



## Heavy Metals Seasonal Variation in Soil Near Jakara River, Kano State, Nigeria

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Received on: April, 2024

Revised and Accepted on: May, 2024

Published on: July, 2024

### ABSTRACT

Many food crops have the potential to absorb substantial amounts of heavy metals while thriving in contaminated soil. Wastewater irrigation, excessive use of agrochemicals, air deposits and other anthropogenic activities stirring excessively around the Jakara River continue to stock the soil in the vicinity of the river with poisonous heavy metals. The food crops produced along the river remain the vehicle for transmitting those heavy metals to humans. The objective of the research is to determine the effect of season and location on the concentrations of Pb, Cd, Ni, Co, Cr and Hg in the soil around Jakara River. Composite soil samples were collected from Airport Road, Jaba and Kumantaka monthly for 12 months from January to December 2022. The soil samples were digested and subjected to heavy metals analysis using an atomic absorption spectrophotometer. The results revealed that Pb, Cd, Ni, Co and Cr are present in all the soil samples collected during the research period. The highest concentration of Pb was found in November, Cd in March, Ni and Co in December and Cr in October. Soil samples collected from Airport Road have the highest accumulation of Pb, Ni and Co and those collected from Jaba have the highest accumulation of Cd and Cr. The Cr content of soil samples collected from Jaba exceeded the WHO permissible limit.

**Keywords:** Heavy metals, Kano, River Jakara, soil

### 1.0 INTRODUCTION

Anthropogenic activities and natural processes continue to stock agricultural soil with toxic heavy metals such as cadmium, lead, arsenic, mercury and chromium (Abdullahi *et al.*, 2023; Priya *et al.*, 2023). Urbanisation and industrialisation account for the massive release of HMs into the environment (Dong *et al.*, 2023). Irrigation using wastewater is also among the leading causes of incessant HM accumulation in agricultural land (Abdullahi *et al.*, 2023). HM are generally non-biodegradable and their toxicity depends to a great extent on the soil's physical, chemical and biological properties (Rashid *et al.*, 2023).

HM contamination can adversely disrupt the food chain, affect soil microbiology and subsequently interrupt physiological and biochemical processes in both plants and animals (Abdullahi *et al.*, 2021a; Priya *et al.*, 2023; Rashid *et al.*, 2023). Crop health and yield can be detrimental when grown in a contaminated field (Haddad *et al.*, 2023).

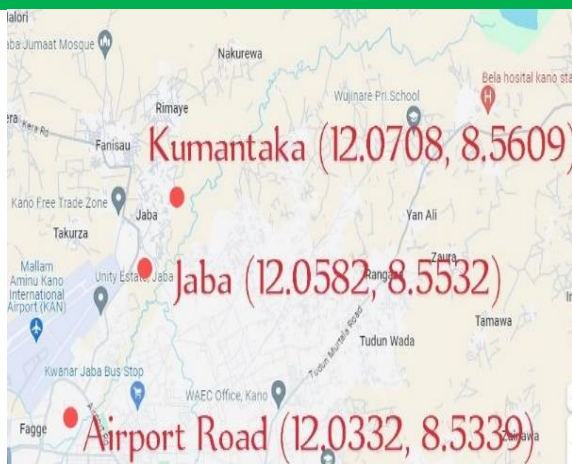
Prolonged use of untreated wastewater in irrigating agricultural soil causes serious damage to the environment, food crops and human health (Emmanuel *et al.*, 2024; Oubane *et al.*, 2021). The continuous discharge of untreated effluent, vehicular release, metal and plastic scrap processing residues, local dyeing and

tanning activities, atmospheric deposition, and abuse of agrochemicals by farmers continue to pollute the water in Jakara River and the surrounding soil with hazardous heavy metals (Abdullahi *et al.*, 2021b; Mshelia, 2024). Excessive use of agrochemicals by farmers producing crops along the Jakara River intensifies the heavy metal contamination (Abdullahi *et al.*, 2020). Massoud *et al.* (2019) reported that extreme use of fertiliser and manure can affect soil HMs content. Vegetables produced in the soil near the Jakara River were observed to significantly increase the level of heavy metals in the blood of Albino rats, also causing a decline in the Heart, Kidney, and Pancreas mass (Muktar *et al.*, 2021). The main objective of the research is to determine the effect of season and location on the concentrations of Pb, Cd, Ni, Co, Cr and Hg in the soil samples collected around Jakara River.

### 2.0 METHODOLOGY

#### 2.1 Study Area/Samples Collection

Composite soil samples were collected from Airport Road, Jaba and Kumantaka from January to December 2022 at monthly intervals. The last two sampling sites were situated after *Magami*; a confluence where the Getsi River joined the Jakara River. The Getsi River is predominantly carrying industrial effluents from Bompai.



**Figure 1: Sampling Locations along the Jakara River**

### 2.2 Samples Preparation/HM Determination

Soil samples were air-dried, grounded and sifted through a 2 mm aperture sieve to obtain fine particles. The soil samples were digested using a mixture of HNO<sub>3</sub>, HCl, and HClO<sub>4</sub> in the ratio 5:1:1 (v/v/v) (Liu *et al.*, 2020).

The concentrations of Pb, Cd, Ni, Co, Cr and Hg in the soil samples were determined using an atomic absorption spectrophotometer (PerkinElmer PinAAcle 900H).

### 2.3 Statistical Analysis

Statistical Analysis was conducted using Statistical Package for Social Science (SPSS, version 20.0 for Windows) Data was analysed using Repeated Measures ANOVA and means were separated using LSD. Values were presented as Mean±SE.

### 3.0 RESULTS AND DISCUSSION

#### Effect of season on the concentrations of Pb, Cd, Ni, Co, Cr and Hg in the soil along Jakara River

The results for the monthly variation of Pb, Cd, Ni, Co, Cr and Hg in soil samples are presented in Table 1. Values are the Mean±SE of three samples (analysed in triplicates). Means in the same row with different superscripts differed significantly at a 5 % level of significance.

Pb, Cd, Ni, Co and Cr were detected in all the soil samples collected during the research period. Hg was not detected in all the 36 samples collected, this is an indication that the soil along the Jakara River is free from Hg or the Hg presence is below the detection limit.

The concentrations of Pb in the soil ranged from 24.00 to 29.43 mg/kg. The lowest Pb concentration (24.00 mg/kg) was recorded in soil samples collected in January while the highest Pb concentration (29.43 mg/kg) was recorded in soil samples collected in November

**Table 1: Effect of Sampling Time on Heavy Metal Contents in Soil Samples Collected from Jakara River (N=36)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean	PL
<b>Pb</b>	24.00 <sup>a</sup> ±0.18	25.32 <sup>b</sup> ±0.22	28.91 <sup>c</sup> ±0.18	27.48 <sup>d</sup> ±0.22	26.49 <sup>e</sup> ±0.17	25.72 <sup>b</sup> ±0.10	24.95 <sup>b</sup> ±0.19	25.29 <sup>b</sup> ±0.21	28.01 <sup>d</sup> ±0.10	26.47 <sup>e</sup> ±0.18	29.43 <sup>c</sup> ±0.16	26.33 <sup>c</sup> ±0.14	<b>26.53</b>	<b>85</b>
<b>Cd</b>	1.73 <sup>a</sup> ±0.02	1.75 <sup>a</sup> ±0.01	1.89 <sup>b</sup> ±0.01	1.68 <sup>c</sup> ±0.01	1.77 <sup>a</sup> ±0.01	1.77 <sup>a</sup> ±0.01	1.71 <sup>ac</sup> ±0.01	1.72 <sup>a</sup> ±0.01	1.73 <sup>a</sup> ±0.02	1.76 <sup>a</sup> ±0.01	1.79 <sup>a</sup> ±0.01	1.71 <sup>ac</sup> ±0.02	<b>1.75</b>	<b>0.8</b>
<b>Ni</b>	12.29 <sup>a</sup> ±0.08	12.76 <sup>b</sup> ±0.11	12.87 <sup>b</sup> ±0.0.15	12.67 <sup>b</sup> ±0.16	11.49 <sup>c</sup> ±0.07	11.43 <sup>c</sup> ±0.08	12.46 <sup>a</sup> ±0.11	10.50 <sup>d</sup> ±0.06	10.48 <sup>d</sup> ±0.10	11.77 <sup>c</sup> ±0.09	12.82 <sup>b</sup> ±0.03	13.21 <sup>c</sup> ±0.08	<b>12.06</b>	<b>35</b>
<b>Co</b>	3.83 <sup>a</sup> ±0.10	4.11 <sup>b</sup> ±0.06	4.13 <sup>b</sup> ±0.09	3.74 <sup>a</sup> ±0.07	3.66 <sup>a</sup> ±0.12	3.79 <sup>a</sup> ±0.15	3.19 <sup>a</sup> ±0.09	2.39 <sup>d</sup> ±0.04	2.63 <sup>d</sup> ±0.33	3.37 <sup>a</sup> ±0.06	3.70 <sup>a</sup> ±0.10	4.59 <sup>c</sup> ±0.05	<b>3.59</b>	<b>50</b>
<b>Cr</b>	72.99 <sup>a</sup> ±0.30	77.42 <sup>b</sup> ±0.37	77.81 <sup>b</sup> ±0.27	72.31 <sup>a</sup> ±0.43	74.83 <sup>c</sup> ±0.35	77.71 <sup>b</sup> ±0.18	68.44 <sup>d</sup> ±0.22	56.92 <sup>e</sup> ±0.32	66.54 <sup>f</sup> ±0.35	82.22 <sup>g</sup> ±0.41	76.93 <sup>b</sup> ±0.30	78.62 <sup>b</sup> ±0.38	<b>73.56</b>	<b>100</b>
<b>Hg</b>	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<b>ND</b>	<b>0.8</b>

**Key:** **PL:** <sup>1</sup>FAO/WHO Permissible limit in Soil adopted from Ogundele *et al* (2015)**ND:** Not detected**Note**

- Data was analysed using Repeated Measures ANOVA and means were separated using LSD
- Values are Mean±SE of 9 measurements
- Mean in the same row with different superscripts differed significantly at a 5 % level of significance.



Pb in the soil was found to have an annual mean content of 26.53 mg/kg. It was discovered that the monthly mean Pb contents in all soil samples were lower than the 85 mg/kg WHO recommended threshold. The statistical analysis results indicate that, at the 5% level of significance, the mean concentrations of lead in the samples taken in February, June, July, and August were statistically identical. Analysis of the data showed significant variations in the Pb level of the soil over the study period.

The Cd content of the soil samples ranged from 1.68 to 1.89 mg/kg. The highest concentration (1.89 mg/kg) was recorded in soil samples collected in March and the lowest concentration (1.68 mg/kg) was recorded in soil samples taken in April.

The annual mean concentration of Cd in the soil was 1.75 mg/kg. The concentrations of Cd observed in all the soil samples exceeded the WHO limit of 0.8 mg/kg. Results for monthly mean separation show no significant difference (at a 5 % level of significance) between the Cd contents of the soil samples collected in January, February, May, June, July, August, September, October, November and December. Unlike in the soil Pb content, consistent values were observed in soil Cd content for 10 months.

The Ni concentrations in the soil samples ranged from 10.48 to 13.21 mg/kg. The highest concentration (13.21 mg/kg) was recorded in soil samples collected in December and the lowest concentration (10.48 mg/kg) was recorded in samples collected in September. The annual mean concentration of Ni in the soil samples was found to be 12.06 mg/kg. The Ni contents of all the soil were found to be below the WHO permissible limit of 35 mg/kg. The results for statistical analysis revealed no significant difference between Ni soil contents between the samples collected in February, March, April and November. Also, in soil samples collected between May, June and October.

Co concentrations in soil samples ranged from 2.39 to 4.59 mg/kg. The highest concentration (4.59 mg/kg)

was observed in the soil samples collected in December while the lowest Co concentration (2.39 mg/kg) was observed in the soil samples collected in September. The Co content determined in all the soil samples is far below the WHO recommended value of 50 mg/kg. The results for mean separation revealed no statistical difference in the Co content between samples collected in January, April, May, June, July, October and November. Also, samples collected between February and March, and August and September.

Cr was detected in all 36 soil samples collected during the 12-month study. The concentrations of Cr ranged from 56.92 to 82.22 mg/kg. The highest Cr content (82.22 mg/kg) was found in the soil samples collected in October and the lowest content (56.92 mg/kg) was found in the soil samples collected in August. The annual mean concentration of the Cr in soil samples was found to be 73.56 mg/kg. The concentrations of Cr in the soil samples fall below the WHO permissible limit of 100 mg/kg. The results for statistical analysis show no significant difference at a 5 % level of significance in the Cr content of soil samples collected in February, March, June, November and December. Likewise, in the soil samples collected in January and April. A significant difference was observed between samples collected in August, September and October and samples collected in the remaining months.

The highest accumulation of Pb was found in November, Cd in March, Ni and Co in December and Cr in October. The lowest concentration of Pb was found in January, Cd in April, Ni and Co in September and Cr in August.

Seasonal variation and environmental factors can manipulate the interaction between various HMs and between HM and other chemicals (Abdullahi *et al.*, 2021a; Niu *et al.*, 2021). The seasonal variation in the soil HM can be attributed to these since these factors can be influenced by season. Other factors compiled by Abdullahi *et al.* (2021a) include age and texture of the soil, organic matter and pH of the soil, redox potential, soil microorganisms and soil water level.

**Table 2: Effect of Sampling Location on Heavy Metal Contents in Soil Samples Collected from Jakara River (N=36)**

Location	Pb	Cd	Ni	Co	Cr	Hg
AR	33.38 <sup>a</sup> ±0.10	1.61 <sup>b</sup> ±0.01	12.83 <sup>a</sup> ±0.03	4.38 <sup>a</sup> ±0.09	67.35 <sup>b</sup> ±0.21	ND
JB	30.00 <sup>b</sup> ±0.10	2.06 <sup>a</sup> ±0.01	12.43 <sup>a</sup> ±0.03	3.96 <sup>b</sup> ±0.09	113.33 <sup>a</sup> ±0.21	ND
KM	16.22 <sup>c</sup> ±0.10	1.58 <sup>c</sup> ±0.01	10.93 <sup>c</sup> ±0.03	2.45 <sup>c</sup> ±0.09	40.00 <sup>c</sup> ±0.21	ND
PL	85	0.8	35	50	100	0.8

**Key:** AR: Airport Road  
 JB: Jaba  
 KM: Kumantaka  
 PL: FAO/WHO Permissible limit in soil adopted from Ogundele *et al* (2015)  
 ND: Not Detected

**Note:**

- Data was analysed using Repeated Measures ANOVA and means were separated using LSD.



- Values are Mean $\pm$ SE of 36 measurements.
- Mean in the same column with different superscripts differed significantly at 5 % level of significance.

The results for the effects of location on the variation of Pb, Cd, Ni, Co, Cr and Hg in the soil samples are presented in Table 2. Pb was detected in all 36 soil samples collected. Mean concentrations of Pb ranged between 16.22 to 33.38 mg/kg. The highest concentration (33.38 mg/kg) was recorded in samples collected from Airport Road and the lowest concentration (16.22 mg/kg) was recorded in samples collected from Kumantaka. The concentrations of Pb in soil samples collected from the three locations vary statistically at a 5 % level of significance. The Pb content in the soil of the three locations falls below the WHO permissible limit in agricultural soil.

Cd was also detected in all the soil samples collected during the period of the research. Cd concentrations ranged between 1.58 to 2.06 mg/kg. The highest concentration (2.06 mg/kg) was observed in the soil samples collected from Jaba and the lowest concentration (1.58 mg/kg) was observed in soil samples collected from Kumantaka. Cd concentrations above the WHO permissible limit (0.8 mg/kg) were recorded in all the locations. Results for statistical analysis revealed statistical differences in the Cd content of the soil samples collected from the three locations.

Ni content of the soil sample ranged from 10.93 to 12.83 mg/kg. The highest concentration (12.83 mg/kg) was found in soil samples collected from Airport Road and the lowest concentration (10.93 mg/kg) was found in soil samples collected from Kumantaka. Results for statistical analysis show no significant difference at a 5 % level of significance between soil samples collected from Airport Road and those collected from Jaba. Soil samples collected from Kumantaka differed statistically from the soil samples collected from the remaining two locations. Ni concentration below WHO permissible limits of 35 mg/kg was observed in all the locations.

Co content in the soil samples was found in the range of 2.45 to 4.38 mg/kg. The highest concentration (4.38 mg/kg) was found in the soil samples collected from Airport Road and the lowest concentration (2.45 mg/kg) was found in the soil samples collected from Kumantaka. The Co content of the soil in the three locations differed statistically at a 5 % level of significance. The concentration of the Co in the soil samples from the three locations was found to be below the WHO recommended value of 50 mg/kg.

Cr concentrations in the soil samples ranged from 40.00 to 113.33 mg/kg. The highest concentration (113.33 mg/kg) was found in soil samples collected from Jaba and the lowest concentration (40.00 mg/kg) was found in samples collected from Kumantaka. The

Co content of the soil in the three locations differed statistically at a 5 % level of significance. The Cr content of soil samples collected from Jaba exceeded the WHO permissible limit of 100 mg/kg while the Cr concentration in the soil from Airport Road and Kumantaka fell below the WHO permissible limit. Common factors that can cause seasonal and space variation in the soil HM include patterns of fertilizer and pesticide application, surface runoff and sewage irrigation (Zhang and Wang, 2020). The influence of fertilisation can be supported by the findings of Liu *et al.* (2022) who reported a positive correlation between soil nutrients and soil HMs content.

Wastewater irrigation, agrochemicals and atmospheric deposits stock up the soil around the river with dangerous levels of HMs (Dawaki *et al.*, 2015). Farmers around the river are using both inorganic and organic fertilisers (Abdullahi *et al.*, 2020). The findings of Massoud *et al.* (2019) confirmed that excessive use of fertilizer and contaminated manure increases soil HMs content. The practice of using urban wastes as compost by urban farmers in Kano (Lewcock, 1995) can be an additional source of HMs to the agricultural soil. Adamu (2019) reported that the dumpsites around the Jakara River are highly contaminated with dangerous HMs.

The concentrations of Pb, Cr and Ni reported by Dawaki *et al.* (2014) in soil samples along the Jakara River exceeded what was reported in this research. Also, the concentrations of Cd, Cr and Ni reported by Yusuf (2010).

The higher concentrations of HMs found in the soil samples collected from Jaba are due to industrial effluents from Bompai industries which are discharging into the Jakara River through *Getsi* tributaries. This can be supported by the findings of Binns *et al.* (2003), Bichi and Halliru (2010) and Tasiu and Sule (2020). The chronology of the citations above indicates that over time *Getsi* tributary is the alpha contributor of HM contamination among all the tributaries discharging into the Jakara River.

It was observed that the concentrations of HM in the soil are affected by season. This agreed with the findings of Mohammed and Olowolafe (2020) and Imam (2012). Mohammed and Olowolafe (2020) attributed seasonal variation in the soil HMs content to the leaching, run-off and dissolution that commonly occur during the rainy season.

The higher concentrations of HM reported in Airport Road and Jaba can be associated with urbanisation. Results of the meta-analysis conducted by Abdullahi *et al.* (2021c) associated HM contamination with urbanisation, industrialisation and population. A large volume of wastewater generated through industrial and



domestic activities is used for irrigation in urban agriculture (Mehmood *et al.*, 2019). Urban soil can be contaminated with HMs due to intense industrial activities that are taking place in many cities (Deng *et al.*, 2020; Margenat *et al.*, 2018; Weber *et al.*, 2019). Atmospheric deposits through fossil fuel combustion and dust from contaminated areas intensify soil contamination in urban areas (Weber *et al.*, 2019).

The soil in Kumantaka is generally characterised by low levels of HMs contamination. Being an outskirts, Kumantaka is expected to be less contaminated. Huang *et al.* (2019) reported low levels of HM contamination in agricultural fields far away from cities. Dawaki *et al.* (2015) reported a downstream decrease in Pb, Cd, Cu, Ni and Zn concentrations in soil samples collected along the Jakara River. Going by the above, the structural development that is taking over the urban farms along the Jakara River can be considered a blessing in disguise. This will force the farmers to occupy spaces in peri urban areas along the Jakara River, where the soil is less contaminated and believed to be safer for food production.

The concentrations of Cd in the soil samples collected from the three locations and Cr in the soil samples collected from Jaba exceeded WHO permissible limits. These tallied with what was reported by Dawaki and Shu'aibu (2013), Adamu (2019) and Abdullahi and Mohammed (2020).

#### 4.0 CONCLUSION

The results of the study show that Pb, Cd, Ni, Co and Cr are present in all the soil samples collected during the research period. Hg was not detected in all the 36 samples collected, this is an indication that the soil along the Jakara River is free from Hg or the Hg presence is below the detection limit. The highest concentration of Pb was found in November, Cd in March, Ni and Co in December and Cr in October. The lowest concentration of Pb was found in January, Cd in April, Ni and Co in September and Cr in August. The monthly means of all the HMs were found to be below allowable limits. Soil samples collected from Airport Road have the highest accumulation of Pb, Ni and Co and those collected from Jaba have the highest accumulation of Cd and Cr. Soil from Kumantaka has the lowest concentrations of all the studied HMs. It is only the Cr content of soil samples collected from Jaba that exceeded the WHO permissible limit. Overall, the results of the findings revealed that the concentrations of Pb, Cd, Ni, Co and Cr in the soil near Jakara River are greatly influenced by year season and location.

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