

*Full Length Research Paper*

# **Impact of industrial effluents, domestic wastewater and natural dams on heavy metals concentrations in vegetables cultivated in Northern Nigeria**

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**Vegetable cultivation is increasing because of its health benefit. However, in areas with limited fresh water, irrigation is from industrial and domestic wastewaters. Consumption of crops with high heavy metal content poses concern to health. A comparative analysis was conducted using AAS (Atomic Absorption Spectrophotometer) to determine the concentration of heavy metals in some vegetables irrigated with industrial effluent, domestic wastewater, and water from natural dams in Kano State. The results indicated that for all the sites, Fe and Zn had mean concentrations above the WHO/FAO permissible limits for edible vegetables with ranges 115 - 4041 mg/kg and 0.00 - 621 mg/kg. There was no mean significant difference at the  $p < 0.05$  level within all the sites for Fe but, Zn showed significant variations between industrial and natural sites. Cr and Ni had a mean significant difference within all the sites and Ni had mean value below the allowable limit, Cr only had below for natural site. The mean concentration for Mn and Cu were below the permissible limit and there was mean significant difference between natural and domestic sites for Mn but, there was none for Cu. Vegetables cultivated from natural dams were relatively safe from contamination. The results highlight the need for the remediation of heavy metal contamination in irrigation waters from domestic and industrial sources to reduce the associated health hazards in the long run.**

**Key words:** Comparative, cultivated, dam, domestic, effluents, vegetables, wastewater

## **INTRODUCTION**

Vegetables form an important part of the human diet, for their supply of proteins, vitamins, and minerals to human bodies (Arai, 2002). They can also stabilize various toxic substances during digestion and reduce the risk of for example colorectal cancer (Bean et al., 2010). The risk associated with heavy metal contamination are well

recognized in respect of food quality (Khan et al., 2008). Growing human activity has increased wastewater generation with the potential to add hazardous concentrations of heavy metals into the environment (Qadir et al., 2010). Soil is the major sink for heavy metals released into the environment through natural and

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anthropogenic sources. Unlike organic contaminants which are biodegraded, most metals do not undergo microbial or chemical degradation (Kirpichtchikova et al., 2006). Wastewater irrigation is a common practice in most developed (United Kingdom) and developing (Nigeria) countries (Wang et al., 2012). However, the quality of the wastewater used and the nature of its usage vary enormously, both between and even within countries. In many low-income countries, the waste water is often inadequately treated (Qadir et al., 2010), which causes the buildup of heavy metals concentration in agricultural soil. The polluted waters not only contaminate soils, but may also endanger the safety and quality of food (Rice et al., 2012). Long term consumption of heavy metal-contaminated vegetables has been associated with increased risk of diseases such as damage to the central nervous function; lower energy levels and damage to blood composition, lungs, kidneys, liver and other vital organs, cancer and dermatitis. (Chary et al., 2008; Yadav et al., 2013).

Like many developing countries, Nigeria has poor environmental management and enforcement policies for wastewater, and owing to the scarcity of fresh water, domestic sewage and industrial effluent are important wastewater sources for the irrigation of vegetables and other crops (Khan et al., 2008; Olayiwola and Emmanuel, 2016; Bayero et al., 2018). The use of wastewater for irrigation can significantly contribute to the increase of heavy metals content in the soil and food chain (Ullah et al., 2012; Hussain et al., 2013).

The objective of this study was to compare the levels of heavy metals in vegetables cultivated using domestic wastewater, industrial effluent and natural river water.

## MATERIALS AND METHODS

### Study area

Kano State is a state in Northern Nigeria with a population of over nine million. The majority of the industries in Kano are tanneries, textiles, and chemical manufacturing. Effluents from most of the industries are discharged into waterways. Kano State has many rivers, ponds and dams. Kano State has a history of agriculture, being one of the most irrigated states in the country with more than 3 million hectares of cultivable land which ensure all year round farming. Vegetables are cultivated on raised beds and irrigated by surface irrigation system. Sources of irrigation water include natural dams, partially treated industrial and untreated domestic wastewater discharged into urban drainage systems and other natural waterways which in turn serve as sources of water for irrigation (Abakpa et al., 2013).

### Sampling site and sample preparation

Sampling site selection shown in Figure 1 was based on the availability of vegetables on the farms, the cooperation of the farmers, the type of vegetables grown, and the source of irrigation water. Twenty-four farms were selected, three each from each locations (domestic, industrial and natural sites) and seventy-five samples consisting of three vegetable samples from each farm:

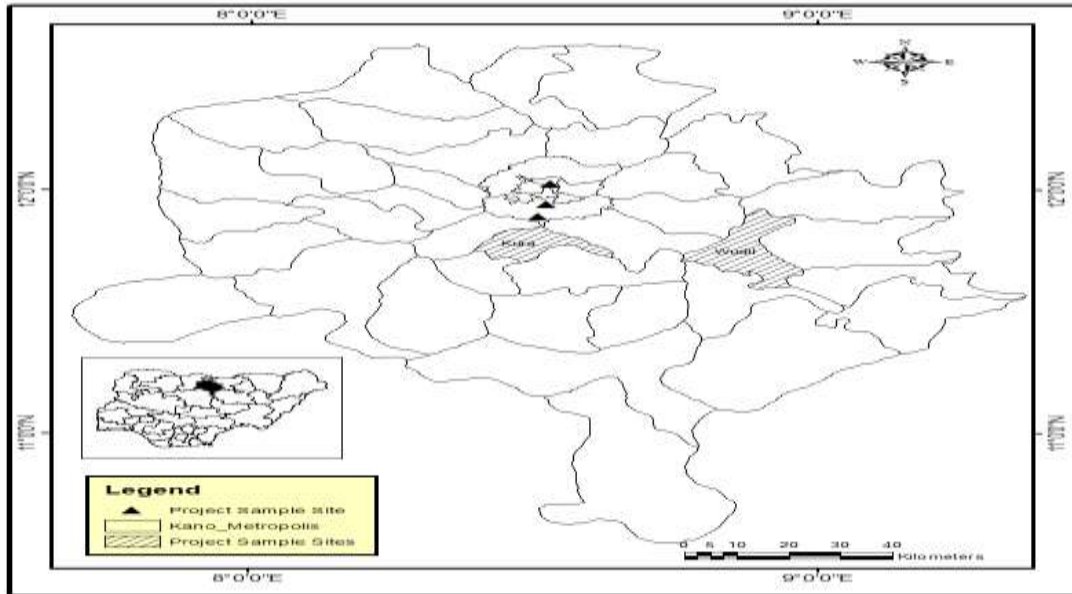
onions, tomatoes, and carrot from industrial sites (Challawa and Sharada); onions, carrot and cabbage from natural sites (Bagwai, Kura and Wudil) and onions, carrots, tomato and lettuce from domestic sites (Wase, Brigade and Kwakwachi). These sites were grouped and referred to collectively as industrial, domestic and natural sites. Samples were collected between the months of March - October, 2015 (rainy and dry season) and analyzed using Atomic Absorption Spectrometry (Buck Scientific 210 Model) for Iron (Fe), Chromium (Cr), Manganese (Mn), Nickel (Ni), Copper (Cu) and Zinc (Zn). A weighed sample was transferred to a beaker, which was then covered with a ribbed watch glass to minimize contamination and placed under a fume hood, 20 mL of concentrated HNO<sub>3</sub> was added and slowly boiled until evaporated to about 5 mL. 20 mL de-ionized H<sub>2</sub>O was added boiled gently until it reduces to about 10 mL. The beaker walls and watch glass were washed down with de-ionized H<sub>2</sub>O and then filtered. The filtrate was transferred to a 100-ml volumetric flask and diluted to mark, thoroughly mixed and analysed using standard method previously described (Rice et al., 2012).

### Statistical computation

Analysis of variance was used to test significant differences in the mean concentrations of heavy metals between sites, at  $p < 0.05$  level of significance. Statistical analysis was performed using the SPSS software platform.

## RESULTS AND DISCUSSION

The heavy metal contents in vegetables cultivated from domestic, industrial and natural sites are detailed in Tables 1, 2 and 3. Table 4 presents the summary of range, mean and standard. Industrial sites had the highest concentrations of most heavy metals, with values of  $209.78 \pm 44.47$  of Zn,  $5.54 \pm 0.16$  mg/kg of Cr,  $4.22 \pm 0.47$  mg/kg of Ni and  $15.54 \pm 2.21$  mg/kg of Cu, following the trend of industrial > domestic > natural. The concentration of Fe ( $572.06 \pm 139.57$ ) was highest at the natural site following the same pattern of an earlier report of  $27.35 \pm 1.17$  for natural;  $24.74 \pm 1.42$  domestic and  $17.36 \pm 1.00$  for industrial site from the same location (Audu and Lawal, 2006). The low concentration of Fe in industrial sites can be attributed to the interfering reaction of natural Fe with the mechanism of reducing Cr(IV) to the more desirable Cr(III) (Di Palma et al., 2015; Gueye et al., 2016). Fe was higher than the permissible limit (Additives, 2008) in onions and lettuce from domestic site, in onions and tomato from industrial site and carrot and cabbage from natural site, while it was lower for other vegetables but in summary concentration of Fe from all sites had mean above the WHO/FAO permissible limits (Additives, 2008) with no significant difference across the sites at  $p < 0.05$  levels. Previously studied contaminated sites of Akwa Ibom and Ado-Ekiti had concentrations in the range of 17.36 - 95.84 mg/kg and 23.5 - 68.8 mg/kg respectively (Essienn et al., 2010; Fagbote and Olanipekun, 2010). High values for Fe of 108.57 - 560.44 and 176.50 - 4272.50 mg/kg have been reported from industrial sites of Bangladesh and Iran (Bigdeli and Seilsepour, 2008; Ahmad and Goni, 2010).



**Figure 1.** Map of Kano state showing the study areas.  
Source: Department of Geography BUK.

**Table 1.** The mean and standard deviation of heavy metals (mg/kg) in onions, carrot, tomato and lettuce irrigated with domestic wastewater.

Crop	Fe	Cr	Mn	Ni	Cu	Zn
Onions	671.91 ± 157.32	2.83 ± 0.22	37.00 ± 6.52	3.27 ± 0.39	9.25 ± 0.74	173.44 ± 61.56
Carrot	368.89 ± 85.77	1.57 ± 0.30	31.44 ± 3.45	2.98 ± 0.16	10.31 ± 1.01	132.91 ± 8.56
Tomato	297.31 ± 40.29	2.19 ± 0.40	33.11 ± 2.23	2.73 ± 0.41	8.56 ± 1.15	113.22 ± 8.52
Lettuce	714.78 ± 80.41	2.88 ± 0.28	48.89 ± 8.82	3.11 ± 0.62	8.91 ± 1.43	153.89 ± 31.80

**Table 2.** The mean and standard deviation of heavy metals (mg/kg) in onions, carrot, and tomato irrigated with industrial effluent.

Crop	Fe	Cr	Mn	Ni	Cu	Zn
Onions	507.87 ± 89.91	4.97 ± 0.16	36.33 ± 5.22	3.28 ± 0.49	8.73 ± 0.82	336.50 ± 109.48
Carrot	402.93 ± 62.37	5.95 ± 0.24	65.33 ± 13.91	6.65 ± 0.48	22.50 ± 5.27	220.00 ± 32.17
Tomato	431.80 ± 84.95	5.72 ± 0.29	38.50 ± 3.00	2.73 ± 0.10	15.40 ± 1.50	72.83 ± 12.97

**Table 3.** The mean and standard deviation of heavy metals (mg/kg) in onions, carrot and cabbage irrigated with water from natural dams.

Crop	Fe	Cr	Mn	Ni	Cu	Zn
Onions	265.64 ± 30.05	1.10 ± 0.30	52.56 ± 4.99	2.53 ± 0.47	9.72 ± 1.21	109.18 ± 17.64
Carrot	498.09 ± 90.17	0.28 ± 0.11	61.40 ± 15.29	1.46 ± 0.18	6.30 ± 1.33	151.33 ± 39.45
Cabbage	952.43 ± 387.78	1.30 ± 0.23	66.67 ± 10.04	2.30 ± 0.27	5.94 ± 1.24	49.42 ± 16.14

Figures in bold exceeded the WHO/FAO limits while those in italics fell below these limits.

Excessive Fe intake can cause disorders such as hemochromatosis (Nanami et al., 2005).

For Mn, the natural site had the highest mean

concentration of 66.67 ± 10.04 in Cabbage and least of 31.44 ± 3.45 in carrot from domestic site. It was below WHO/FAO acceptable levels in all the sites. In summary,

**Table 4.** Summary of the range, mean and standard deviation of heavy metals (mg/kg) in vegetable irrigated using natural dam water, domestic wastewater and industrial effluent.

S/N	Element	Statistical analysis	Natural Sites	Domestic Sites	Industrial Sites	WHO/FAO Limit
1	Fe	Range	162.8 - 4041	115 - 1523	197 - 871.20	425.5
		Mean	572.06 ± 139.57	513.21 ± 57.00	447.53 ± 44.68	
2	Mn	Range	24.00 - 148.00	10.00 - 101.00	10.00 - 108.00	500.0
		Mean	60.21 ± 6.18 <sup>a</sup>	37.61 ± 3.03 <sup>b</sup>	46.72 ± 5.72	
3	Zn	Range	0.00 - 320.00	0.00 - 496.00	45.00 - 612.00	99.4
		Mean	103.31 ± 16.90 <sup>a</sup>	143.37 ± 17.24	209.78 ± 44.47 <sup>b</sup>	
4	Cr	Range	0.00 - 2.31	0.00 - 4.50	4.30 - 6.90	2.3
		Mean	0.90 ± 0.15 <sup>a</sup>	2.30 ± 0.17 <sup>b</sup>	5.54 ± 0.16 <sup>c</sup>	
5	Ni	Range	0.40 - 5.40	0.90 - 6.50	2.00 - 8.3	67.90
		Mean	2.10 ± 0.21 <sup>a</sup>	3.02 ± 0.21 <sup>b</sup>	4.22 ± 0.47 <sup>c</sup>	
6	Cu	Range	0.00 - 14.00	0.00 - 15.00	6.56 - 45.00	73.3
		Mean	7.30 ± 0.78 <sup>a</sup>	9.26 ± 0.54 <sup>b</sup>	15.54 ± 2.21 <sup>b</sup>	

highest value of 60.21 ± 6.18 was recorded from natural site with a mean difference exceeding the 0.05 level of significance occurring between the domestic and natural sites.

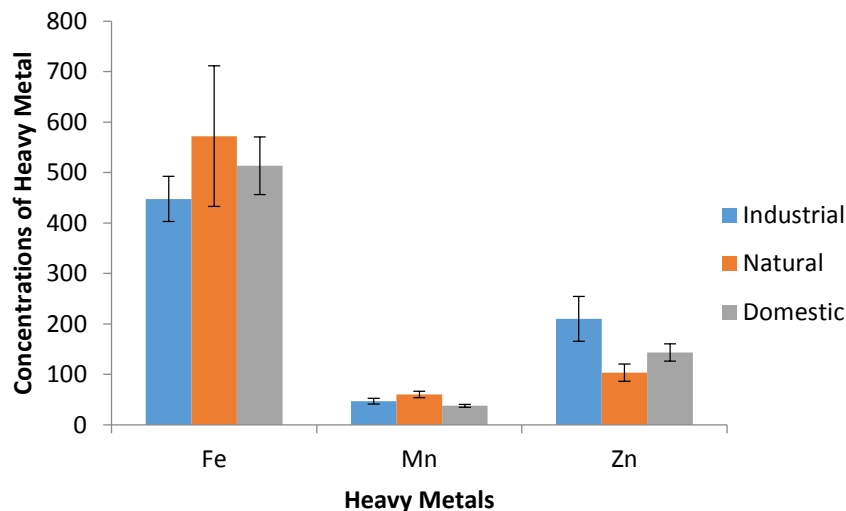
Earlier, more studies from the same site revealed 3.69 ± 1.17 for natural; 4.87 ± 1.02 for domestic and 5.79 ± 0.55 for industrial, (Audu and Lawal, 2006) and a range of 9.00 - 24.00 mg/kg (Muazu et al., 2010). High values of 14.93 - 284.75, 11.77 - 208.35 mg/kg and 9.75-62.75 mg/kg were reported from contaminated sites in Iran, Akwa Ibom and Port Harcourt (Bigdeli and Seilsepour, 2008; Essiett et al., 2010; Kalagbor et al., 2014) respectively. Other sites from Ado-Ekiti (Fagbote and Olanipekun, 2010), North Eastern Nigeria (Akan et al., 2013) and South West (Olufunmilayo et al., 2014) reported lower values of 1.8 - 17.5 mg/kg, 0.23 to 3.43 mg/kg and 4.28 mg/kg respectively. Mn is an important element for human health but, in excess it can cause a condition known as manganism, a neurodegenerative disorder that leads to dopaminergic neuronal death and symptoms similar to Parkinson's disease (Bowman et al., 2011).

Zn concentrations (Tables 1, 2 and 3) for all vegetables from domestic sites, onions and carrot from both industrial and natural sites had concentrations higher than the allowable limits. In contrast, tomatoes from industrial and cabbages from natural sites were below the same limits. In summary, all the sites had mean concentration above the WHO/FAO allowable limits, with industrial site having the highest. There was mean significant difference between industrial and natural sites at the  $p < 0.05$  level. Previous reports from same location gave lower value of 8.00 - 35.00 mg/kg from industrial (Muazu et al., 2010) and 18.89 ± 1.93 for natural; 15.48 ± 0.83 domestic and 11.78 ± 1.00 for industrial site (Audu and Lawal, 2006), and from Ado-Ekiti was 5.6 - 15.5 mg/kg (Fagbote and Olanipekun, 2010) respectively. In contrast, a higher range of 39.02 - 1132.00 and 54.27-

170.23 mg/kg were reported from Iran (Bigdeli and Seilsepour, 2008; Nazemi et al., 2010). Excess Zn in the soil cannot be adsorbed by plants and so have a negative impact on the activity of microorganisms and earthworms, leading to reduced decomposition of organic matter (Wuana and Okieimen, 2011) and excessive intake by humans may cause tachycardia, vascular shock, dyspeptic nausea, vomiting, diarrhea, pancreatitis and damage of hepatic parenchyma (Salgueiro et al., 2000).

The mean concentration of Cr was above permissible value for all vegetables from industrial site, onions and lettuce from domestic sites, while carrot and tomato from domestic sites and all vegetables from natural sites had lower values (Tables 1, 2 and 3). Cr had mean significant difference at the  $p < 0.05$  level within all sites. The value (5.54 ± 0.16) for industrial sites was over 100% higher than WHO/FAO permissible limits (Additives, 2008). It was at the threshold (2.30 ± 0.17) for domestic and below (0.90 ± 0.15) for natural sites. Similar reports from the same location revealed lower mean range of 0.64 ± 0.08 - 0.87 ± 0.20 and higher range of 4.00 - 19.00 (Audu and Lawal, 2006; Muazu et al., 2010). Previous reports of concentrations above 5.5 mg/kg were reported from Borno (Akan et al., 2013), Port Harcourt (Kalagbor et al., 2014) and Bangladesh (Ahmad and Goni 2010). This high concentration can be ascribed to the large scale use of chromium salts by tanneries and other related industries. Less industrialized areas like Ado-Ekiti (Fagbote and Olanipekun, 2010) and Akwa Ibom (Essiett et al., 2010) reported lower ranges of 0.6 - 1.2 and 0.01 - 0.08 respectively. Cr is associated with allergic dermatitis in humans (Wuana and Okieimen, 2011).

The mean concentration of Ni was highest in carrot (6.65 ± 0.48) and onion (3.28 ± 0.49) from industrial sites and least in carrot (1.46 ± 0.18) and cabbage (2.30 ± 0.27) from natural sites. The mean concentrations from all sites were below WHO/FAO permissible limits (Additives, 2008) with industrial site having the highest



**Figure 2.** Mean concentrations of Fe, Mn and Zn in vegetables irrigated with natural dam, domestic wastewater and industrial effluent.

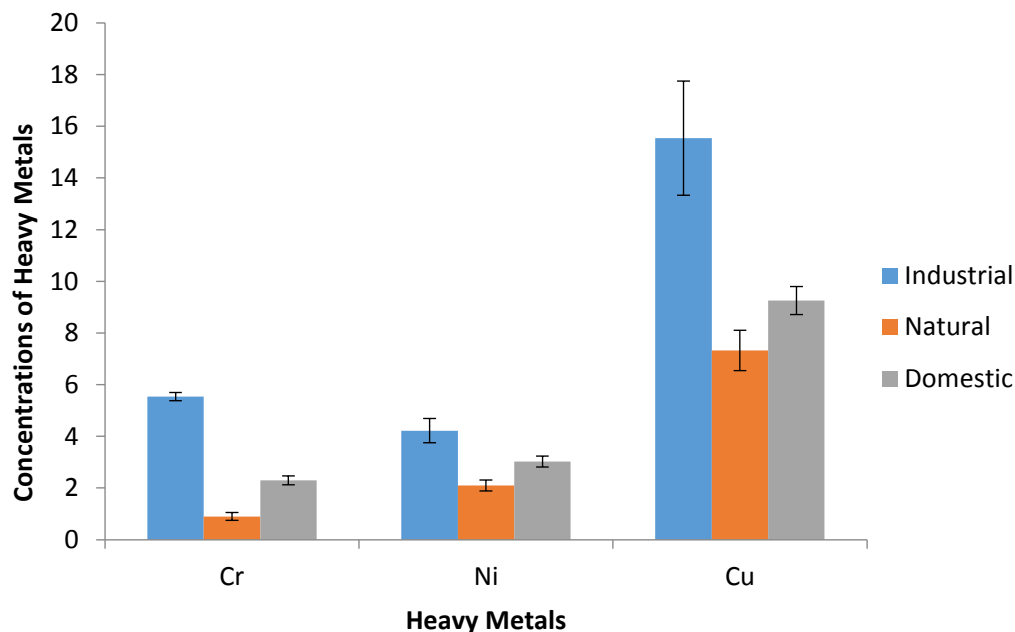
value of  $4.22 \pm 0.47$  and there was mean significant difference at the  $p < 0.05$  level within all sites.

The reported value was in agreement with earlier findings from same location of 2.00 – 10.00 mg/kg (Muazu et al., 2010) and a trend of industrial > natural > domestic (Audu and Lawal 2006), whereas 1.8 – 3.1 from Ado-Ekiti (Fagbote and Olanipekun, 2010) and Kalagbor et al. (2014) showed a value as high as 15.75-19.25 mg/kg from Port Harcourt which could be attributed to the crude oil and coalbeds. Contaminated sites from Bangladesh, Iran and Libya reported 2.41 – 26.63; 0.00 – 20.52 and 0.19-5.14 mg/kg respectively (Bigdeli and Seilsepour, 2008; Ahmad and Goni, 2010; Elbagermi et al., 2012). Ni has been considered to be an essential micronutrient for activation of urease in higher plants and some enzymes systems in trace amount for human and animal health. It is not known to accumulate in plants or animals (Wuana and Okieimen, 2011; Schaumlöffel, 2012).

Highest mean concentration of Cu were in carrot ( $22.50 \pm 5.27$ ) and tomato ( $15.40 \pm 1.50$ ) from the industrial site and the least were in cabbage ( $5.94 \pm 1.24$ ) and carrot ( $6.30 \pm 1.33$ ) from natural sites. Cu was present in concentrations below the WHO/FAO allowable limits (Additives, 2008) and there was no mean significant difference at the  $p < 0.05$  level within natural and domestic sites. Earlier findings from same location had a contrasting pattern in the order of natural > domestic > industrial (Audu and Lawal, 2006) and a range of 3.2 – 8.4 (Muazu et al., 2010), and from Port Harcourt was 7.75 - 11.00 (Kalagbor et al., 2014). These findings were higher than those from Borno and Akwa Ibom (Akan et al., 2013; Essienn et al, 2010). Similar value of 4.54 – 39.99 was reported from Iran (Bigdeli and Seilsepour, 2008). Cu is necessary for both plants and animals

growth. In humans, it helps in the production of blood haemoglobin, body pigmentation, and prevention of anaemia and maintenance of a healthy central nervous system. In plants, it is especially important in seed production, disease resistance, and regulation of water but excess of Cu may result in liver and kidney damage, stomach and intestinal irritation and brain tumors (Ellis and Salt, 2003; Wuana and Okieimen, 2011).

In summary, Figures 2 and 3 show that the presence of industrial sites in the watershed drives contamination of vegetables while in contrast those with relatively unpolluted water, the so-called natural sites the least. By comparing the results with other studies from the same location, the abnormal concentrations of heavy metals in industrial effluent exceeded the maximum permissible limit (Dan'Azumi and Bichi, 2010; Bernard and Ogunleye, 2015). This elevated level of heavy metals in agricultural fields was mainly due to the use of contaminated water for irrigation, which gave rise to high concentrations of heavy metal presence in vegetables intended for human consumption and its characteristic health hazards. Mn, Ni and Cu in all the sites were within WHO/FAO acceptable limit (Additives, 2008), which supported earlier reports at similar sites (Audu and Lawal, 2006; Muazu et al., 2010), Iran (Bigdeli and Seilsepour, 2008) and Bangladesh (Ahmad and Goni, 2010). There was contrasting reports for concentration of Cr from the same location for industrial sites. It was found to be present above (Muazu et al., 2010) and below (Audu and Lawal, 2006) permissible limits; these lower values can be attributed to the earlier enforcement of installation of treatment plants in the region which later relapsed into near dormancy. High concentration were equally revealed from Bangladesh and Port Harcourt (Ahmad and Goni, 2010; Kalagbor et al., 2014). Although Fe had high value,



**Figure 3.** Graph for summary of mean concentrations of Cr, Ni and Cu in edible vegetables from industrial, rural and domestic sites.

higher concentration (176.50 – 4272.50 mg/kg) was reported from Iran (Bigdeli and Seilsepour, 2008).

### Conclusions

The use of contaminated water for growing vegetables and other crops has become widespread all over the world. Results obtained in this study shows that untreated domestic wastewater and industrial effluents are significant sources of pollution to soil and contamination of vegetables with heavy metals in Kano State, Nigeria. This has given rise to high concentrations of heavy metals in the crops that can be harmful to the environment and pose serious health risks. Urgent steps need to be taken by relevant agencies to address the issue by enforcing existing regulations on the treatment of contaminated water and prohibiting introduction of pollutants into water canals. The concentration levels of most heavy metals shown in this study was found to be higher than the permissible limits and threaten to be harmful to humans, animals and the future safety of the environment.

### CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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