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ASSESSMENT OF MANGANESE LEVELS IN WASTEWATER, SOIL AND VEGETABLE SAMPLES GROWN ALONG KUBANNI STREAM CHANNELS IN ZARIA, KADUNA STATE, NIGERIA

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ABSTRACT
The concentration of manganese was determined in wastewater, soil and vegetable (carrot, lettuce, onion, spinach, cabbage, tomato and okro) samples that were collected on seasonal basis from January, 2013 to September 2014 along Kubanni stream channels in Zaria using Atomic Absorption Spectrophotometer. The results showed manganese levels in wastewater were in the range of 5.00 – 20.04 mg/L for the year 2013 and 1.08 – 5.50 mg/L in 2014; 2.10 – 15.30 mg/Kg for the year 2013 and 3.42 – 13.57 mg/Kg in 2014 for the soil while the vegetables had concentrations in the range of 4.39 – 15.04 mg/Kg for the year 2013 and 0.10 – 13.42 mg/Kg in 2014. Statistical analysis revealed no significant difference in manganese levels across the locations and seasons for wastewater, soil and vegetables analyzed at p = 0.050. Pearson correlation showed negligible (r = 0.166) relationship between manganese levels in wastewater for the year 2013 and 2014, moderate (r = 0.479) relationship was also obtained for the soil between these two years likewise, moderate (r = 0.457) relationship was obtained for vegetables cultivated in 2013 and that of 2014 respectively. Manganese concentrations obtained in this study was higher than Maximum Contaminant Levels set by Standard Organizations such as W.H.O. and F.A.O for wastewater while both soil and vegetables were within the limits set by these bodies.
Keywords: Kubanni River, Manganese level, Soil, Vegetable and Wastewater.

INTRODUCTION

Manganese has recently become a metal of global concern because of the introduction of methylcyclopentadienyl manganese tricarbonyl (MMT) as a gasoline additive. Proponents of the use of MMT have claimed that the known link between occupational manganese exposure and the development of a Parkinson's disease-like syndrome of tremor, postural instability, gait disorder and cognitive disorder has no implications for the relatively low levels of manganese exposure that would ensure from its use in gasoline (WHO, 1988). However, this argument is starkly reminiscent of the rationale given for adding lead to gasoline. Manganese, one of the most abundant metals in the earth's crust usually occurs together with iron. The most environmentally important manganese compounds are those that contain Mn^{2+}, Mn^{4+} and Mn^{7+} (ATSDR, 1992). Manganese is used principally in the manufacture of iron, steel and other alloys. Manganese (IV) oxide and other manganese compounds are used in products such as batteries, glass, and fireworks. Potassium permanganate is used as an oxidant for cleaning, bleaching and disinfection purpose (US-EPA, 1984). Manganese in the environment arises from both natural and anthropogenic source. Manganese is present in drinking water, food, soil, air, dust and alloys (Catharine *et al.,* 2011). It can be adsorbed onto soil to an extent depending on the organic content and cation exchange capacity of the soil. It may bioaccumulate in lower but not higher organisms, so that biomagnifications in food chain is not significant (ATSDR, 1992). Manganese is an essential element for many living organisms including humans. Adverse health effects can be caused by inadequate intake. Manganese deficiency in animals' exhibit impaired growth, skeletal abnormalities, reproductive deficits, ataxia of the new born and defects in lipid and carbohydrate metabolism (Hurley and Keen, 1987). Although no specific manganese deficiency syndrome has been described in humans, an association between manganese deficiency and disorders such as anaemia, bone changes in children, and lupus erythematosis has been suggested (Pier, 1975).

Modern agriculture is becoming nuisance to mankind. The insecticides, pesticides, chemical fertilizers especially nitrate and phosphate are used annually to boost agricultural production and these chemicals are leached down to the soil and eventually end up to contaminate the ground water and stream waterways and River Kubanni is equally surrounded by these types of activities which are likely to pollute the waterway (Iguisi *et al.,* 2001). The major causes of water pollution in most countries of the tropics can be linked to human activities such as sewage and refuse disposal, industrial effluents, agricultural activities, mining and quarrying activities (Olofin, 1991).

The most common source of water pollution in developing nations is domestic sewage and refuse. Iguisi *et al.* (2001) is of the opinion that several chemical elements including manganese have their origin in the decomposing high refuse dumps that is similar to pollution pattern in the catchment area of Kubanni River. Several other studies have shown that a considerable number of elements are leached from refuse dumps during rainy season into ground water and stream (Ademoroti, 1996).

MATERIALS AND METHODS

Study Area

Zaria city is in northern Nigeria on longitude 7°42˙E and latitude 11°03˙N, within the drainage of River Kubanni flowing to the south east direction through Ahmadu Bello University (Figure 1). The vegetation of the area is the savannah type with more grasses than hard wood trees. The average annual rainfall is 875mm and the temperature varies between 27 to 35°C with a relative humidity of 39% (Frederick *et al.,* 2006). The geology of the study area is composed mainly of fine grain gneisses and migmatite with some coarse-grained granitic outcrops in few places. The soil of the study area is mainly sandy-clay loam with poor infiltration because of the high clay content (Iguisi, 1997). The entire vegetation and soils of the study area have been under great anthropogenic influences which have greatly modified the entire landscape (Butu, 2013). Kubanni River is known for its human activities like farming, source of drinking water, washing and fishing. Some peasant farmers use its bank for farming throughout the year especially Sabon-gari area, here there is planting of vegetables of different varieties. This necessitates irrigated farming system to meet up with the demand for vegetables and promotes the use of wastewater, herbicides, fungicides, pesticides and fertilizers which are sources of pollutants. High population of the area coupled with the amount of waste that is indiscriminately discharged into the body of Kubanni River makes it prone for contamination which necessitates the study on the nature of vegetables consumed by people from the area. This study is aimed at ascertaining the extent to which manganese is accumulated in wastewater, soil and vegetables through man-made activities**.**

Sampling

Wastewater samples from Kubanni stream were obtained from five different sampling points on a four month basis along the stream channels for the period of two years. Sampling was conducted in the harmattan, dry and rainy seasons. Wastewater samples were collected using composite sampling in a polyethylene plastic container that were previously cleaned by washing in non-ionic detergent and then rinsed with tap water and soaked in 10% HNO_3 for 24 hours and finally rinsed with deionized water prior to usage (Ademoroti, 1996). During sampling, sample bottles used were rinsed with sampled water three times and then filled to the brim at a depth of one meter below the wastewater from each of the five designated sampling points. Wastewater sample bottles were labelled, stored in ice-blocked coolers and transported to the laboratory. While in the laboratory, they were stored in the refrigerator at about 4 °C prior to the analysis (APHA, 1998). Soil samples were collected at three depths (0-5 cm, 5-10 cm and 10-15 cm) from both sides of the river banks by using spiral auger of 2.5 cm diameter. Soil samples were randomly sampled and bulked together to form a composite sample from each designated point. They were then put in clean plastic bags, labelled and transported to the laboratory. The full grown vegetables [i.e spinach (*Amaranthus hybridus*), lettuce (*Lactuca sativa*), cabbage *(Brassica oleracea*), carrot (*Daucus carota*), okro (*Hibiscus esculentus*), onion (*Allium cepa*) and tomato (*Lycopersicon esculenetum*)] were randomly handpicked from various garden plots along Kubanni stream channels using hand gloves, bulked together to form a composite sample, wrapped in big brown envelopes, labeled accordingly and transported to the laboratory.

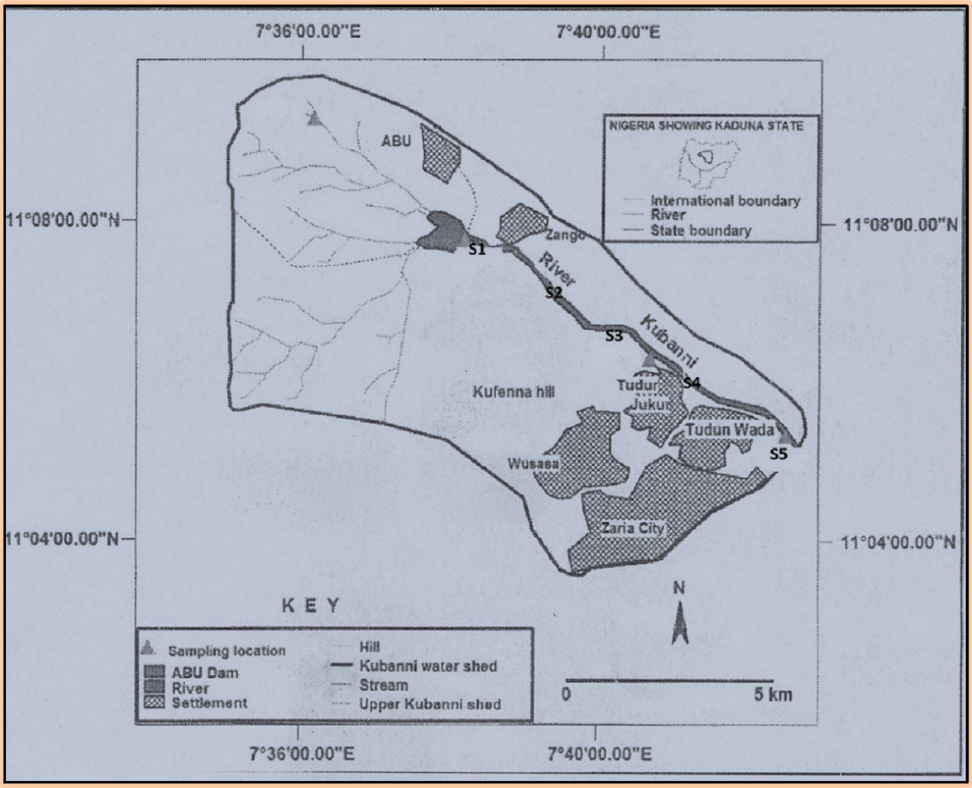

Figure 1:- Map of Sampling Locations

Sample Treatment

Wastewaters used for manganese determinations were acidified at the points of sampling with five cm^3 of concentrated HNO_3 as to avoid microbial activities on the wastewaters which might reduce the concentrations of intended manganese before analysis and they were kept in a refrigerator prior to analysis (APHA, 1998). Soil samples were air-dried, crushed and passed through two mm mesh sieve. The soil samples were then put in clean plastic bags, sealed and labelled accordingly. Each vegetable samples were washed with tap water, followed by deionized water, air dried in the laboratory, grounded to powder and sieved using 250 µm sieve (Samira *et al.,* 2009).

Digestion of Wastewater Samples for Manganese Determination

One thousand centimeter cube of each wastewater sample was transferred into a 1000 cm^3 beaker and 50 cm^3 concentrated HNO_3 was added. The beaker with the content was placed on a sand bath and evaporated down to about 20 cm^3 and this was analyzed as described by Association of Official Analytical Chemist (AOAC, 1995). Manganese concentration was determined at 280 nm wavelengths using Alpha-4 Model AAS.

Determination of Manganese in Soil Samples

Two grams of each soil sample was weighed into acid-washed glass beakers. Soil samples were digested by the addition of 20 cm^3 of aqua-regia (mixture of HCl and HNO_3 in ratio 3:1) to each soil sample and 10 cm^3 of 30 % H_2O_2 were added in small portion to avoid any possible overflow leading to loss of material from the beaker. The beakers were covered with the watch glasses and heated on a water bath for 2 hours at 90 ºC. The beakers and watch-glasses were washed with deionized water. The samples were filtered out to separate the insoluble solid from the supernatant liquid. Soil samples volume was made up to 100 cm^3 by adding deionized water to the mark levels. It was then analyzed for Mn concentration at 280 nm wavelengths using Alpha-4 Model Atomic Absorption Spectrophotometer (AAS) (AOAC, 1995).

Digestion of Vegetable Samples for Manganese Determination

Three grams of the dry sample of each vegetable sample was ashed using muffle furnace set at 450 °C on cooling, the ash was transferred to a decomposition flasks and one cm^3 of concentrated HNO_3 was added and then analyzed as described by AOAC (1995).

RESULTS

The results of manganese in wastewater, soil and vegetables analyzed were expressed in form of bar-charts using Microsoft Excel (Window 7 Professional), the results obtained were subjected to one way Analysis of Variances (ANOVA) and Pearson Product Moment Correlations (PPMC) using Statistical Package for the Social Sciences (SPSS) 20.0 version software. Null hypothesis was adopted and this was set at 95% Confidence Mean level to check if there is significant difference in the concentrations of manganese analyzed. Statistical decision for Pearson Correlation Coefficients (r) was taken as follows;

1. If 0.05 ≤ r ≤ 0.20 there is negligible relationship
2. If 0.21 ≤ r ≤ 0.40 there is low relationship
3. If 0.41 ≤ r ≤ 0.60 there is moderate relationship
4. If 0.61 ≤ r ≤ 0.80 there is substantial relationship
5. If 0.81 ≤ r ≤ 1.00 there is very high relationship (Robert, 1992)

Manganese concentrations in wastewater from Kubanni stream channel is presented in Figure 2. The concentrations determined were in the range of 5.00 – 20.04 mg/L for the year 2013. Highest level of 20.04 mg/L was obtained at Industrial area along Jos road during the harmattan season followed by 15.70 mg/L at the same sampling site but in the dry season. High levels were also observed at Kwangila (15.00 mg/L) during harmattan season, 13.75 mg/L at the same site but in the dry season, 12.70 mg/L at Tundun-wada, 12.05 mg/L at Unguwa-fulani both in the dry season whereas Sabon-gari sampling site (5.00 mg/L) showed least level of manganese. Elevated levels of manganese during the harmattan and dry seasons could be as a result of anthropogenic activities as suggested by Butu (2013). Generally, rainy season showed least levels of manganese (5.00 – 10.01 mg/L) and this could be traced to dilution effect as suggested by Chapman (1997). In 2014, the concentrations determined were in the range of 1.08 – 5.50 mg/L. Highest level of 5.50 mg/L was obtained during the rainy season at Unguwa-fulani followed by 3.97 mg/L during harmattan season at Industrial area along Jos road and this was followed by 3.41 mg/L in the rainy season at Tundun-wada sampling site while the least concentration of 1.08 mg/L during the harmattan season was observed at Sabon-gari. Generally, low levels of manganese were recorded in the year 2014 with rainy season showed highest concentrations (1.78 – 5.50 mg/L). In this period, Unguwa-fulani (5.50 mg/L) sampling site was observed with the highest level of Mn while Kwangila (1.78 mg/L) had the least concentration. Comparing the results obtained for the year 2013 with that of 2014, it was revealed from Figure 2 that harmattan season of 2013 (5.00 – 20.04 mg/L) had high concentration of manganese than harmattan season of 2014 (1.08 – 3.97 mg/L). Likewise, dry season of 2013 (7.45 – 15.70 mg/L) had high level of manganese than dry season of 2014 (1.98 – 3.04 mg/L). In the same way, rainy season of 2013 (5.05 – 10.01 mg/L) indicated high level of manganese than rainy season of 2014 (1.78 – 5.50 mg/L).

Figure 3 shows manganese levels in soil obtained from Kubanni stream channels. The concentrations determined were in the range of 2.10 – 15.30 mg/Kg for 2013. Industrial area along Jos road had highest level of 15.30 mg/Kg during the dry season followed by 12.50 mg/Kg from the same sampling site but in the harmattan season. High levels were also obtained at Kwangila sampling site (7.85 mg/Kg), 7.43 mg/Kg at Tundun-wada and 6.85 mg/Kg at Sabon-gari all these results were obtained in the dry season. Elevated levels of manganese recorded during harmattan and dry seasons could be attributed to deposition of harmattan-dusts coupled with excessive use of wastewater for irrigation as suggested by Nwadiogbu *et al*., (2013) and Abdu *et al*., (2011). Manganese showed almost the same concentrations at Kwangila (7.43 – 7.85 mg/Kg) and Tundun-wada sampling site (7.43 – 7.45 mg/Kg) from harmattan to dry seasons however least levels were obtained at Unguwa-fulani (2.35 mg/Kg) and Tundun-wada (2.10 mg/Kg) both in the rainy season. The chart showed a decline in manganese levels from dry season to rainy season as indicated in figure 3 which might be as a result of lesser use of wastewater for irrigation and dilution effects in the rainy season as suggested by Wong (1996) and Chapman (1997). In the year 2014, manganese had concentrations in the range of 3.42 – 13.57 mg/Kg. Highest level was observed at Industrial area along Jos road (13.57 mg/Kg) during the harmattan season followed by 12.01 mg/Kg at Tundun-wada in the same season and closely followed by 9.24 mg/Kg at the same sampling site but in the dry season. High concentrations were also obtained at Sabon-gari (9.35 mg/Kg), 8.43 mg/Kg at Kwangila sampling site and 7.33 mg/Kg at Unguwa-fulani all these concentrations were obtained in the harmattan season whereas Unguwa-fulani (2.94 mg/Kg) showed least level of manganese in soil. Elevated levels of manganese during harmattan and dry seasons could be as a result of prolong use of these sampling sites for farming led to accumulation of manganese metals in soil as suggested by Prasad (2004). Comparing the results obtained in the year 2013 with that of 2014, it was revealed that harmattan season of 2013 (2.50 – 12.50 mg/Kg) had less level of manganese in soil than harmattan season of 2014 (7.33 – 13.57 mg/Kg). Likewise, rainy season of 2013 (2.10 – 5.00 mg/Kg) showed less concentration of manganese compared with rainy season of 2014 (3.42 – 5.71 mg/Kg) whereas dry season of 2013 (2.75 – 15.30 mg/Kg) indicated high concentration of manganese than dry season of 2014 (2.94 – 9.24 mg/Kg).

Manganese concentrations in vegetables obtained along Kubanni stream channels is shown in Figure 4. In the year 2013, the concentrations determined were in the range of 4.39 – 15.04 mg/Kg. Highest level was observed in spinach (15.04 mg/Kg) during the harmattan season followed by tomato (14.75 mg/Kg) and this was closely followed by 13.64 mg/Kg in spinach both results were obtained in the dry season whereas the least concentration of 4.39 mg/Kg was noted during the dry season in tomato. High levels of manganese were also observed in onion (9.65 mg/Kg) during the harmattan season, okro (9.21 mg/Kg), cabbage (8.64 mg/Kg) both in the dry season and 7.59 mg/Kg in lettuce during the harmattan season. High concentrations of manganese during harmattan and dry seasons could be as a result of harmattan-dusts coupled with excessive use of wastewater to irrigate the farmland as suggested by various workers like; Uwah *et al*., (2007), Arora *et al.,* (2008) and Akan *et al*., (2010). Least levels of manganese (5.00 – 8.54 mg/Kg) were obtained during the rainy season and this could be linked to dilution effects as suggested by Chapman (1997). In this period, okro (8.54 mg/Kg) had highest concentration while carrot (5.00 mg/Kg) showed the least level. Vegetables analyzed had concentrations in the range of 0.10 – 13.42 mg/Kg in the year 2014.

Tomato (13.42 mg/Kg) was found with highest level followed by spinach (10.41 mg/Kg) and cabbage (8.08 mg/Kg) all cultivated in the dry season whereas the least concentrations were observed in onion (0.37 mg/Kg) and cabbage (0.05 mg/Kg) both planted in the rainy season. High concentrations were also noticed in carrot (7.73 mg/Kg), okro (7.31 mg/Kg) and lettuce (5.94 mg/Kg) all these values were obtained in the dry season. Similar concentrations were observed in vegetables planted during harmattan season (0.36 – 2.25 mg/Kg) and rainy seasons (0.05 – 2.26 mg/Kg) of 2014. This could be traced to flooding of 2013 that led to heavy erosion and this might have washed away the manganese in soil for vegetables uptake as suggested by Arora *et al*., (2008). Comparing the results obtained in 2013 with that of 2014, there was a drastical reduction in manganese levels during the harmattan season of 2013 (7.48 – 15.04 mg/Kg) to harmattan season of 2014 (0.36 – 2.25 mg/Kg). Likewise, reduction was observed from rainy season of 2013 (5.00 – 8.54 mg/Kg) to that of rainy season 2014 (0.05 – 1.26 mg/Kg). This could be connected to reason given above and sandy nature of soils from sampling sites would allow leaching of the required nutrients beneath the earth crust as suggested by Nyle and Ray 1999. There was no much disparity in manganese levels between dry season of 2013 (4.39 – 14.75 mg/Kg) and dry season of 2014 (3.33 – 13.42 mg/Kg).

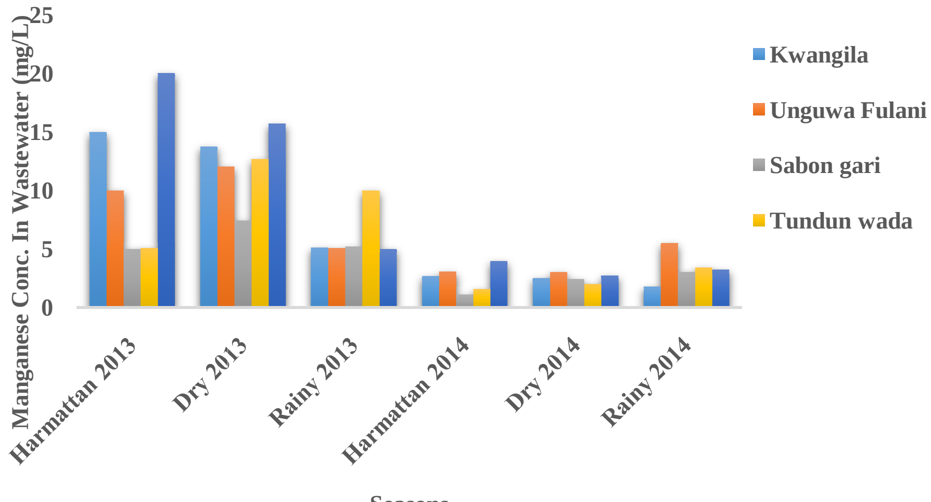

Fig. 2:- Manganese Concentrations in Wastewater from Kubanni stream Channels, Zaria

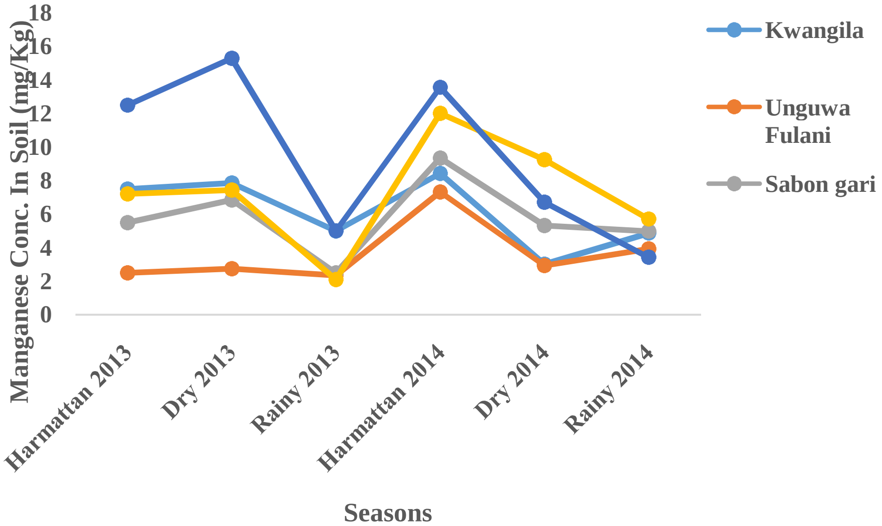

Fig. 3: Manganese Concentrations in Soil from Kubanni stream Channels, Zaria

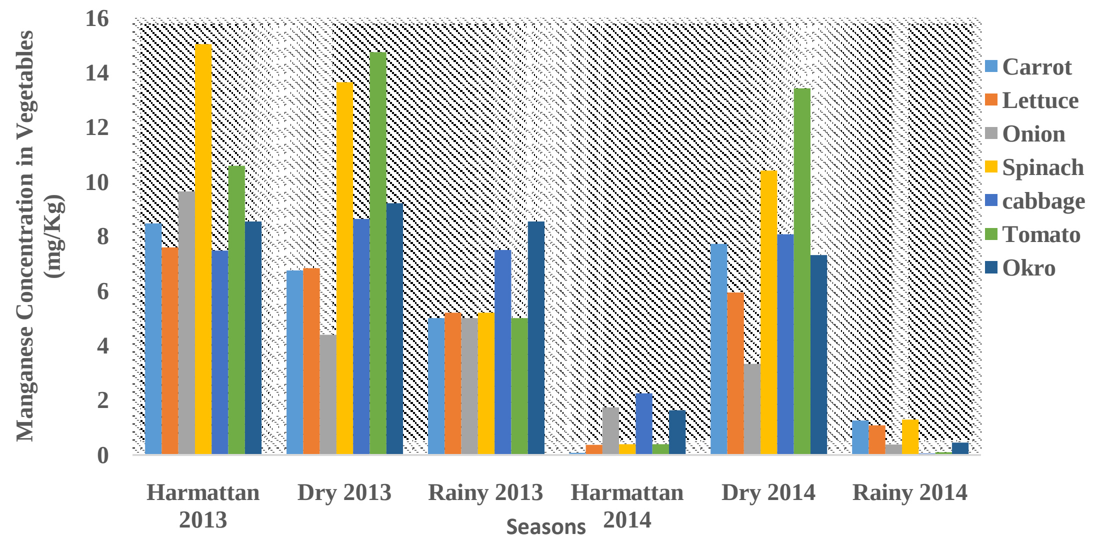

Fig. 4: Manganese Concentrations in Vegetables from Kubanni Stream Channels, Zaria

Table 1 presents Analysis of variance (ANOVA) for manganese levels in wastewater between the year 2013 and 2014. Statistical analysis showed the mean with standard deviation level for manganese as thus; Kwangila (6.802±5.985), Unguwa-fulani (6.448±3.742), Sabon-gari (4.027±2.296), Tundun-wada (5.782±4.568) and Industrial-area along Jos road (8.445±7.468) respectively. ANOVA Table 1 shows $p = 0.675 > 0.050$ this means that there is no significant difference in manganese levels across the sampling sites as observed from their mean. Manganese concentrations were also examined across the seasons to establish their differences. From ANOVA Table 1, $p = 0.989 > 0.050$ this means that there is no significant difference in manganese concentrations across the seasons. This might be due to sampling sites are falling within the same vicinity thereby source of contamination with manganese ions are similar irrespective of change in seasons as suggested by Farooq *et al.*, (2008). Pearson Product Moment Correlation (PPMC) was conducted to establish the relationship between manganese levels in wastewater between the year 2013 and 2014 as presented in Table 2. Statistical analysis indicated Pearson correlation (r) = 0.166, degree of freedom (df) = 13 and $p = 0.554 > 0.050$ this means that there is negligible relationship between manganese level in wastewater for the year 2013 and 2014 respectively.

From the ANOVA Table 3 below, $p = 0.677 > 0.050$ shows there is no significant difference in manganese levels across the sampling sites. Also, Table 3 shows $p = 0.883 > 0.050$ this means that there is no significant difference in manganese concentrations across the seasons. These values are relatively close to one another and may be attributed to anthropogenic activites in the sampling sites as suggested by Butu (2013). Table 4 presents Pearson Product Moment Correlation (PPMC) for manganese levels in soil between the year 2013 and 2014. This mean that there is moderate relationship between manganese levels in soil for year 2013 to that of 2014.

Analysis of Variance in Table 5 shows, $p = 0.753 > 0.050$ this means that there is no significant difference in manganese levels from one species of vegetable to another. The same Table 5 also shows, $p = 0.995 > 0.050$ this means that there is no significant difference in manganese concentrations from one season to another. In addition, ANOVA Table 5 indicates $p = 0.757 > 0.050$ this means that there is no significant difference in manganese concentrations in wastewater, soil and vegetables of the sampling sites. This implies that each constituent (wastewater, soil and vegetable) accumulates similar concentrations of manganese as reflected from their mean and standard deviation as thus; wastewater (6.439±3.494), soil (6.301±4.984) and vegetable (5.730±4.342) respectively. Table 6 presents summary of Pearson Product Moment Correlation (PPMC) to show the relationship between manganese levels in vegetables for the year 2013 and 2014. Statistical data showed the mean with standard deviation level for manganese to be 8.240±3.139 in 2013 while 3.221±3.946 was obtained in 2014. Statistical analysis showed Pearson correlation (r) = 0.457, degree of freedom (df) = 19 and $p = 0.037 < 0.050$ this means that there is moderate relationship between manganese level in vegetables for the year 2013 and 2014 respectively.

Table 1:- Analysis of Variance (ANOVA) for Manganese in Wastewater

Analysis of Variance		Sum of Square	df	Mean Square	F	Signif.
Manganese in Wastewater (Locations)	Between Groups	61.868	4	15.467	0.587	0.675
	Within Groups	658.640	25	26.346		
	Total	720.509	29			
Manganese in Wastewater (Seasons)	Between Groups	16.039	5	3.208	0.109	0.989
	Within Groups	704.470	24	29.353		
	Total	720.509	29			

Table 2:-Summary of Pearson Product Moment Correlation for Manganese in Wastewater

Variables	*N*	$\bar{x}$	SD	r	df	Signif.
Manganese 2013	15	9.807	4.897	0.166	13	0.554
Manganese 2014	15	2.795	1.066			

Table 3:- Analysis of Variance (ANOVA) for Manganese in Soil

Analysis of Variance		Sum of Square	df	Mean Square	F	Signif.
Manganese in Soil (Locations)	Between Groups	108.177	4	27.044	0.584	0.677
	Within Groups	245.919	25	9.837		
	Total	354.097	29			
Manganese in Soil (Seasons)	Between Groups	23.511	5	4.702	0.341	0.883
	Within Groups	330.585	24	13.774		
	Total	354.097	29			

Table 4:-Summary of Pearson Product Moment Correlation for Manganese in Soil

Variables	*N*	$\bar{x}$	SD	r	df	Signif.
Manganese 2013	15	6.156	3.818	0.479	13	0.071
Manganese 2014	15	6.723	3.247			

Table 5:- Analysis of Variance (ANOVA) for Manganese in Vegetable

Analysis of Variance		Sum of Square	df	Mean Square	F	Signif.
Manganese in Vegetable (Among various vegetable)	Between Groups	68.616	6	11.436	0.568	0.753
	Within Groups	704.359	35	20.125		
	Total	772.975	41			
Manganese in Vegetable (Seasons)	Between Groups	8.556	5	1.711	0.081	0.995
	Within Groups	764.419	36	21.234		
	Total	772.975	41			
Manganese Among Wastewater, Soil & Vegetable	Between Groups	10.400	2	5.200	0.279	0.757
	Within Groups	1847.580	99	18.662		
	Total	1857.981	101			

Table 6:-Summary of Pearson Product Moment Correlation for Manganese in Vegetable

Variables	*N*	$\bar{x}$	SD	r	df	Signif.
Manganese 2013	21	8.240	3.139	0.457	19	0.037
Manganese 2014	21	3.221	3.946			

DISCUSSION

There was a decline in manganese concentrations in wastewater from the year 2013 to 2014 which might be related to flooding in 2013 that led to heavy erosion thereby most of manganese metals might have been washed away or leached beneath the earth crust as was also observed by Nyle and Ray (1999). Results obtained in this study exceed the maximum permissible limit for manganese in irrigated water according to FAO/WHO (1985) (0.20 mg/L). Akan *et al.,* (2008) reported (5.22 – 9. 34 mg/L) as manganese level in wastewater which was in agreement with results obtained in this present study but less than reported concentration but Mohsen and Seilsepour (2008). There was a decline in manganese levels in soil from dry season (2.75 – 15.30 mg/Kg) to rainy season (2.10 – 5.00 mg/Kg) for both years. This could be traced to dilution effects coupled with lesser use of herbicides, fungicides, pesticides and other chemicals in the rainy season as reported by Chapman (1997) and Akan *et al.,* (2008). Kwangila sampling site (3.93 – 9.35 mg/Kg) showed moderate levels of manganese in soil while Unguwa-fulani (2.50 – 7.33 mg/Kg) had the least concentration. The maximum allowable limit for manganese in soil according to FAO/WHO (1985) is 200.00 mg/Kg and this indicates that the soils of sampling locations are not polluted with this metal. Akan *et al.,* (2010) reported (13.76 – 19.96 mg/Kg) as manganese levels in soil which was similar to the concentrations obtained in this study but these results were less than reported concentrations by Sodipo *et al*., (2012) and Uwah *et al.,* (2007). Vegetable analyzed showed least accumulation of manganese during the rainy season of 2014 (0.05 – 1.29 mg/Kg) while highest accumulation was observed during the dry season of 2013 (4.39 – 14.75 mg/Kg) and cabbage (2.25 – 8.84 mg/Kg) had moderate level of manganese concentration among the vegetables analyzed and this was in conformity with reported concentration by Uwah *et al.,* (2007). Results obtained in this study were below the threshold limits set by FAO/WHO, (1985) (500 mg/Kg) for vegetable and other workers who reported levels above this study findings include; Mohsen and Seilsepour, (2008) (14.93 – 284.75 mg/Kg) and Sodipo *et al*., (2012) (80.00±2.83 mg/Kg). Statistical analysis results revealed that manganese levels in soil and vegetables could be traced to the same source of contaminations as they showed moderate relationship and this may be attributed to anthropogenic activities as it was also observed by Butu (2013).

CONCLUSION

The levels of manganese analyzed in the various sampling sites for wastewater were found in this order: Industrial area along Jos road > Tundun wada > Kwangila > Sabon gari > Unguwa fulani while the vegetables showed the order of spinach > tomato > okro > cabbage > carrot > lettuce > onion. In conclusion, it can be deduced that, there is the need to find means of removing this heavy metal (manganese) which might make these vegetables unsuitable for human consumption in near future. Also, irrigating the farmland with untreated wastewater should be discouraged and indiscriminate discharge of refuse into the body of Kubanni River should be stopped by regulating agents and government should provide appropriate dumpsites within the vicinity for this purpose.

Conflict of Interest

The research showed that using wastewater to irrigate the farmland contributes to build-up of heavy-metals (manganese) in soil and vegetables especially during the dry and harmattan seasons. This metal is harmful to body at concentration exceeding threshold limits thereby farmers need to be discouraged in using untreated wastewater to irrigate their farmland irrespective of seasons in the study areas.

Contributions of each Author

The article is an extract from Oladeji, S.O.'s PhD thesis, which M.D. Saeed supervised.

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