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The Potential Role of Cadmium, Chromium, Lead and Nickel to the Prevalence of Chronic Kidney Disease in Hadejia, Jigawa State, Nigeria

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ABSTRACT
This study examined the potential role of cadmium (Cd), chromium (Cr), lead (Pb) and nickel (Ni) in the prevalence of chronic kidney diseases (CKD) in Hadejia. These heavy metals were analyzed in water, vegetables and blood samples of CKD patients. All samples were prepared using acid digestion, and heavy metals were determined using Atomic Absorption Spectrophotometry (AAS). The results indicate that Cd, Cr, Pb and Ni levels found in all the blood and drinking water samples analyzed exceeded the WHO permissible limit. While the Cd, Cr and Ni levels in spinach, lettuce and onions were below the threshold limit. However, the levels of Pb in onions (0.110±0.880mg/kg to 0.030±0.0001mg/kg) and lettuces (0.050±0.0013mg/kg to 0.740±0.0001mg/kg) analyzed exceeded the recommended limit in most of these samples. The elevated Cd, Cr, Pb, and Ni concentrations observed in both CKD patients and control subjects suggest environmental exposure to these heavy metals within the study area. The presence of high levels of these heavy metals in water and blood samples is of great concern, as these metals have been implicated for their nephrotoxic effects. The findings indicate that heavy metals contamination may be a potential contributing factor to the increasing burden of chronic kidney disease in Hadejia.

Keywords: Hadejia, Chronic Kidney Disease, Cadmium, Lead, Nickel

INTRODUCTION

Heavy metals cannot be broken down by micro-organism, as such they build up and biomagnify at the different stages of the food chain, their presence in animals affect their health (Pompilio *et al.*, 2021). Water is a vital natural resource essential for life, serving as a medium for biological, chemical, and ecological processes. It is used for drinking, agriculture, industry, and sanitation. However, water quality can be compromised by contamination from natural and anthropogenic sources, including heavy metals, which may originate from industrial discharge, agricultural runoff, and geological weathering. Contaminated water poses serious health risks when consumed, particularly when toxic metals exceed permissible limits set by regulatory bodies such as the World Health Organization (UNEP, 2023; WHO, 2022).

Several heavy metals transfer as a result of application of manure in agriculture, pesticides and industrial activities such as production of batteries, alloys, and textile dyes. Moreover, natural phenomena such as earthquakes, volcanic eruptions occur and contribute significantly to environmental pollution. Heavy metals may chronically be transported into the human body via food, water, air or skin (Lentini *et al*., 2017).

Exposure to heavy metals can adversely affect multiple organs and physiological systems in humans. Depending on the type of metal, concentration, route, and duration of exposure, heavy-metal toxicity may result in gastrointestinal disturbances, renal dysfunction, neurological and cardiovascular disorders, and other systemic complications. Prolonged exposure may also promote cellular damage through oxidative stress, enzyme inhibition, and disruption of normal cellular processes, with some metals being associated with carcinogenic effects (Balali-Mood *et al.*, 2021).

Vegetables are edible part of plants commonly taken by populations throughout the world as it is capable of providing essential nutrients, antioxidants and metabolites. They also serve as a buffering agent for acid substance obtained during the digestion process. However, both essential and toxic elements can be found in vegetables at some certain concentrations as they are known to accumulate metals from the soil (Abrham and Gholap 2020).

Due to the increasing prevalence of chronic kidney disease (CKD), its expensive management requirements, and their association to cardiovascular diseases, it continues to pose a significant public health challenges all over world. Even though hypertension and in some cases diabetes were considered as the major factors for CKD, more investigation has to be done especially on the potential role of environmental pollutants like heavy metals, in the development of renal failure. Lead (Pb), cadmium (Cd), and mercury (Hg) are well-recognized nephrotoxins at high exposure levels (Kim *et al.*, (2015)).

Furthermore, the kidneys are among the most vulnerable organs affected by heavy metal toxicity because they are responsible for filtering blood and excreting toxic substances from the body. Chronic exposure to heavy metals has been linked with oxidative stress, inflammation, tubular dysfunction, fibrosis, and progressive renal impairment. Zuo *et al.*, (2025) investigated the association between whole blood concentrations of arsenic, lead, and mercury and kidney function among 58,864 adults in Germany. The study demonstrated that increasing concentrations of arsenic, lead, and mercury were significantly associated with reduced estimated glomerular filtration rate (eGFR), even among individuals without known kidney disease. The authors further reported that combined exposure to these metals produced stronger nephrotoxic effects than exposure to individual metals alone, suggesting synergistic toxicity.

Several epidemiological studies have also established strong associations between heavy metal exposure and chronic kidney disease (CKD). Shi *et al.*, (2024) examined mixed exposure to cadmium, lead, manganese, and mercury among adults in the United States using NHANES data. The study found that exposure to mixed metals significantly increased the risk of CKD, especially among individuals with type 2 diabetes mellitus. Likewise, Yao and Xu (2024) reported that higher blood concentrations of cadmium and lead were significantly associated with CKD occurrence, particularly among elderly and hypertensive individuals. The researchers explained that cadmium and lead accumulate in renal tissues and induce nephrotoxicity through oxidative stress and proximal tubular damage.

Research has further shown that heavy metals can induce direct cellular damage to kidney tissues. Patel *et al.,* (2025) examined the effects of cadmium, mercury, and lead on human kidney epithelial cells and reported substantial reductions in cell viability following exposure to these metals. Cadmium produced the highest level of cytotoxicity, while mercury and lead also caused oxidative stress, membrane damage, mitochondrial dysfunction, and apoptosis in kidney cells. The study concluded that heavy metal-induced oxidative stress plays a critical role in renal tissue injury and kidney disease progression.

Despite the growing body of evidence on heavy metal contamination and its adverse health effects, there is limited information in Hadejia, Jigawa State, on the combined assessment of heavy metals in environmental media and their potential association with chronic kidney disease (CKD). Previous studies in the area have mainly focused on heavy metal contamination in water, sediments, or food samples without evaluating the body burden of these metals in CKD patients. Consequently, the possible link between environmental exposure to cadmium (Cd), chromium (Cr), nickel (Ni), and lead (Pb) and the increasing prevalence of CKD in the study area remains poorly understood. Therefore, this study was undertaken to assess the concentrations of these selected heavy metals in water, vegetables, and blood samples of CKD patients in Hadejia Local Government Area, Jigawa State, in order to provide baseline data for environmental monitoring and public health decision-making.

MATERIALS AND METHODS

Study Area

The study was conducted in Hadejia community, located within Hadejia Local Government Area (LGA) of Jigawa State, northwestern Nigeria. Hadejia LGA lies approximately between latitude 12.27^0N and 12.45^0N and longitude 10.04^0E to 10.23^0E. The Local Government Area shares boundary with Kirikasamma LGA to the east, Malammadori LGA to the north, and Auyo LGA to the west.

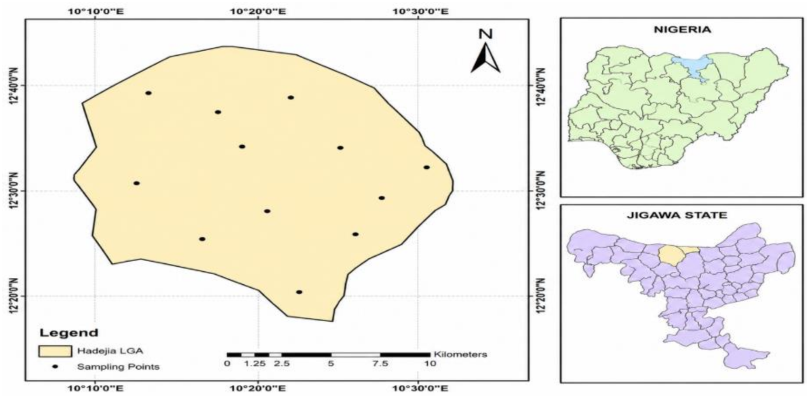

Figure 1: Jigawa State and its Local Government Areas including Hadejia

Sample Collection

The sample population for this study consists of blood, water and vegetable samples collected from selected locations within the study area. A total of ten blood samples were collected from chronic kidney disease (CKD) patients and coded as B1 to B10 while six blood samples obtained from apparently healthy individuals serving as the control group were coded as C1 to C6; Ethical approval for the collection of blood samples was obtained from Ministry of Health Jigawa State and Hadejia General Hospital. Ten drinking water samples were collected from domestic water sources and labeled from D1 to D10.

In addition, ten lettuce samples were labeled (L1–L10), onion (O1–O10), and spinach samples labeled (S1–S10). These samples were collected from agricultural farms within the study area. A total of fifty six (56) samples were used for the determination of concentrations of selected heavy metals.

Venous blood (3–5 mL) was collected by using metal free Safety Vacutainer blood collecting tubes containing >1.5 mg K_2EDTA. The samples were stored at 0°C until the start of the analysis (Kazi *et al.,* (2008)).

Sample Digestion

Accurately 0.5 ml of whole blood was taken into Pyrex flask separately. 3ml of freshly prepared mixture of concentrated nitric acid and hydrogen peroxide (HNO_3 - H_2O_2) (2:1) was added and allowed to stand for 10 minutes. The flasks was covered with watch glass and then digested at 70 ^{0}C for 2hours. The digests was then treated with 2 ml nitric acid and few drops of H_2O_2, while heating continue until a clear digested solution was obtained. The excess acid mixture was evaporated to almost dry mass, then cooled and diluted with 0.1 ml of nitric acid. The mixture was then transferred into 100 ml volumetric flask and diluted to the mark using distilled-dionizd water (Yahaya *et al., (*2013)).

Accurately 500 ml of the filtered water sample was measured and transferred into 1000 ml beaker and then placed on a hot plate where it was evaporated until about 50ml was obtained. It was then allowed to cool and transferred into a 250 ml beaker. 5 ml of concentrated HNO_3 was added and the resulting solution was heated at 85 ^{0}C until a clear solution was obtained. The digested sample was allowed to cool, then transferred into a 100 ml volumetric flask and made up to the mark with deionized water (Yusuf *et al*. 2021).

Exactly 1 g of dried powdered vegetable (cabbage and lettuce) samples was weighed and transferred into a separate 100 ml digestion tube, where 9 ml of newly produced aqua regea was added and the volume was increased to 50 ml with distilled water. The mixture was then allowed to gradually boil on a heated plate (at 90°C) to almost dryness. The digest was filtered using Whatman No. 42 filter paper and diluted to 50 ml in a volumetric flask, Sagagi *et al.,* (2022).

RESULTS AND DISCUSSION

Blood Samples

Among the CKD blood samples, the mean cadmium concentration is 0.0334±0.006mg/L (Fig. 2). The highest cadmium concentration was recorded in sample B10 (0.043±0.0003mg/L), while the lowest concentration was observed in sample B1 (0.023±0.0007mg/L). This showed that the Cd levels in all the blood samples were found above the WHO recommended limit of 0.005 mg/L. T-test analysis showed a significant difference between the groups, indicating that blood cadmium levels were significantly higher in control group than in CKD patients.

The cadmium concentrations observed in the present study are comparable to those reported by Aminu *et al.,* (2021), who found elevated blood cadmium concentration in blood of CKD patients with a mean concentration of 0.051mg/L for CKD patients. Similar findings were also reported by Yeon *et al.,* (2025), who observed increased cadmium concentrations in populations with prolonged exposure to contaminated food and water, they obtained a mean cadmium concentration of 1.2 µg/L among 4,222 participants. The elevated cadmium levels recorded in this study further support the role of environmental exposure as an important source of cadmium accumulation in humans.

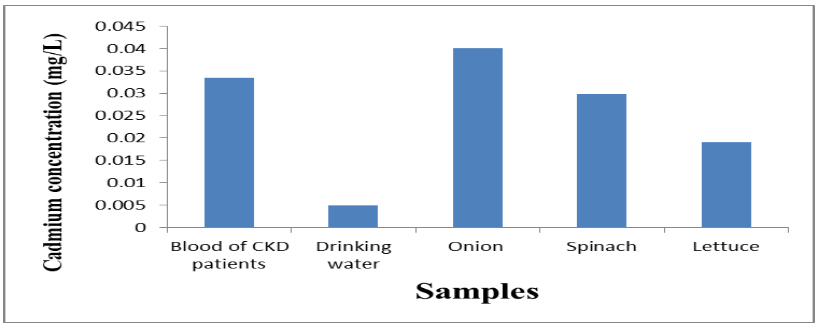

Figure 2: Mean Cadmium concentration in samples.

The mean chromium concentration among CKD blood samples was 0.045±0.035mg/L (Fig. 3), with the highest concentration recorded in sample B2 (0.108±0.0013mg/L), while the lowest concentration was observed in sample B6 (0.007±0.0002mg/L). Comparison with the WHO threshold limit of 0.05mg/L showed that chromium concentrations in B1, B2, B3 and B7 samples exceeded the WHO recommended level. The independent samples t-test revealed no statistically significant difference in blood nickel concentrations between the CKD patients and controls.

The chromium concentrations observed in blood samples are comparable to those reported by Aminu *et al.,* (2021), who detected elevated chromium levels among male and female individuals with Cr concentrations of 0.047mg/L and 0.112mg/L respectively.

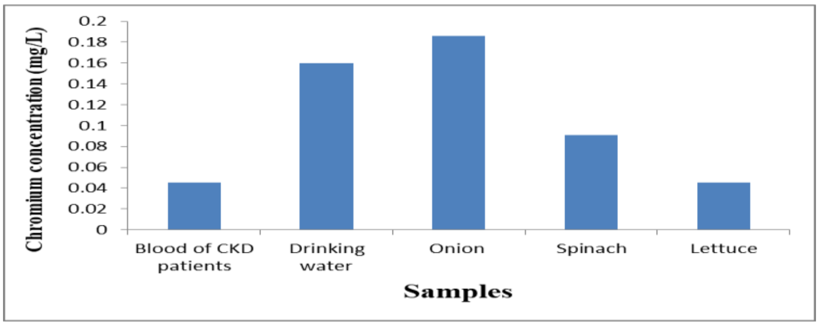

Figure 3: Mean Chromium concentration in samples

The highest nickel concentration among CKD blood samples was recorded in sample B2 (0.214±0.0008mg/L), while the lowest concentration was observed in sample B10 (0.027±0.0011mg/L). The mean nickel concentration in CKD bloods was 0.0985±0.0624mg/L, while 0.0991±0.0636mg/L was recorded for the control group (fig. 4). All of the samples show nickel concentration above WHO reference value of 0.02mg/L for nickel in blood. No statistically significant difference in blood nickel concentrations was observed using individual samples t-test between the CKD patients and controls.

The nickel concentrations recorded in the blood samples are comparable to those reported by Aminu *et al.,* (2021), who observed elevated blood nickel concentration greater than WHO standard level in male and female CKD patient with mean concentration of 0.075mg/L in blood.

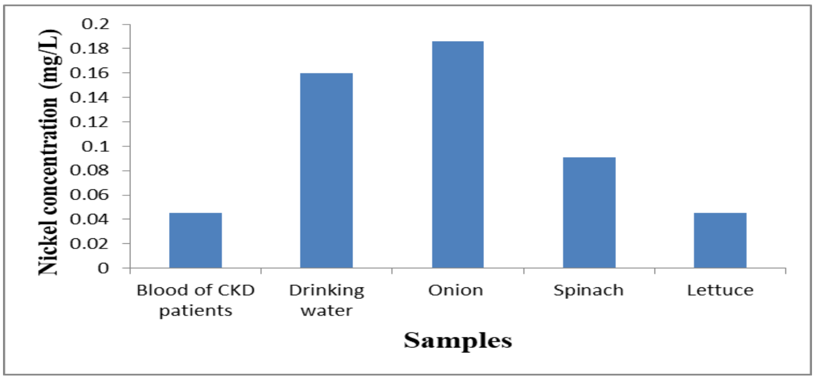

Figure 4: Mean Nickel concentration in samples

Lead concentrations in CKD blood samples ranged from the highest concentration in sample B9 (0.440±0.0021mg/L) to the lowest concentration in sample B10 (0.050±0.0016mg/L) with a mean concentration of 0.188±0.1070mg/kg (fig. 5). The WHO acceptable limit for lead in blood is approximately 0.01mg/L, which showed that all blood samples exceeded the recommended limit. Individual samples t-test shows that the CKD patients and controls are statistically similar.

The lead concentrations recorded in blood samples are similar to those reported by Aminu *et al.,* (2021), whose findings reveals higher concentration of lead in blood and urine of CKD patients with concentration of 0.112mg/L.

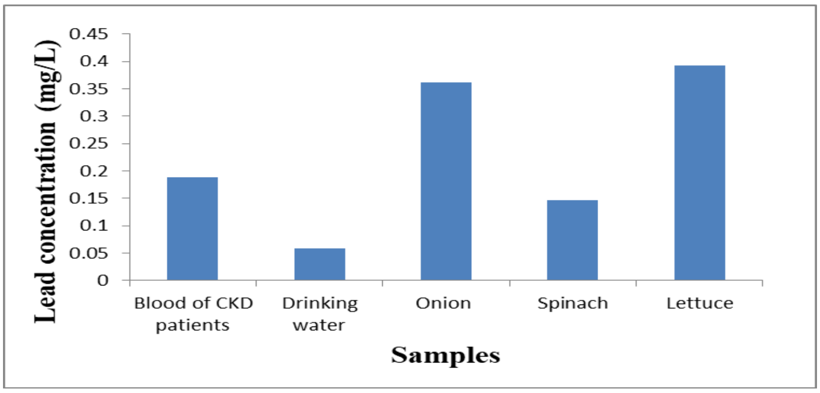

Figure 5: Mean Lead concentration in samples

Drinking Water Samples

For drinking water samples, the highest cadmium concentration was observed in sample D1 (0.008±0.0003mg/L), while the lowest concentration was observed in samples D3 and D7 (0.003±0.0003mg/L) with a mean concentration of 0.005±0.001 mg/L (fig. 2). Samples D1, D2, D4, D5, D6, D8, D9, and D10 recorded concentrations above the WHO limit of 0.003mg/L, while D3 and D7 were found within the permissible limit.

Similar cadmium concentrations in drinking water have been reported by Khokhar *et al.,* (2023), who found cadmium levels exceeding WHO threshold limits at groundwater Hyderabad rural (GWHR) and ground water Hyderabad city (GWHC), the cadmium levels were observed between 0.1 to 0.0408 mg/L in GWHR and between 0.0033 to 0.0256 mg/L in GWHC.

The mean chromium concentration was 0.1600±0.065mg/L (fig. 3), the highest concentration was recorded in sample D10 (0.314±0.0029mg/L), while the lowest concentration was observed in sample D1 (0.102±0.0005mg/L). The results showed all drinking water samples exceeded the recommended limit of 0.05mg/L set by WHO.

Similar chromium concentrations in drinking water were reported by Garba *et al.,* (2023) whom Cr concentration from 0.243mg/L to 0.358mg/L in groundwater. They observed that the Cr concentrations obtained in all the sampling sites were higher than the acceptable limit of 0.05 mg/L set by WHO. They concluded that the higher values of Chromium could lead to the health implications among residents within the sampling sites. These findings are consistent with the elevated chromium concentrations observed in the present study.

Nickel concentrations in drinking water samples ranged from 0.033±0.0007mg/L in sample D1 to 0.140±0.0008mg/L in sample D5. The mean nickel concentration was recorded was 0.0934±0.0378mg/L (Fig. 4). Comparison with the WHO permissible limit of 0.07mg/L showed that samples D2, D4, D5, D6, D7, D8, and D10 exceeded the recommended limit, D1 and D9 were below, while D3 was found within the permissible limit.

Similar nickel concentrations in drinking water have been reported by Adeyemi *et al.,* (2023) and Rizwan *et al.,* (2024), who observed elevated nickel levels in water sources affected by geological weathering and anthropogenic activities.

Lead concentrations in drinking water exceeded WHO permissible limit of 0.01mg/L in all of the samples with the highest lead concentration of 0.149±0.0012mg/L in sample D8 and the lowest concentration of 0.014±0.0004mg/L in D4. The mean concentration recorded was found to be 0.0585±0.0489mg/L (fig. 5).

Similar lead concentrations in drinking water have been reported by Garba *et al.,* (2023), who observed highest lead concentration of 0.053mg/L. This concentration was found above WHO permissible limits in drinking water sources. Their findings support the evidence of lead contamination observed in the present study, which was recorded slightly above their own observations.

Vegetable Samples

Among the vegetable samples, the onion samples, the highest cadmium concentration was recorded in sample O10 (0.054±0.0003mg/kg), while the lowest concentration was observed in sample O1 (0.030±0.0001mg/kg) with a mean cadmium concentration of 0.0401±0.007mg/L (Fig. 2). Comparison with the WHO/FAO permissible limit of 0.1mg/kg showed that all onion samples were found below the recommended limit. The low cadmium concentrations recorded in onion samples are comparable to those reported by Mohammed *et al.,* (2022), who found cadmium concentration of 0.03 mg/kg, which is below permissible limits in edible vegetables cultivated under normal agricultural conditions and similar to the results in current study.

For spinach samples, the mean cadmium concentration was 0.0298±0.003mg/L Fig. 2), where samples S9 and S10 recorded the highest cadmium concentration (0.034 mg/kg), while sample S1 recorded the lowest concentration (0.022±0.0004 mg/kg). However, were below the recommended limit set by WHO/FAO. Abdul Latif *et al.,* (2018) documented 0.35 mg/kg Cd concentration in spinach sample, which exceed the result in the present study and again crossed the safe limits of 0.2mg/kg set by WHO/FAO. Chinnannan *et al.,* (2024) also reported Cd concentration of 0.634 mg/kg in spinach samples, which is higher than the concentrations in the current study.

For lettuce samples, the highest cadmium concentration was recorded in sample L10 (0.025±0.0002mg/kg) and the lowest concentration was observed in sample L2 (0.012±0.0004mg/kg) with a mean concentration of 0.019±0.004mg/L (Fig. 2). Meanwhile, the values recorded were below the recommended limit. Similar cadmium concentrations have been reported by Alturiqi and Ali (2020), who observed 0.049 mg/kg cadmium concentration in lettuce samples. Their finding for Cd concentrations was observed to be above the result in the current study.

The highest onion chromium concentration was recorded in sample O9 (0.337±0.0006mg/kg), while the lowest concentration was observed in sample O6 (0.073±0.0006mg/kg), having a mean chromium concentration of 0.1862±0.0900mg/kg (Fig. 3). The values recorded were below the WHO/FAO permissible limit. Similar chromium concentrations in onion samples have been reported by Mohammed *et al.,* (2022) who found chromium levels below permissible limits in edible vegetables with a mean concentration of 0.15 mg/kg. Chromium concentrations in spinach samples ranged from 0.047±0.00mg/kg to 1.849±0.00 mg/kg with mean chromium concentration of 0.0909±0.0655mg/kg (fig. 3), which was below the WHO/FAO permissible limit of 2.3mg/kg. Sample S2 recorded the highest chromium concentration (1.849±0.0000mg/kg), while sample S1 recorded the lowest concentration (0.047±0.0000mg/kg). The chromium concentrations recorded in spinach samples are comparable to those reported by Mohammed *et al.,* (2022), who observed chromium concentrations from 0.05 to 0.15 mg/kg. Chromium concentrations in lettuce samples ranged from 0.015±0.0003 mg/kg to 0.077±0.0030mg/kg. The mean concentration was 0.0454±0.0224mg/kg (Fig. 3), with the highest concentration recorded in sample L4 (0.077±0.003 mg/kg) and the lowest concentration was observed in sample L7 (0.015±0.0003 mg/kg). These values were below the recommended limit and were in agreement with the report of Manegabe *et al.,* (2025), who found chromium accumulation in lettuce at 0.006-300.52 mg/Kg.

Nickel concentrations in onion samples ranged from 0.028±0.0024 mg/kg to 0.311±0.0007 mg/kg, with a mean concentration of 0.1478±0.1040 mg/kg (Fig. 4). The vales obtained were below the recommended limit. Furthermore, Mohammed *et al.,* (2022) found nickel levels of 2.56 mg/kg which is higher than those reported in the present study. Nickel levels in spinach samples ranged from 0.045±0.0021 mg/kg to 0.484±0.0008 mg/kg with a mean concentration of 0.1997±0.1547mg/kg (Fig. 4). These values fell below the threshold limit. The nickel concentrations recorded in spinach samples are comparable to those reported by Rizwan *et al.,* (2024), who observed relatively low nickel accumulation in leafy vegetables cultivated on agricultural soils. Lettuce samples were also observed to record the highest in sample L7 (0.281±0.0010mg/kg), while the least levels were observed in sample L4 (0.028±0.0016mg/kg). Comparison with the WHO/FAO permissible limit of 0.5mg/kg showed that all the samples were below the recommended limit.Similar nickel concentrations have been reported by Sagagi *et al.,* (2022), who found the highest Ni concentration of 11.263 mg/kg for lettuce. These findings recorded Ni concentration far above those reported in the present study.

Lead concentrations in onion samples ranged from 0.110±0.0016mg/kg in O4 to 0.880±0.0019mg/kg in O10. The levels of Pb in samples O7, O8, O9, and O10 exceeded the recommended. Similar Pb concentrations were reported by Muhammed *et al.,* (2022), who obtained 0.036 mg/kg in onion. The findings are consistent with the elevated concentrations recorded in some onion samples in the present study.

In spinach samples analysed, sample S10 had the highest Pb concentration (0.237±0.0006mg/kg), while sample S7 recorded the lowest concentration (0.054±0.0013mg/kg), with a mean concentration of 0.1472±0.0679mg/kg (fig. 5). Evaluation with the WHO/FAO permissible limit of 0.30mg/kg showed that all spinach samples were below the recommended limit. This result agree with those reported by Sabbagh *et al.,* (2025).

The values for most of sampling sites (L1, L3, L4, L5, L8, L9, and L10) exceeded the recommended limit. This finding was similar to the of 0.43mg/kg reported by Alturiqi and Ali (2020).

The result for cadmium showed a statistically significant difference among the sample groups at 95% confidence level ($p < 0.05$). Tukey post hoc test revealed that the concentration of Cd in bloods samples of CKD patients were significantly higher than Cd concentrations in drinking water, onions and lettuce samples. This suggests that drinking water, onions and lettuce could contribute to Cd exposure to the study population. Also, the test shows that there is no significant difference between the Cd concentrations among blood and spinach samples.

The Pearson's correlation analysis revealed that blood cadmium concentration exhibited a very strong positive correlation with onion, lettuce, and spinach. These findings indicate that increased cadmium concentrations in these vegetables were associated with increased cadmium concentrations in the blood of the study participants.

The Tukey HSD post hoc analysis for chromium revealed that the concentration of Cr in blood of CKD patients did not differ significantly from drinking water, lettuce, or spinach ($p > 0.05$), but had a significantly lower chromium concentration than onion ($p < 0.05$).

The Tukey HSD post hoc analysis for nickel demonstrated that the concentration of Ni in all the samples (blood, drinking water, onion, lettuce, and spinach) have similar concentrations, indicating that there was no statistically significant differences among the mean nickel concentrations of all the samples ($p > 0.05$). This finding suggests a relatively uniform distribution of nickel across the environmental matrices and blood samples in the study area, signifying that nickel exposure may be widespread rather than associated with a specific environmental source.

The Tukey HSD post hoc analysis for Pb revealed that the concentration of Pb in blood of CKD patients did not differ significantly from drinking water, onion, lettuce, or spinach ($p > 0.05$), indicating comparable lead concentrations among these samples.

Discussion

Heavy Metal Concentrations in Blood Samples

The concentrations of Cd, Cr, Ni, and Pb detected in blood samples indicate exposure to both CKD patients and control subjects. Cd, Ni, and Pb were found above the permissible limits in both groups, while Cr exceeded recommended levels in several blood samples. The broadly similar exposure pattern between CKD patients and controls suggests that these elevated levels likely reflect comparable environmental exposure within the general population rather than specific exposure to individuals with CKD. Exposure to multiple potentially toxic metals has commonly been linked to contaminated food, water, and other environmental sources (Genchi *et al.,* 2020).

These elevated metal levels may result from combined exposure through drinking water, consumption of contaminated vegetables, and other environmental pathways. Cadmium, lead, nickel, and chromium are known to cause harmful biological effects when exposure is prolonged or excessive, although their toxicity depends on factors such as chemical form, dose, duration, and individual susceptibility (Tchounwou *et al.*, 2012). Their simultaneous presence in blood and environmental samples therefore supports the likelihood of transfer through food and water, but it should not be interpreted as direct evidence that these metals alone are responsible for CKD.

Heavy Metal Concentrations in Drinking Water

Drinking water samples contained Cd, Cr, Ni, and Pb, although contamination levels varied across metals and locations. Chromium and lead were the most consistently elevated, exceeding permissible limits in most water samples, while Cd and Ni exceeded limits in some locations. The presence of these metals in drinking water is particularly concerning because it represents a direct route of human exposure (Tchounwou *et al.*, 2012). The observed contamination may be associated with agricultural runoff, weathering of metal-bearing rocks, domestic waste disposal, fertilizer application, corrosion of metal-containing materials, and other anthropogenic activities. These contamination sources have been widely reported to contribute to the deterioration of groundwater quality and the accumulation of heavy metals in drinking water (Liu *et al.*, 2023; Hoque *et al.*, 2024).

Heavy Metal Concentrations in Vegetables

The heavy metals, Cd, Cr, Ni, and Pb were detected in onion, spinach, and lettuce, showing that metals are being transferred from the environment into edible crops. Cd, Cr, and Ni were generally within permissible limits, while Pb exceeded recommended levels in some onion and lettuce samples. This variation suggests that different vegetables have different capacities to absorb and accumulate metals depending on their biological and environmental characteristics (Xiao *et al.*, 2023; Yu *et al.*, 2023).

Differences in accumulation among the vegetables may be due to variations in root uptake, translocation ability, transpiration rate, soil chemistry, and metal availability. Leafy vegetables may also accumulate metals through both root uptake and atmospheric deposition. These factors help explain why crops grown under similar conditions can still show different metal concentrations (Genchi *et al.,* 2020; Rizwan *et al.*, 2024).

The higher Pb levels in some onion and lettuce samples suggest localized accumulation and highlight vegetables as an important pathway linking environmental contamination to human exposure. The presence of Pb in irrigation water and soil likely contributes to its uptake into edible plant parts. Similar findings have been reported where contaminated irrigation water and soils led to metal accumulation in vegetables and increased dietary exposure risk (Manegabe *et al*., 2025).

CONCLUSION

This study demonstrated that heavy metals (Cd, Cr, Pb, and Ni) are present in water, vegetables and blood samples collected from Hadejia LGA, Jigawa State, at varying concentrations. Significant contamination was observed in drinking water, which likely contributes to the uptake of these metals in edible vegetables. The presence of elevated cadmium, chromium, lead and nickel levels in water and blood samples is particularly concerning, as these metals are well known for their nephrotoxic effects. The higher concentrations recorded in CKD patients suggest a possible association between chronic exposure to heavy metals and kidney dysfunction in the study area. The findings indicate that environmental contamination may be an important contributing factor to the increasing burden of chronic kidney disease in Hadejia. Continuous exposure through contaminated water and food could lead to bioaccumulation of toxic metals in humans over time.

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