Journal of Science and Technology Research 1(2) 2019 pp. 136-143 ISSN-2682-5821

NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Health Risk Assessment of some Heavy Metals (*Cd, Pb, Cr*) in Soil Sample from Gashua, Yobe, Nigeria

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ARTICLE INFORMATION

Article history:
Received 27 May, 2019
Revised 06 June 2019
Accepted 10 June 2019
Available online 13 June 2019

Keywords:
Heavy metals
Soil, Concentration
Health risk
Kidney

ABSTRACT

The extent of heavy metal concentration in agricultural soil has serious health implication such as kidney failure, mental lapse and central nervous system disorder on human and higher animals. In this paper samples of agricultural soil where collected from four different farmlands (Mashangwari I, Mashangwari II, Gada right and Gada left) along Gada River, Gashua. The samples collected were analyzed for their cadmium (Cd), lead (Pb) and Chromium (Cr) concentrations, using atomic absorption spectrophotometry (AAS) technique. The analysis showed the highest concentration of Pb (6.3130 $\mu g\ ml^{-1}$) in Gada (left) farmland, followed by Cr (1.5082 $\mu g\ ml^{-1}$) in Gada (right). While the average concentration of Cd (0.40485 $\mu g\ ml^{-1}$) is relatively low. Mashangwari I has the highest concentration of Cd (0.7405 $\mu g\ ml^{-1}$). These values of the Pb, Cr, and Cd concentration are higher than the world health organization (WHO) permissible limits in soil. Since the values of the Pb, Cr, and Cd concentrations obtained from all the four soil samples were higher than the WHO permissible limits, this indicates that Pb, Cr, and Cd concentration in the soil had the higher capability to pose severe health risk to Gashua community. Therefore, it is suggested that Cd, Pb and Cr concentration in Gashua agricultural soil could be linked to chronic kidney disease that affects the community.

1. Introduction

Soil is composed of mineral constituents, organic matter, living organisms, air and water. These serve as a natural medium for plants growth [1-4]. The extent of heavy metal concentration in agricultural soil is very alarming [5] and their solubility in soil was mainly influence by many factors such as pH, conductivity, moisture content [6]. These become a world-wide problem during recent years due to the fact that heavy metals unlike some other pollutants are not detoxified but are bioaccumulated in the environment [4, 7]. Soil pollution by heavy metals has serious health implication especially with regards to plants grown on such soils [8]. Long-term effect of heavy metal exposure to human and higher animals includes mental lapse, kidney failure, and central nervous system disorder [9]. Chronic exposure of *Cd* can have harmful effects such as lung cancer, bone fractures, kidney dysfunction, and hypertension. Müller *et. al.*, (2014) found that the increased cadmium (*Cd*) concentrations found in the soils under organic fertilizer applications resulted in cadmium (*Cd*) concentrations in the apples to exceed the maximum permissible concentrations for fresh produce grown in South Africa [10]. Exposure to lead (*Pb*) may cause plumbism, anemia, nephropathy, gastrointestinal colic, and central nervous system symptoms [4, 11].

Heavy metals occur naturally in soils by geological processes, such as alteration and erosion of the geological underground materials [12, 13]. The accumulation of heavy metals in soils includes agricultural and industrial pollution [14]. Several researchers have subsequently shown that the continuous applications of both organic and inorganic/chemical fertilizers, as well as other agrochemicals such as pesticides, herbicides, fungicides, waste water and sewage sludge, allow for bioaccumulation of heavy metals and other chemical residues in agricultural soils [10, 15-25]. The use of pesticide and chemical fertilizer alongside sludge in the farms is an additional reason for transferring *Cr*, *Ni* and *Pb* from soil to edible parts of the crops [26] and thereafter contaminate the plants [12, 27] and crops grown in that area. Arora *et al.* (2008) also indicated 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. The heavy metals concentrations in plants depend on the soil concentration [24]. An increase in heavy metal concentrations in agricultural soils would lead to an increase in the uptake of these heavy metals by the vegetables grown on these soils and may enter the food chain as a result of their uptake by edible plants [28]. In this study, the heavy metal (*Cd, Cr* and *Pb*) concentration in agricultural soil on which fruits and vegetables cultivated in Gada (a major supplier of vegetables to Gahua area) were investigated to assess the health risk of such heavy metals to Gashua community.

2. Materials and Method

The equipment 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.

2.1 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 100mg of each sample was weighed in to thoroughly clean plastic container (microwave tube) and 6ml 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*.

2.1.1 Preparation of 1000 *mg/Litre* stock AAS standard solution for selected heavy metals (such as *Pb, Cr* 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.

2.2 Determination of metal content by AAS

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. Calibration curve for each metal ion to be analyzed was prepared by plotting the absorbance as a function of metal ion standard concentration.

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.

2.3 Data Analysis

Data was analyzed using Microsoft Office Excel.

3. Results and Discussion

Table 1 showed the concentration of cadmium (*Cd*), lead (*Pb*) and Chromium (*Cr*) in their first absorption. Calibration curves for the *Cd, Pb* and *Cr* 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 cadmium (*Cd*), lead (*Pb*) and Chromium (*Cr*) in their first absorption

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

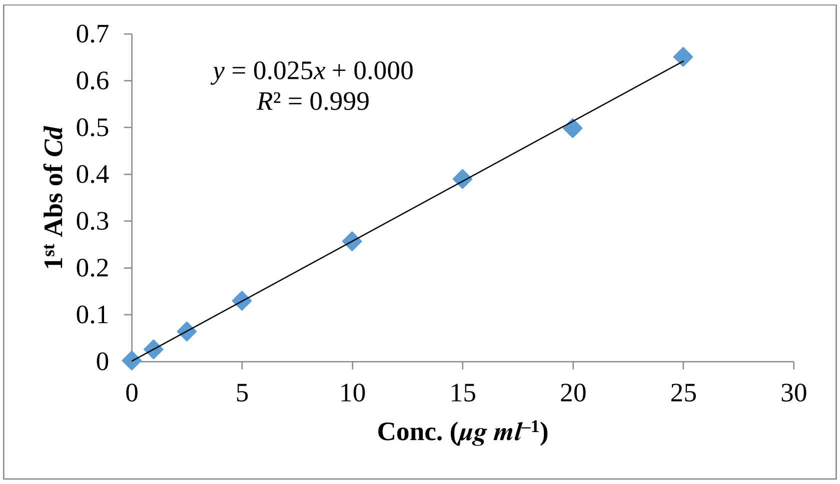


Figure 1: Linearity plot of the concentration of cadmium (*Cd*) in their first absorption

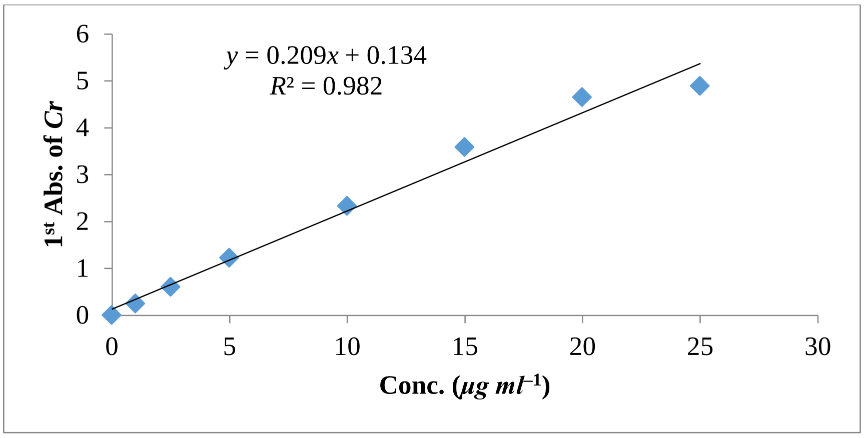


Figure 2: Linearity plot of the concentration of Chromium (*Cr*) in their first absorption

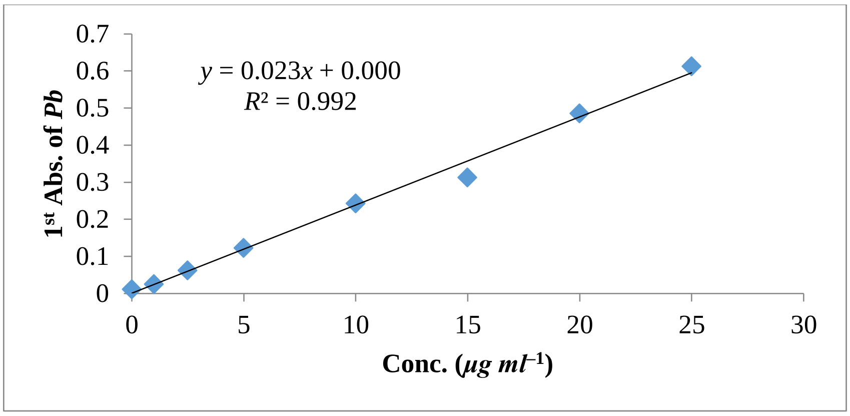


Figure 3: Linearity plot of the concentration of lead (*Pb*) in their first absorption

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.

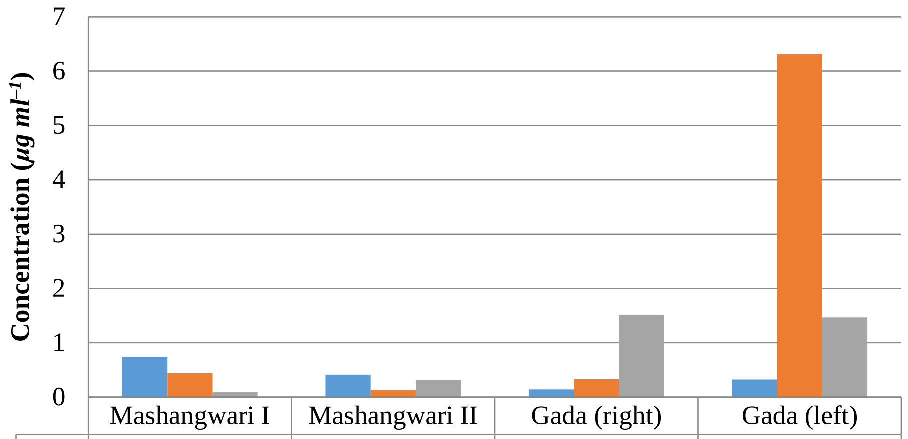
Table 3: Regression data for the calibration plots

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

Table 4 showed the concentrations of *Cd*, *Pb* and *Cr*, obtained from atomic absorption spectrophotometry (AAS) technique, in soil sample collected from Mashangwari I, Mashangwari II, Gada (right) and Gada (left). All heavy metals investigated (*Cd*, *Pb*, *Cr*) were found present in the soil samples and the order of their concentration in the samples is *Cd* > *Pb* > *Cr*. The values of concentration of *Cd*, *Pb*, and *Cr* obtained from the analysis were 0.7405, 0.4443 and 0.0871 $\mu g\ ml^{-1}$; 0.4133, 0.1311 and 0.3208 $\mu g\ ml^{-1}$; 0.1416, 0.3279 and 1.5082 $\mu g\ ml^{-1}$ and 0.3235, 6.3130 and 1.4666 $\mu g\ ml^{-1}$ for Mashangwari I, Mashangwari II, Gada right and Gada left respectively. The concentration of *Cd* in soil sample from Gashua farming site ranges from 0.1416 $\mu g\ ml^{-1}$ in Gada (right) to 0.7405 $\mu g\ ml^{-1}$ in Mashangwari I. Table 4 showed the *Pb* concentration ranges from 0.1311 $\mu g\ ml^{-1}$ in Mashangwari II to 6.3130 $\mu g\ ml^{-1}$ in Gada (left). Therefore, the concentrations of *Pb* detected in Gada (left) were greater than other location. It can be seen from the result (Table 4) that *Cr* was also detected in all the four samples with the maximum values of 1.5082 $\mu g\ ml^{-1}$ and 1.4666 $\mu g\ ml^{-1}$ in Gada (right) and Gada (left) respectively.

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

S/No	**Clay Soil**	**Concentration ($\mu g\ ml^{-1}$)**		
		Cd	***Pb***	***Cr***
1	Mashangwari I	0.7405	0.4443	0.0871
2	Mashangwari II	0.4138	0.1311	0.3208
3	Gada (right)	0.1416	0.3279	1.5082
4	Gada (left)	0.3235	6.3130	1.4666



	Mashangwari I	Mashangwari II	Gada (right)	Gada (left)
Cd	0.7405	0.4138	0.1416	0.3235
Pb	0.4443	0.1311	0.3279	6.313
Cr	0.0871	0.3208	1.5082	1.4666

Figure 4: The concentration of cadmium (*Cd*), lead (*Pb*) and Chromium (*Cr*) in soil samples from four locations.

The highest concentration of *Pb* (6.3130 $\mu g\ ml^{-1}$) detected in Gada (left) samples can be attributed to waste deposit in the area. The higher level of *Cd, Pb* and *Cr* obtained from each sample could post a thread of the toxicity of heavy metals. 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 plants and to other consumers. Therefore consumption of food cultivated from this area should be discourage, because, heavy metals such as *Cd*, *Pb* and *Cr* have been reported with high tendency to binding tenaciously to organic matter contained in the soil. 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. A study conducted by Sommar *et al.*, [35] correlated *Pb*, *Hg* and *Cd* with renal damage and progression of 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 [29, 30].

4. Conclusion

This study showed the concentration of *Cd*, *Pb* and *Cr* in agricultural soil of the Gashua community is relatively high and is beyond the permissible limit set by WHO [31]. Since the concentrations of these heavy metals are greater than the recommended standards, it is therefore suggested that:

i. Consumption of food cultivated from this area should be discouraged.
ii. Waste disposal should be monitored and controlled at the farmland.
iii. The people in Gashua community should be educated on health risk associated with human exposure to heavy metals to prevent further pollution.
iv. There is need to study the concentration of such heavy metals in plants, vegetables, animals and any other source that directly or indirectly link to the source of food of the populace.

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