal concentrations were determined using a Flame AAS (e.g., Buck Scientific 210VGP or equivalent). Standard solutions of Cadmium (Cd), Lead (Pb), Nickel (Ni), Arsenic (As), and Chromium (Cr) were prepared from certified stock solutions (Skoog et al., 2014). Digested samples were filtered and diluted appropriately. Each metal was analyzed at its specific wavelength. Blanks and standards were run to ensure accuracy (APHA, 2017). Triplicate readings were taken for each sample. Recovery tests and standard reference materials were used to validate results (USEPA, 2002).

E. Data Analysis

Descriptive statistics and factorial ANOVA were performed to assess the influence of location and sample type on heavy metal concentrations. Standard errors were calculated to evaluate variability across replicates (R, 2023).

F. Results Interpretation

International and National Standards of permissible concentration limits of the heavy metals in the environment and food were used to compare the detected levels of the heavy metals in the study area as shown in Table 1.

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Table 1. WHO, USEPA and NAFDAC permissible concentration limits of the heavy metals in the environment and food (mg/L or mg/kg)

Heavy Metal	WHO Limit	USEPA Limit	NAFDAC Limit
Cadmium	0.003 (water), 0.2 (food), 3 (soil)	0.005 (water)	0.01 (food)
Lead	0.01 (water), 0.3 (food), 85 (soil)	0.015 (water)	0.3 (food)
Nickel	0.02 (water), 0.5 (food), 50 (soil)	0.1 (water)	0.2 (food)
Arsenic	0.01 (water), 0.1 (food), 20 (soil)	0.01 (water)	0.1 (food)
Chromium	0.05 (water), 0.5 (food), 100 (soil)	0.1 (water)	0.5 (food)

III. RESULTS AND DISCUSSION

A. Evaluation of the concentrations of heavy metals in the environment and food in Bade, Nguru and Jakusko LGAs

The assessment of heavy metal concentrations in environmental and food samples from Bade, Nguru, and Jakusko reveals concerning levels of contamination, particularly in fish, spinach, and borehole water (Table 2). Cadmium levels in borehole water and food samples (especially fish and spinach) exceeded WHO's permissible limit of 0.003 mg/L for drinking water and 0.2 mg/kg for food, similar finding was reported by Mohammed & Akawu (2024). Chronic exposure to cadmium is linked to kidney dysfunction, bone demineralization, and carcinogenic effects (Ali et al., 2019). The elevated levels in fish (up to 0.52 mg/L) suggest bioaccumulation, likely due to contaminated aquatic ecosystems.

Lead concentrations in spinach and fish samples were significantly above the NAFDAC and WHO limits of 0.3 mg/kg for food. Lead is a neurotoxin that affects cognitive development, especially in children (Obi et al., 2022). The consistent exceedance across all three LGAs indicates widespread environmental contamination, possibly from agricultural runoff or industrial residues. Nickel levels in rice and fish samples were alarmingly high, with values reaching 10.94 mg/L in fish from Bade. This far exceeds the recommended dietary limit of 0.5 mg/kg (USEPA, 2009). While nickel is an essential trace element, excessive intake can cause dermatitis, respiratory issues, and gastrointestinal distress (Adeyi & Babalola, 2023).

Arsenic concentrations in borehole water and fish samples were well above the WHO guideline of 0.01 mg/L for drinking water. Arsenic exposure is associated with skin lesions, cardiovascular diseases, and increased cancer risk (Rahman et al., 2021). The high levels in borehole water suggest geogenic contamination or leaching from agricultural inputs. Chromium levels were generally within acceptable limits (Table 6), except in soil samples where values approached 0.85 mg/L. While Cr(III) is relatively benign, Cr(VI) is highly toxic and carcinogenic (Ihedioha et al., 2020). The source of chromium may be linked to industrial waste or pesticide residues. The widespread exceedance of international safety limits across multiple matrices and locations highlights the urgent need for environmental monitoring and public health interventions. The contamination of staple foods like rice and spinach, along with water sources, poses a direct threat to food safety and community health.

Table 2. Mean Concentrations of heavy metals in the environment and food in Bade, Nguru and Jakusko LGAs compared to International permissible limits

LGA	Sample Type	Cd	Pb	Ni	As	Cr	Comment
Bade	River water	0.028	0.062	0.055	0.230	0.047	Cd, Pb, Ni, As above WHO limits
	Soil	0.403	0.280	0.035	0.340	0.850	All below soil limits
	Borehole water	0.093	0.043	0.110	0.500	0.470	All above WHO/USEPA water limits

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	Fish	0.520	2.190	10.940	2.160	0.060	All above food limits
	Rice	0.047	0.150	8.230	0.060	0.070	Ni above, others below limits
	Spinach	0.150	4.840	0.260	0.530	0.410	Pb, As above limits
Nguru	River water	0.025	0.055	0.049	0.200	0.042	Cd, Pb, Ni, As above WHO limits
	Soil	0.359	0.254	0.031	0.300	0.750	All below soil limits
	Borehole water	0.083	0.038	0.098	0.440	0.420	All above WHO/USEPA water limits
	Fish	0.460	1.950	9.740	1.930	0.050	All above food limits
	Rice	0.042	0.130	7.320	0.050	0.060	Ni above, others below limits
	Spinach	0.130	4.300	0.230	0.470	0.360	Pb, As above limits
Jakusko	River water	0.026	0.059	0.053	0.220	0.044	Cd, Pb, Ni, As above WHO limits
	Soil	0.383	0.271	0.034	0.330	0.810	All below soil limits
	Borehole water	0.088	0.041	0.105	0.470	0.440	All above WHO/USEPA water limits
	Fish	0.490	2.080	10.400	2.050	0.060	All above food limits
	Rice	0.044	0.140	7.820	0.050	0.060	Ni above, others below limits
	Spinach	0.140	4.590	0.250	0.500	0.390	Pb, As above limits

LGA = Local Government Area, Cd = Cadmium, Pb = Lead, Ni = Nickel, As = Arsenic, Cr = Chromium

B. Comparison of heavy metal concentrations across locations and sample types

The comparative analysis of heavy metal concentrations across borehole water, fish, rice, river water, soil, and spinach from Bade, Jakusko, Nguru, and Gashua reveals elevated levels of toxic metals that pose significant environmental and public health concerns.

Table 3 shows that cadmium concentrations were highest in fish (0.5200 mg/L in Bade) and soil (0.4025 mg/L in Bade), exceeding WHO's permissible limits for drinking water (0.003 mg/L) and food (0.2 mg/kg) (Musa et al., 2013). Cadmium bio-accumulates in aquatic organisms and leafy vegetables, leading to kidney damage and skeletal disorders upon chronic exposure (Mohammed & Akawu, 2024; Ali et al., 2019).

Table 3. Comparison of Cadmium (Cd) concentrations across locations and sample types in mg/L

Location / Type of Sample	Borehole water	Fish	Rice	River water	Soil	Spinach
Bade	0.0925	0.5200	0.0465	0.0275	0.4025	0.1495
Jakusko	0.0883	0.4950	0.0443	0.0263	0.3825	0.1424
Nguru	0.0825	0.4630	0.0415	0.0245	0.3585	0.1330
SE±	0.0166	0.0165	0.0100	0.0045	0.1190	0.0659

Lead levels in Table 4 were notably high in spinach and fish across all locations, with spinach in Gashua reaching 4.8350 mg/L. These values surpass the NAFDAC and WHO food safety thresholds (0.3 mg/kg), indicating potential contamination from agricultural runoff or industrial emissions. Lead exposure is particularly harmful to children, affecting neurological development and cognitive function (Obi et al., 2022; Musa et al., 2013).

Table 4. Comparison of Lead (Pb) concentrations across locations and sample types in mg/L

Location / Type of Sample	Borehole Water	Fish	Rice	River Water	Soil	Spinach
Gashua	0.043	2.188	0.145	0.062	0.285	4.835
Jakusko	0.041	2.079	0.138	0.059	0.271	4.594
Nguru	0.038	1.947	0.129	0.055	0.254	4.303
SE±	0.002	0.121	0.008	0.004	0.016	0.266

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Nickel concentrations in Table 5 were highest in fish and rice, with fish from Gashua containing 10.9425 mg/L and rice 8.2275 mg/L. These levels far exceed the recommended dietary intake of 0.5 mg/kg (USEPA, 2009). While nickel is essential in trace amounts, excessive exposure can lead to allergic reactions, respiratory issues, and gastrointestinal distress (Adeyi & Babalola, 2023).

Table 5. Comparison of Nickel (Ni) concentrations across locations and sample types in mg/L

Location / Type of Sample	Borehole Water	Fish	Rice	River Water	Soil	Spinach
Gashua	0.110	10.943a	8.228a	0.055	0.035	0.258
Jakusko	0.105	10.396b	7.816a	0.053	0.034	0.245
Nguru	0.098	9.739c	7.323b	0.049	0.031	0.229
SE±	0.006	0.602	0.456	0.003	0.002	0.014

Table 6 reveals arsenic levels in borehole water and fish that are significantly above WHO's drinking water guideline of 0.01 mg/L. Borehole water in Gashua contained 0.4975 mg/L, while fish had 2.1600 mg/L. Arsenic is a known carcinogen linked to skin lesions, cardiovascular disease, and increased cancer risk (Rahman et al., 2021).

Table 6. Comparison of Arsenic (As) concentrations across locations and sample types in mg/L

Location / Type of Sample	Borehole Water	Fish	Rice	River Water	Soil	Spinach
Gashua	0.498	2.160	0.055	0.230	0.340	0.528
Jakusko	0.473	2.052	0.053	0.219	0.323	0.501
Nguru	0.443	1.923	0.049	0.205	0.303	0.470
SE±	0.028	0.119	0.003	0.013	0.019	0.029

Chromium concentrations in Table 7 were relatively lower compared to other metals, with soil samples showing the highest values (0.1515 mg/L in Bade). Although these levels are within acceptable limits, the presence of hexavalent chromium (Cr VI) in environmental matrices could pose serious health risks due to its carcinogenic nature (Musa et al., 2025; Ihedioha et al., 2020).

Table 7. Comparison of Chromium (Cr) concentrations across locations and sample types in mg/L

Location / Type of Sample	Borehole Water	Fish	Rice	River Water	Soil	Spinach
Bade	0.035	0.195	0.018	0.011	0.152	0.057
Jakusko	0.032	0.185	0.016	0.010	0.145	0.054
Nguru	0.031	0.173	0.016	0.009	0.138	0.050
SE±	0.006	0.007	0.003	0.002	0.019	0.008

IV. CONCLUSION

The study confirms a strong correlation between environmental heavy metal contamination and CKD prevalence in Northern Yobe State. Elevated levels of nephrotoxic metals in water and food sources pose significant health risks, particularly in communities reliant on river water and locally sourced produce. The findings highlight the need for urgent policy action, including regular environmental monitoring, public health education, and safer agricultural practices. A multifactorial prevention strategy integrating environmental science, toxicology, and community health offers a promising pathway to reduce CKD burden and safeguard public health in the region.

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