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HEAVY METAL SEASONAL VARIATION IN IRRIGATION WATER ALONG JAKARA RIVER, KANO STATE, NIGERIA

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ABSTRACT

The water in the Jakara River is a blend of domestic sewage from the north and central parts of the Kano metropolis and industrial effluent from the Bompai Industrial Estate. The wastewater in the river is the main source of irrigation water used by urban farmers in the city. Wastewater contaminated with heavy metals can be of public health concern when used for irrigation. The increasing concentration of several metals in soil and waters due to the Industrial Revolution has created an alarming situation for human life and aquatic biota. The study aims to determine the effect of season and location on the concentrations of Pb, Cd, Ni, Co, Cr and Hg in the irrigation water from the Jakara River. Water samples were collected from three locations monthly for 12 months from January to December 2022. The water samples were digested and subjected to heavy metals analysis using an atomic absorption spectrophotometer. Results of irrigation water analysis show that Pb and Cr are present in all the 36 samples taken during the study period. Co and Hg were not detected in all the samples taken during this period. Cd and Ni were not detected during September sampling, additionally, the concentrations of Pb and Cr detected in September were also the lowest. The highest concentrations were found in samples collected from Jaba and Kumantaka. It is only Pb concentration that exceeded the FAO/WHO permissible limit. Water samples collected in September at Airport Road possess the lowest heavy metals contamination. It is fortunate that the concentrations of most of the studied heavy metals fall below the FAO/WHO recommended threshold.

Keywords: Wastewater, Irrigation, Heavy Metal, Kano, Nigeria

INTRODUCTION

Environmental contamination has become a global challenge and poses a serious risk to humans and animals (Ekevwe and Bartholomew, 2015). The use of untreated wastewater from domestic sewage and industrial effluent for irrigation is rising in developing countries. Wastewater contaminated with heavy metals can be of public health concern when used for irrigation (Dike and Oniye, 2016). The increasing concentration of several metals in soil and waters due to the Industrial Revolution has created an alarming situation for human life and aquatic biota (Dixit *et al*., 2015). Their random release into water and soil is a major health concern globally, as they cannot be broken down into non-toxic forms and therefore have long-lasting effects on the ecosystem (Ali *et al*., 2013; Dixit *et al*., 2015).

The use of wastewater for urban and suburb agriculture in Kano is responsible for heavy metal contamination in vegetables, the contaminated wastewater used in irrigation deposits heavy metals in the irrigation sites which are then later absorbed by the plants and transported to their edible portion (Dawaki *et al*., 2013). Vegetables irrigated with contaminated water can accumulate heavy metals in their edible portions (Dike and Oniye, 2016). Certain crops such as amaranth, lettuce, carrot and radish, can accumulate heavy metals such as Cd, Cu, Mn, Pb and Zn in their tissues, uptake is increased in plants that are grown in areas with increased soil contamination (Intawongse and Dean, 2006).

Year seasons were reported to significantly affect water quality. Ganiyu *et al.* (2018) reported seasonal variation in the quality of groundwater used for irrigation. A similar finding was also reported by Dey *et al.* (2021) in pond water. A Significant variation in nitrate and phosphate concentration was also observed between seasons in surface water samples (Dike *et al*., 2010). Changes in the level of contaminants were also observed by Bexfield and Jurgens (2014) in the water of public supply wells.

Jakara River is the main source of water for urban agriculture in Kano (Sanda *et al*., 2016). The river is economically important to Kano State and the farming activities along the river are lucrative (Shu'aib *et al*., 2017). The principal objective of the study is to determine the effect of season and location on the concentrations of Pb, Cd, Ni, Co, Cr and Hg in the irrigation water samples collected from the Jakara River.

MATERIALS AND METHODS

Three locations along the river were selected for water sampling. Contamination sources reported by Abdullahi *et al.* (2021) shows that different locations along the river can differ in heavy metals composition and concentration. Water samples were collected from these locations monthly for 12 months from January to December 2022. Two liters, acid-treated polypropylene jars were used for samples collection. Water samples were collected at approximately 0.5 meter depth. The designated locations are Airport Road, Jaba and

Kumantaka in Kano metropolis, Kano State, Nigeria. It was believed by many researchers that contaminations before *Magami*; a confluence where the *Getsi* tributary joins the Jakara River, are mostly organic since there is no discharge from the industrial source up to that point. The *Getsi* tributary is supplying the Jakara River with effluent from the Bompai Industrial Area. The first sampling location (Airport Road) is before the confluence, while the remaining two locations (Jaba and Kumantaka) are after the confluence.

Water samples were digested according to the procedure described by Gerenfes and Teju (2018). The samples were digested using NHO_3 and HCl (1:2.5). Digested samples were filtered through Whatman filter paper No.42 and diluted with deionized water.

The concentrations of Pb, Cd, Ni, Co, Cr and Hg in the irrigation water and soil samples were determined using an atomic absorption spectrophotometer (PerkinElmer PinAAcle 900H) and the results were reported as Mean±SD of triplicate measurements.

RESULTS AND DISCUSSION

Effect of Season on the Concentrations of Pb, Cd, Ni, Co, Cr and Hg in the Irrigation Water from Jakara River

The results for seasonal variation of Pb, Cd, Ni, Co, Cr and Hg in the irrigation water samples are presented in Table 1. Values are the Mean±SE of three samples (analysed in triplicates). Data was analysed using Repeated Measures ANOVA and means were separated using LSD. Mean in the same row with different superscripts differed significantly at a 5 % level of significance.

The monthly (except for September) mean concentrations of Pb in the irrigation water samples exceeded the FAO/WHO recommended level of 0.06 mg/L. Also, the annual mean was found to be 0.144 mg/L. The statistical results for mean separation indicated no statistical difference (at 5 % level of significance) between samples collected in January, February, March, June, July, October and December. Also, between samples collected in April and November. The highest concentration of Pb was observed in May, which was believed to be the driest month in Kano, and the lowest concentration of Pb was reported in September.

Cd was detected in all the irrigation water samples, except that collected in September. The concentrations of Cd reported were all below the FAO/WHO recommended level of 0.01 mg/L. Also, the annual mean was determined to be 0.002 mg/L. The highest concentration (0.004 mg/L) of Cd was observed in water samples collected in February while a concentration below the detection limit was observed in September. Results for statistical analysis of the data revealed no significant difference (at a 5 % level of significance) in Cd concentrations in the samples collected between January, April, May and August, and also, between March, November and December. The Cd concentrations in the water samples collected in June, July and October also show to statistical difference at a 5 % level of significance.

Similar to Cd, Ni was also detected in all the irrigation water samples, except that collected in September. The concentration of Ni in all 36 irrigation water samples falls below the FAO/WHO recommended level of 1.40 mg/L. Also, the annual mean was calculated to be 0.039 mg/L. The highest Ni concentrations (0.054 mg/L) were recorded in April while the lowest (below detection) was observed in September. Results for mean separation show that samples collected in January, February, March, November and December are statistically the same at a 5 % level of significance. No statistical difference was also observed in the samples collected between April, May and June.

Cr was detected in all the samples collected during the research period. The concentrations of Cr in the irrigation water samples range between 0.068 to 0.172 mg/L. The lowest concentration (0.068 mg/L) was recorded in September and the highest concentration (0.172 mg/L) was recorded in April. The annual mean for Cr concentration in the irrigation water was found to be 0.117 mg/L. The monthly means and annual mean of Cr concentration in the irrigation water fall below the FAO/WHO recommended value of 0.55 mg/L. The results for statistical analysis show that the concentrations of Cr in the samples collected in January, February, March, July, October and November are statistically the same at a 5 % level of significance. The same applies to samples collected in April and May, and August and December.

The complete absence of Co and Hg in all the 36 irrigation water samples taken in 12 12-month period is a clear indication that the potential HM-contamination sources in Kano do not either contain these HM or are present in quantity below their detection limit. Additionally, both Co and Hg were also not reported by other researchers. Pb and Cr which are potential carcinogens are omnipresent throughout the research period.

Another important factor that affects the concentrations of HM in the irrigation water along Jakara River is the availability of tap water from the municipal supply. Rainfall in Kano lasted for only four months (June-September). The only source of water for the river in the remaining eight months is the wastewater from domestic use and effluent from the Bompai industries. If the municipal supply is not adequate the stream use to shrink, and the reduction in the volume will increase the HMs concentration in water, increasing their availability and their potential to contaminate the farmland along the Jakara River. An adequate municipal supply of tap water can do the opposite.

Table 1: Effect of Season on Heavy Metal Contents in Water Samples Collected from Jakara River (N=36)

Heavy Metal	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean	PL
Pb	$0.093^{a}\pm0.00$	$0.094^{a}\pm0.00$	$0.099^{a}\pm0.01$	$0.124^{b}\pm0.01$	$0.144^{c}\pm0.00$	$0.112^{a}\pm0.01$	$0.091^{a}\pm0.00$	$0.083^{d}\pm0.00$	$0.057^{e}\pm0.01$	$0.111^{a}\pm0.01$	$0.129^{b}\pm0.01$	$0.098^{a}\pm0.01$	0.103	0.06
Cd	$0.003^{a}\pm0.00$	$0.004^{b}\pm0.00$	$0.002^{c}\pm0.00$	$0.003^{a}\pm0.00$	$0.003^{a}\pm0.00$	$0.001^{d}\pm0.00$	$0.001^{d}\pm0.00$	$0.0003^{a}\pm0.00$	ND	$0.001^{d}\pm0.00$	$0.002^{c}\pm0.00$	$0.002^{c}\pm0.00$	0.002	0.01
Ni	$0.044^{a}\pm0.00$	$0.041^{a}\pm0.00$	$0.043^{a}\pm0.00$	$0.054^{b}\pm0.00$	$0.050^{b}\pm0.00$	$0.050^{b}\pm0.00$	$0.037^{c}\pm0.00$	$0.025^{d}\pm0.00$	ND	$0.036^{c}\pm0.00$	$0.046^{a}\pm0.00$	$0.042^{a}\pm0.00$	0.039	1.40
Co	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		0.05
Cr	$0.107^{a}\pm0.00$	$0.107^{a}\pm0.00$	$0.102^{a}\pm0.00$	$0.172^{b}\pm0.00$	$0.161^{b}\pm0.01$	$0.144^{c}\pm0.01$	$0.108^{a}\pm0.00$	$0.098^{d}\pm0.00$	$0.068^{e}\pm0.01$	$0.120^{a}\pm0.01$	$0.117^{a}\pm0.01$	$0.097^{d}\pm0.00$	0.117	0.55
Hg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		0.001

Key: PL: FAO/WHO Permissible limit in Irrigation Water (Chiroma *et al*., 2014)
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 5 % level of significance.

Pb and Cr were detected in all the 36 samples taken during the 12 months of sampling, Co and Hg were not detected in all the samples taken during the period of the research. Cd and Ni were not detected during September sampling, additionally, the concentrations of Pb and Cr detected in September were also the lowest. The absence of Cd and Ni and the lowest concentrations of Pb and Cr recorded in September can be attributed to the dilution resulting from volume increase from rainfall, which traditionally reached a peak in August.

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

Location	Pb	Cd	Ni	Co	Cr	Hg
AR	$0.100^{b}\pm0.00$	ND	$0.034^{c}\pm0.00$	ND	$0.028^{c}\pm0.00$	ND
JB	$0.121^{a}\pm0.00$	$0.001^{b}\pm0.00$	$0.040^{b}\pm0.00$	ND	$0.052^{b}\pm0.00$	ND
KM	$0.087^{c}\pm0.00$	$0.004^{a}\pm0.00$	$0.043^{a}\pm0.00$	ND	$0.270^{a}\pm0.00$	ND
PL	0.06	0.01	1.40	0.05	0.55	0.001

Key: AR: Airport Road
JB: Jaba
KM: Kumantaka
PL: [1]FAO/WHO Permissible limit in Irrigation Water (Chiroma *et al*., 2014)
ND Not Detected

Note
Data was analysed using Repeated Measures ANOVA and means were separated using LSD.
Values are Mean±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 irrigation water samples are presented in Table 2. Values are the Mean±SE of 12 samples (analysed in triplicates). Data was analysed using Repeated Measures ANOVA and means were separated using LSD. Means in the same column with different superscripts differed significantly at a 5 % level of significance.

Co and Hg were not detected in all the water samples collected from the three sampling locations during the study period. Cd was detected in all the water samples collected from Airport Road.

The highest concentration of Pb was recorded in water samples collected from Jaba and the lowest was in the samples collected from Kumantaka. The highest Pb concentration (0.121 mg/L) was recorded in water samples collected from Jaba and the lowest concentration (0.087 mg/L) was recorded in samples taken from Kumantaka. The substantial amounts of Pb recorded in the samples collected from Airport Road is an indication that the domestic wastewater also contributing to Pb contamination in the river. The results of statistical analysis show that the concentrations of Pb in the three locations differed significantly at a 5 % level of significance. The mean concentrations recorded in all three locations exceeded the FOA/WHO recommended permissible limit of 0.06 mg/L.

Cd was only detected in water samples collected in Jaba and Kumantaka, a clear indication that the major source of Cd contamination to the Jakara River is effluent from the Getsi tributary which is supplying water from Bompai Industrial Estate. The highest mean concentration (0.004 mg/L) of Cd was observed in samples taken from Kumantaka and concentrations below detection limit were observed in samples taken from Airport Road. The mean concentrations of Cd in Jaba and Kumantaka differed statistically at a 5 % level of significance and are far below the FOA/WHO recommended limit of 0.01 mg/L.

Ni was detected in the water samples collected from three locations. The lowest concentration (0.034 mg/L) of Ni in water samples collected from Airport Road is an indication of the least contribution from domestic sources. The higher concentrations of 0.040 mg/L and 0.043 mg/L were recorded in water samples collected from Jaba and Kumantaka respectively suggesting higher Ni contamination from industrial waste. The mean concentrations of Ni observed in the water samples collected from the three locations deferred statistically at a 5 % level of significance. The mean concentrations of Ni along the river are far below the FOA/WHO recommended limit of 1.40 mg/L.

Cr was detected in all the samples collected from the three locations. The lowest concentration (0.028 mg/L) was reported in samples collected from Airport Road and the highest concentration (0.270 mg/L) was reported in water samples collected from Kumantaka. Similar to Ni, Cr contamination in the irrigation water is commonly sourced from industrial discharge. The Cr content of the water sample collected from the three locations falls below the FAO/WHO recommended limits of 0.55 mg/L. Results for statistical analysis show a significant difference in the concentrations of Cr between the three locations at a 5 % level of significance.

Pb and Cr were detected in all the 36 samples taken during the 12 months of sampling, Co and Hg were not detected in all the samples taken during the period of the research. Cd and Ni were not detected during September sampling, additionally, the concentrations of Pb and Cr detected in September were also the lowest. The absence of Cd and Ni and the lowest concentrations of Pb and Cr recorded in September can be attributed to the dilution resulting from volume increase from rainfall, which traditionally reached a peak in August.

The ideal sources of pollution in the Jakara River are sewage, industrial waste and agricultural imputes (Mustapha and Aris, 2011). Household effluent strongly influences the quality of the water by depositing a large amount of organic contaminants (Mustapha, 2012). Domestic and industrial wastes are discharged into the river without treatment (Ibrahim and Ibrahim, 2017). Local dyeing in some areas of Kano and untreated wastewater from proximate industries are among the prominent sources of heavy metal contamination (Ekevwe and Bartholomew, 2015). Vehicular releases, solid wastes and agrochemicals also contribute to contamination in addition to wastewater (Dawaki *et al*., 2013).

Dawaki *et al*. (2013) reported Pb, Cd and Cr concentrations far above what was observed in this research. Imam (2012) also reported higher concentrations of Cr and Pb in water samples collected in 2009. The data reported by Mukhtar (2016) shows a substantial reduction in the HMs content of the irrigation water when compared with what was reported by Dawaki *et al*. (2013) and Imam (2012).

Similar to this finding, Dawaki *et al*. (2015) reported variation in the concentrations of Pb, Cd, Cr, Cu, Ni and Zn along the Jakara River. Mustapha *et al*. (2012) and Agbazue *et al*. (2015) reported seasonal variations in the overall quality of the water and Mustapha and Aris (2012) opined that variation in the overall quality is determined by the HM level. Seasonal variation in the irrigation water HM contents was also reported by Imam (2012), Binns *et al*. (2003) and Badamasi (2014). Mustapha *et al*. (2013) and Razali *et al*. (2020) associated seasonal variation in the quality of irrigation water to agricultural activities, construction work, discharge of domestic and industrial effluents and natural processes such as runoffs and erosion.

Unlike what was observed in this study, the concentrations of HM in the irrigation water reported by researchers (Agbazue *et al*., 2015; Dawaki *et al*., 2013; Ekevwe and Bartholomew, 2015; Imam, 2012) in previous years exceeded WHO permissible limits. This significant reduction in the HM concentrations can be attributed to the shutdown of many companies in Bompai and the substantial reduction of local dyeing in Kano.

It can be summed from the above that industrial effluent from Bompai is the main source of Pb, Cd, Ni and Cr contamination in Jakara River since higher concentrations of these HMs were mostly found after Getsi confluence. Fortunately, it was only concentrations of Pb in the three locations that exceeded the FAO/WHO, although a Cr concentration close to the FAO/WHO permissible limit was observed in water samples collected from Jaba. Higher concentrations of Pb observed in all three locations signify contamination from both domestic and industrial sources.

CONCLUSION

Results of irrigation water analysis show that Pb and Cr are present in all the 36 samples taken during the study period. Co and Hg were not detected in all the samples taken during the period of the research. Cd and Ni were not detected during September sampling, additionally, the concentrations of Pb and Cr detected in September were also the lowest. The absence of Cd and Ni and the lowest concentrations of Pb and Cr recorded in September can be attributed to the dilution resulting from volume increase from rainfall, which traditionally reached a peak in August. Industrial effluent from Bompai is the main source of Pb, Cd, Ni and Cr contamination in the Jakara River, higher concentrations of these HMs were mostly found after the Getsi confluence. Fortunately, it was only concentrations of Pb that exceeded the FAO/WHO, although a Cr concentration close to the FAO/WHO permissible limit was observed in water samples collected from Jaba. Higher concentrations of Pb observed in all the locations signify contamination from both domestic and industrial sources. The highest accumulation of Pb was found in May, Cd in February and Ni and Cr in April. The lowest concentrations of all the studied HMs were recorded in September.

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