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Chronic Kidney Disease Associated With Heavy Metals (Cr, Pb, Cd) Analyzed From Irrigation Water of Gashua, Yobe, Nigeria

[1]Salamatu Ahmad Amshi, [2]Ibrahim Iliya And [3]Aliyu Adamu
[1,2]Department of Pharmaceutical Chemistry, University of Maiduguri, Nigeria
[3]Department of Physics, University of Maiduguri, Nigeria
Corresponding Author: 1Salamatu Ahmad Amshi

Abstract: *Chronic kidney disease (CKD) is a global public health problem; its rate is rapidly increasing in Gashua, region of Yobe State. The main cause of this CKD has not yet been identified, but it is suspected to be as a result of toxins or heavy metals in food or water, therefore, in this study, the concentrations of cadmium (Cd), lead (Pb) and Chromium (Cr) in irrigation water were determined from four different water sources (Mashangwari I, Mashangwari II, Gada right and Gada left). The samples collected were analyzed for their Cd, Pb, and Cr contents, using atomic absorption spectrophotometry (AAS). The analysis showed the higher concentration of Cr, (0.0048 – 1.5987 μg/mL) with highest values, 1.598 μg/mL and 1.0689 μg/mL in irrigation water of the Gada (right) and Gada (left) respectively. While the concentrations of Cd (0.0351 – 0.0912 μg/mL) and Pb (0.0386 – 0.1086 μg/mL) in the water source were relatively low. These values of the Cr, Pb and Cd concentration are higher than the world health organization (WHO) permissible limits (0.01 μg/mL, 0.003 μg/mL and 0.05 μg/mL, for Pb, Cd, and Cr respectively). Since the values of the heavy metal concentrations obtained from all the four water samples were higher than the WHO permissible limits, therefore the study suggested that the use of these water sources for irrigation should be stopped. The uptake of Cd, Pb, and Cr through roots of the plants grown in that area can lead to their accumulation in the tissues of organisms that feed on the water or plants cultivated in that area and to other consumers. These post a thread of the toxicity of Cd, Pb, and Cr which are linked to chronic kidney disease. This study provides for the first time, the information on the role of Cd, Pb, and Cr concentration in irrigation water sources and their relation to chronic kidney disease in Gashua.*

Key words: *chronic kidney disease, water quality indices, Heavy metals, concentration, contamination,*

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I. Introduction

The incidence of kidney disease, particularly diabetic kidney disease, is increasing rapidly in many disadvantage populations throughout the world [1,2]. It was found that the kidney disease is very prevalent among Africans. Several published studies emphasizes that chronic kidney disease (CKD) is under-diagnosed and under-treated. Despite the high burden and associated high morbidity, the causes of CKD in a high percentage of individuals remain largely elusive [3] especially in developing countries where lack of modern diagnostic techniques and late presentation to nephrologists greatly limit the characterization of kidney diseases. Those limitations have probably led to the misclassification of significant number of patients with the findings of bilaterally contracted kidneys as chronic glomerulonephritis. A research was carried out at University of Maiduguri Teaching Hospital (UMTH) and was found that about 15% of the people who come to the hospital from the catchment areas have kidney disease and 20 out of 100 patients are from Bade community (Gashua) of Yobe State [4]. The rate of kidney disease is rapidly increasing in Bade community and the main cause of this disease has not yet been identified, but it is suspected to be as a result of toxins or heavy metals in food or water.

Heavy metals have been used by humans for thousands of years and the study of their toxic effects in humans has gained particular importance, since large quantities of these products, discarded as part of the industrial activity, are not biodegradable and persist in the environment for long periods of time [2,5]. The exposure of heavy metals to human is increasing particularly in less developed countries [6]. The accumulation of heavy metals in agricultural soils irrigated with wastewater pose a significant risk in the accumulation of heavy metals, a problem that affects agriculture and human health. [7-11]. Arora et al. (2008) reported that using wastewater to irrigate agricultural soils resulted in significantly higher concentrations of heavy metals in the edible portions of the crops grown on these soils [12]. Several authors have shown the risk of increasing trend of heavy metal concentration in irrigation water [13-24] and thereafter contaminate the vegetable and fruit cultivated in that area. There was ample research on the potential health risk to human health due to consumption of vegetable and fruit with heavy metals contamination [22,25-32].

In order to examine the role of chromium (Cr), lead (Pb) and cadmium (Cd) contamination in kidney disease, the study aims at the spectroscopic investigation of heavy metals (Cr, Pb and Cd) concentrations in samples of wastewater used for irrigation in from three selected area in Gashua, the most important agricultural area in Yobe State, Nigeria. Simultaneously, the present study examines the potential environmental health risk of these metals concentration to Gashua community. The concentration of these heavy metals was compared to the maximum permissible limits established in the NOM-001-ECOL-1996.

II. Material and Methods

The equipments and instruments used in this study were all calibrated to check their status before and in the middle of the experiments. Apparatus such as volumetric flasks, measuring cylinder and digestion flasks were thoroughly washed with detergents and tap water and then rinsed with deionized water. All Glass wares were cleaned with 10% concentrated Nitric acid (HNO_3) in order to clear out any heavy metal on their surfaces and then rinsed with distilled-deionised water. The digestion tubes were soaked with 1% (w/v) potassium dichromate in 98% (v/v) H_2SO_4 and the volumetric flasks in 10% (v/v) HNO_3 for 24 hours followed by rinsing with deionized water and then dried in oven and kept in dust free place until analysis began. Prior to each use, the apparatus were soaked and rinsed in deionized water.

Equipment and Apparatus: Analytical balance (Ohaus) with precision of + 0.001 g, Borosilicate volumetric flasks (25, 50 ml, 100 ml and 1000 ml), Measuring cylinders, Micropipettes (1-10 ml, 100-1000 ml), Microwave digester (Master 40 Serial No:40G106M) and Atomic absorption spectrophotomer (Buck scientific model 210VGP AAS, USA) hollow cathode lamps with air-acetylene flame).

Reagents and Chemicals: Reagents and chemicals used for the laboratory works were all analytical grade: Deionized water (chemically pure with conductivity 1.5 µs/cm and below was prepared in the laboratory) was used for dilution of sample and intermediate metal standard solutions prior to analysis and rinsing glassware and sample bottles.

Sample Pre-Treatment/Digestion: The samples were allowed to dry using hot oven (Model 30GC lab oven) and then ground into fine powder by using a porcelain mortar and pestle. As much as 100 mg of each sample was weighed in to thoroughly clean plastic container (microwave tube) and 6 ml of 65% HNO_3 and 2 ml of hydrogen peroxide 3:1 was added and allowed and to stand for a while. The plastic container (microwave tube) was then covered and placed in to microwave digester (Master 40 serial No: 40G106M) and digested. The digestion was carried out at a temperature of (120 ℃) for 30 min and then ramped at 20 ℃ per min to 180 ℃ and hold for 10 mins. The digestion was followed by a cooling to room temperature in the microwave.
Potential presence of heavy metal in chemical which used in digestion was determined. Blanks were used simultaneously in each batch of the analysis to authenticate the analytical quality. The digested samples were diluted with deionized water to a total volume of 25 ml.

Preparation of 1000 mg/Litre stock AAS standard solution for selected heavy metals (such as Cr, Pb and Cd and other metals): The determination of a given metal concentration in the experimental solution was based on its respective calibration curve. In plotting the calibration curves for lead, cadmium, zinc and other metals, a stock solution of each metal ion of (1000 ppm) was prepared by dissolving; 1.5980 g of $Pb(NO_3)_2$, 2.1032 g of $Cd(NO_3)_2$ (and other metals so as to get exactly 1.0 g of the desired metal in 100 mL of solution) in deionized water and then diluting to 1 liter in a volumetric flask.

Standard working solution: 100 ppm was prepared as working solution from the 1000 ppm already prepared. A simple dilution formula ($C_1V_1 = C_2V_2$) was used to calculate the volume of the stock solution to be diluted to the new desired concentration. To prepare 100 ppm, 10 ml of the standard Pb $(NO_3)_2$, Cr $(NO_3)_2$ $.9H_2O$, Cd $(NO_3)_2$ and other stock solutions were pipetted and added in to 100 ml calibrated flasks finally diluted with deionized water and the solution was mixed thoroughly. The other standard working solutions was prepared from100 ppm by pipetting out appropriate volume in to calibrated flasks and made up to volume with deionized water.

Determination of metal content by AAS

Preparation of calibration curve: Calibration curves were prepared to determine the concentration of the metals in the sample solution. The instrument was calibrated using series of working standards. The working standard solutions of each metal were prepared from standard solutions of their respective metals and their absorbances were taken using the AAS. Standard working parameters were set and given in table 1. Calibration curve for each metal ion to be analyzed was prepared by plotting the absorbance as a function of metal ion standard concentration.

Determination of metal contents of each sample: Concentration of the metal ions present in the sample was determined by reading their absorbance using AAS (Buck scientific model 210GP) and comparing it on the respective standard calibration curve. Three replicate determinations were carried out on each sample. The metals were determined by absorption/concentration mode and the instrument readout was recorded for each solution manually. The same analytical procedure was employed for the determination of elements in digested blank solutions and for the spiked samples.

III. Result

Table 1 showed the concentration of Chromium (Cr), lead (Pb) and cadmium (Cd) in their first absorption. Calibration curves for the heavy metals (Cr, Pb and Cd) were prepared from Table 2 by plotting the absorbance as a function of metal ion standard concentration. The concentrations of heavy metals (cadmium, lead and Chromium) in irrigation water collected from four different samples source (Mashangwari I, Mashangwari II, Gada right and Gada left) were determined using atomic absorption spectroscopy (AAS) and the results obtained were presented in Table 4.

Table 1: Working parameters of atomic absorption spectrophotometer

S/No	Element	Wavelength (nm)	Slit (nm)
1	Lead	283.2	0.7
2	Chromium	357.9	0.7
4	Cadmium	228.8	0.7

Table 2: The concentration of Chromium (Cr), lead (Pb) and cadmium (Cd) in their first absorption

S/No	Concentration (µg/mL)	1st absorption		
		Cr	Pb	Cd
1	0	0.00125	0.010512	0.002150
2	1	0.24530	0.024243	0.025810
3	2.5	0.60271	0.061455	0.064551
4	5	1.22040	0.122215	0.130040
5	10	2.32640	0.242520	0.256880
6	15	3.58621	0.312445	0.390220
7	20	4.65281	0.484890	0.498580
8	25	4.88540	0.612450	0.651230

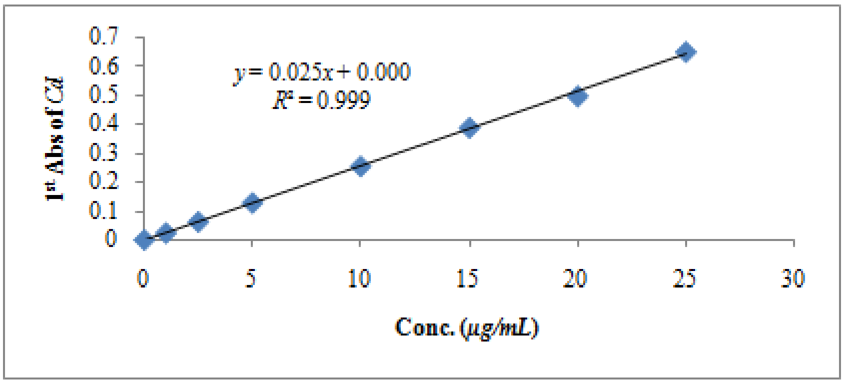

Figure 1: Linearity plot of the concentration of cadmium (Cd) in their first absorption

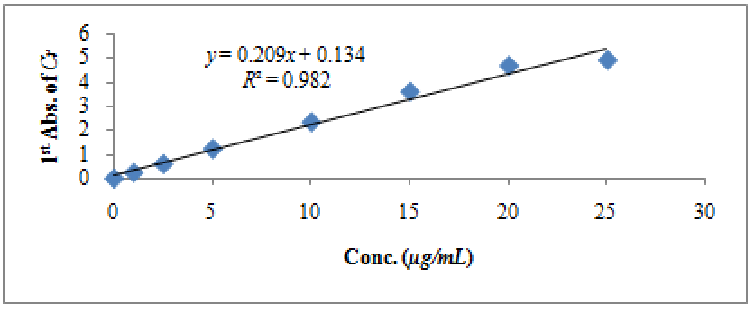

Figure 2: Linearity plot of the concentration of Chromium (Cr) in their first absorption

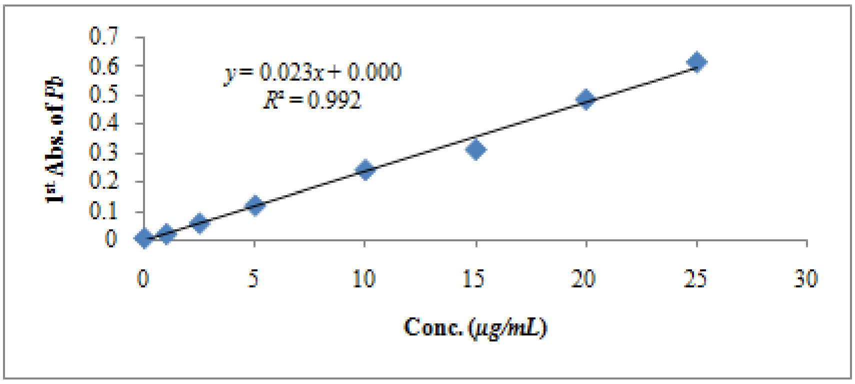

Figure 3: Linearity plot of the concentration of lead (Pb) in their first absorption

It can be observed from Figure 1 to 3 that the correlation coefficient (R^2) values were 0.982, 0.992 and 0.999 for Chromium (Cr), lead (Pb) and cadmium (Cd), respectively. These showed that the concentration of Cd, Pb and Cr with their first absorption were linear. The visual characteristics of statistical parameters such as regression equation, coefficient of determination, correlation coefficient and percentage error of R^2 were calculated, and the results have been summarized in Table 3.

Table 3: Regression data for the calibration plots

Statistical parameters	Heavy Metals		
	Cr	Pb	Cd
Regression Linear Equation	y = 0.209x + 0.134	y = 0.023x + 0.000	y = 0.025x + 0.000
Coefficient of Determination	R^2 = 0.982	R^2 = 0.992	R^2 = 0.999
Correlation Coefficient	0.991	0.996	0.999
Percentage Error of R^2 (%)	1.832	0.806	0.100

Table 4 showed the results obtained for the concentrations of Cr, Pb and Cd in irrigation water collected from Mashangwari I, Mashangwari II, Gada right and Gada left. The order of these heavy metals concentration in water samples is Cr > Pb > Cd and their concentration in water samples obtained from atomic absorption spectrophotometry (AAS) are interpreted as follows:

Chromium (Cr): It can be seen from the result that the concentration of Cr was detected in all the three samples with the maximum values of 1.5982 µg/ml and 1.0689 µg/ml in Gada (right) and Gada (left) respectively (Table 4). Thus, the values of Cr concentrations in the irrigation water were not complying with the permissible limit set by WHO (0.05 µg/ml for Cr).

Lead (Pb): Table 4 showed the Pb concentration ranges from 0.0386 µg/ml in Gada (left) to 0.1086 µg/ml in Gada (right). Therefore, the concentrations of Pb detected in all the samples were greater than the standard value given by WHO (0.01 µg/ml).

Cadmium (Cd): The concentration of Cd in irrigation water of Gashua farming site ranges from 0.0352 µg/ml in Mashangwari I to 0.0912 µg/ml in Gada (left) (Table 4).
Based on WHO, () guideline these values of concentration of Cd in all the samples collected are not in compliance with the set WHO guideline, which are 0.01 µg/mL for Pb, 0.003 µg/mL for Cd and 0.05 µg/mL for Cr respectively. Therefore, this study suggested that the irrigation water for Gashau community is not safe for farming.

Table 4: The concentration of Chromium (Cr), lead (Pb) and cadmium (Cd) in water samples from four locations

S/No	Water	Concentration (µg/ml)		
		Cr	Pb	Cd
1	Mashangwari I	0.0048	0.1057	0.0352
2	Mashangwari II	0.0085	0.1054	0.0836
3	Gada (right)	1.5987	0.1086	0.0876
4	Gada (left)	1.0689	0.0386	0.0912

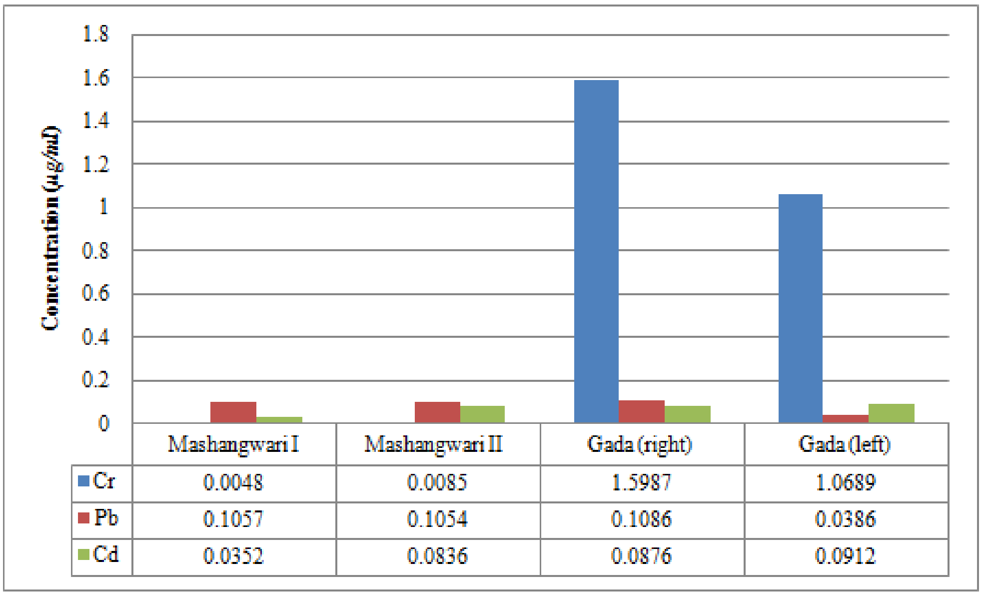

Figure 2: The concentration of Chromium (Cr), lead (Pb) and cadmium (Cd) in water samples from four locations

IV. Discussion

This result showed the highest concentration of Cr 1.598 µg/ml and 1.0689 µg/ml in irrigation water of the Gada (right) and Gada (left) respectively. The concentrations of heavy metals (Cd, Pb and Cr) were found much lesser in Mashangwari I and Mashangwari II irrigation water as compared to Gada (right) and Gada (left) irrigation water. Since the WHO permissible limit for Cd, Pb and Cr were 0.003, 0.01 and 0.05 µg/ml, respectively, the irrigation quality of irrigation water is altered with some heavy metals contamination. Therefore, the irrigation water for Gashua community has relatively high concentration of Cd, Pb and Cr and the uptake of these heavy metals through roots from irrigation water can contaminate the plants grown in that area. This can also lead to accumulation of these heavy metals in the tissues of organisms that feed on the plants grown in the area and to other consumers in the food chain [34]. Adverse human health effects of heavy metals such as chromium (Cr), lead (Pb), cadmium (Cd), mercury (Hg) and arsenic (As) have been extensively studied and regularly reviewed by international bodies such as the WHO. Heavy metals (Cd, Pb, As and Hg) are clearly associated with renal damage and progression of Chronic kidney disease [2]. A study conducted by Sommar et. al., [35] correlated Pb, Hg and Cd with Chronic kidney disease; they found that Cd levels increase the development of Chronic kidney disease, while mercury levels are not associated with Chronic kidney disease. However, they mention the need for more studies to assess causality. Gender-specific analyzes suggest possible differences in the susceptibility or reliability of the exposure to the biomarker [2].

V. Conclusion

This study showed the concentration of Cd, Pb and Cr in irrigation water of the Gashua community is relatively high and is beyond the permissible limit set by WHO. Since the study showed that the concentrations of these heavy metals are greater than the recommended standards, this study suggested that the use of these water sources as irrigation should be stopped. The uptake of these heavy metals through roots of the plants grown in that area can lead to their accumulation in the tissues of organisms that feed on the water or plants grown in that area and to other consumers since Cd, Pb, and Cr are associated with Chronic kidney disease. This study provides for the first time the information on the role of heavy metals concentration in irrigation water and their relation to chronic kidney disease in Gashua community. The study recommended that there is also need to study the concentration of such heavy metals in agricultural soil, plants and vegetables, animals and any other source that directly or indirectly link to the source of food of the populace.

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