Estimation of Lead, Cadmium and Copper in urban irrigation sites in Katsina urban area, Northern Nigeria

Abdu Yaro*, Lawal Abdulrashid, Yahaya Sani

Department of Geography, Umaru Musa Yar'adua University, P.M.B. 2218, Katsina, NIGERIA
*Correspondence Author (+234-80-34273500; yaroooabdul@gmail.com)

Abstract
Domestic wastewater use for irrigation is common practices in urban and peri-urban areas of northern Nigeria. This study investigates levels of Cadmium, Lead and Copper in soils irrigated with wastewater in urban Katsina, northern Nigeria. Two surface and subsurface soil samples were collected from 15 locations along Ginzo drainage where irrigation of vegetable crops was taking place for over 30 years. The soil samples were analyzed for the concentration of Cadmium (Cd), Lead (Pb) and Copper (Cu) using DTPA (diethylenetriamine pentacetic acid) extraction procedures. Mean concentration of Cadmium at top layer was found to be the highest in Kofar Sauri while mean subsurface soil cadmium was highest at Kofar Durbi sampling site. High mean lead concentration was discovered at Kofar Marusa. Mean lead concentration exhibited significant decrease with soil depth as well as high spatial variability in all the three sampling sites. Similarly, mean Copper concentration exhibit decrease with soil depth and high spatial variability at both surface and subsurface layers of the soil. The study concluded that evidences of metals build-up in soils samples existed. In light of this, there is the need to embark on frequent monitoring of the levels of hazardous metals in soil, water and crop samples so as to ensure that they do not exceed the maximum approved limit.

Key words: Heavy metals**,** Urban, Ginzo, Irrigation, Katsina

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Introduction

Wastewater for irrigation serves as valuable source of plant nutrients and organic matter needed for maintaining fertility levels of soils (Muhammed and Ayadi 2004; Rattan et al., 2005; Rusan *et al.,* 2007). Re-use of domestic and industrial wastewater in irrigation appears to be a lucrative option. It serves as a potential solution to reducing fresh water demand, for zero water discharge and avoiding pollution loads in the receiving sources (Kiran *et al.,* 2012). For many countries wastewater re-use is now part of water management plans (USEPA, 1997).

However, the use of wastewater from domestic, industrial, commercial, agricultural and other human activities, despite its obvious benefits, has some recorded human and environmental health concerns (Mollahoseini, 2013; Mahmood and Malik, 2014). Many reports correlate the relationship between fresh vegetables and food borne diseases outbreaks that have led to the concerns about contamination of soils and vegetables with faecal pathogenic bacteria in the agricultural environment (Mapanda *et al*, 2005). Application of contaminated irrigation water to soils thus, represents possible sources of contamination. The use of wastewater and sludge in agricultural lands was found to enrich soils with heavy metals that may pose potential environmental and health risks in the long term (Sanchez-martin *et al.,* 2007; Tabari*et al.,* 2008). According to Singh et al., 2010, application of saline/sodic water results in deterioration of crop yields as well as deterioration of the physico-chemical characteristics of soils (Amin et al., 2011). Sridharachary, (2008) asserted that, excessive accumulation of metals in vegetables pose serious threats to those who consume the crops or vegetables grown on such contaminated soils.

While the cost of treating wastewater through recycling is too high to be generally feasible in developing countries like Nigeria (Pescod, 1992; Weber*et al.,* 1996; Agrawal, 2004), harmful effects, like roots and shoot growth inhibition and reduction of yields due to the accumulation of heavy metals in plants grown at wastewater irrigated fields were also reported (Singh, 2010).

Long before the creation of Katsina state, many people were engaged in urban irrigation for vegetable crops production to supplement rain-fed crop production. However, the creation of Katsina state in 1987 resulted in rapid increase in population –a situation responsible for increased high demand for food supply which eventually put more pressure on urban soil through increased irrigation activities.

However, the use of wastewater for irrigation despites its obvious benefits, many researchers have indicated that, continuous application of wastewater to the soil for crop production may lead to the heavy metals build up in soils which pollute the soil and eventually the crops under cultivation (Hussain et al., 2002; Darvishi et al., 2010). Sidharachary (2008) reported that excessive accumulation of metals in vegetables pose serious threat to those who consume crops produced or vegetables grown on such contaminated soils.

Exposure to heavy metals can lead to lower IQ, mental deterioration, loss of memory, joint weakness, reproduction defects, kidney and liver damages, neurological complications, hypertension, cardiovascular disease (Mahmood and Malik, 2014). Hence, the need to assess levels of soil pollution along Ginzo urban drainage in Katsina Metropolis Northern Nigeria will no doubt contribute more to the existing volume of knowledge.

2.0 Materials and Methods

2.1 Description of study sites and sampling location

Katsina is the capital city of Katsina state. It is located between latitude 12° 45' and latitude 13° 15' N, and longitude 7° 30' and 80° 00'E. The location of the study sites is along Ginzo drainage basin in eastern parts of urban Katsina (Figure 1).

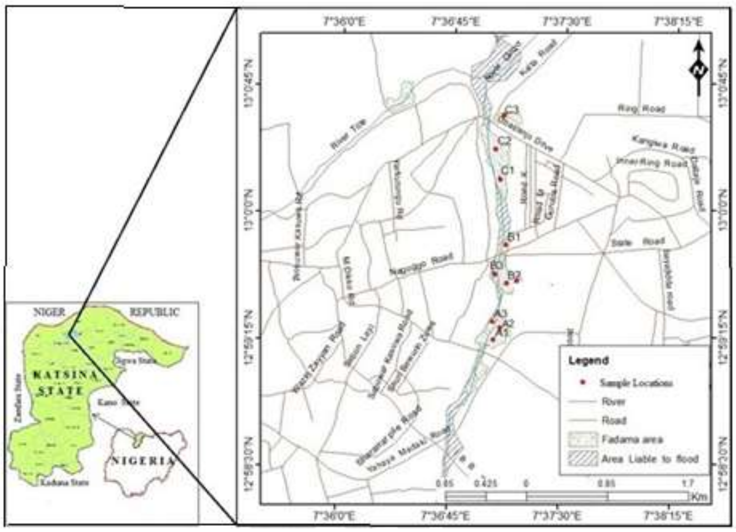


Figure 1.Location of the study area

2.2 Reconnaissance Survey

Reconnaissance survey of the irrigation sites in urban Katsina was carried out during the months of February, 2016. This helped in selecting appropriate sites for conducting the study. Some information collected during the survey included farm sizes, tenure status, crops irrigated and types of inputs such as fertilizer, manure, pesticide among others.15 farmsteads were selected at different locations along Ginzo drainage passing through three major neighborhoods (Kofar Marusa, Kofar Durbi, Kofar Sauri) in Katsina urban area. Thirty soil samples were collected from these farmsteads at surface and sub-surface layers respectively.

2.3 Soil Sample Collection Procedure

In view of the highly fragmented farm sizes along Ginzo drainage, a quadrant of 3m x 3m was selected in each selected site. Every quadrant was divided into 9 equal-sized grid squares, and at mid points of every grid square soil samples were collected at two different depths viz: 0-15cm, 20-30cm. Selection of these depths was deliberately made because the crops being grown in the area have about 30cm as their maximum rooting depth. Also sampling from similar depth across the various sample farmsteads helped in making it possible for comparison among the different farmsteads. A total of 60 samples was collected; 30 samples at the top and 30 samples at subsurface layers of the soil. The soil samples collected were put in a sterile polyethylene bag, sealed, marked and labeled, and transported within 2 hours of collection to the laboratory.

2.4 Soil Samples Analyses

The soil samples were digested using DTPA (diethylenetriamine pentacetic acid) extraction procedures. The collected soil samples were first air dried. 1g sub-samples were then taken from every air-dried sample which were then digested using 20cm^3 of 1:1 nitric acid and heated to boil until the volume was reduced to 5 cm^3. 20 cm^3 of distilled water was added and boil greatly until the volume reduced to 10 cm^3. It was cooled and filtered and make up to the 50 cm^3 mark of volumetric flask.

3.0 Results and Discussions

3.1 Cadmium (Cd)

Being a rapidly growing urban setting characterized by fast growing small and medium scale enterprises as well as local crafts, the three selected neighborhoods serve as enclave where numerous metal works, motor cycle mechanics, petrol filling stations, battery repairs were located. Cadmium is encountered in cadmium-nickel battery production, although it continues to be used in paints as well as in plastic productions where it is an effective stabilizing agent. Occupational exposure to Cadmium occurs through metal refining processes, where Cadmium is often associated with copper and can be released into the atmosphere during heating. Individuals exposed to cadmium can develop Osteoporosis, Anemia, Eosinophilia, Emphysemia, and Renal Tubular damage. Long term Cadmium toxicity can produce *itai-itai* disease, in which individual suffer from bone fractures, severe pains, proteinuria, and severe osteomalacia (Mahmood and Malik, 2014).

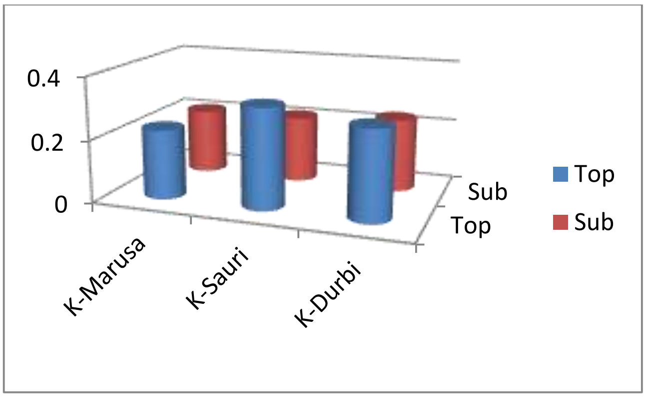
Table 3.1.1 presents distribution of Cadmium (Cd) in Kofar Marusa (KMA), Kofar Durbi (KDB) and Kofar Sauri (KSC) sampling sites respectively. This table exhibits spatial variations of Cd among the three selected sampling sites at surface and subsurface layers of the soil.

Table 3.1.1: Descriptive statistics of Cadmium (Cd) Content in soil samples

Sampling sites	Depths	Range	Mean	St. Dev.	CV%
KMA	Top	0.203 – 0.301	0.223	0.011	4.93
	Sub	0.210 – 0.232	0.212	0.013	6.13
KDB	Top	0.132 – 0.452	0.287	0.024	8.36
	Sub	0.174 – 0.309	0.235	0.016	6.80
KSC	Top	0.218 – 0.429	0.322	0.14	45.65
	Sub	0.117 – 0.323	0.215	0.128	59.53

Note: The mean values are for 60 soil samples

Mean cadmium concentration at the top soil ranges between 0.223 mg/kg at KMA and 0.322 mg/kg at KSC. Mean Cd concentration at sub surface soil ranges between 0.212 mg/kg at KMA and 0.235 mg/kg at KDB respectively. This appeared moderate to what was obtained in this study. These concentrations appeared similar to 0.13 mg/kg in Kaduna by Balogun (2013).



Mean Top and sub soil Cadmium Concentration among sampling sites

The results also revealed that spatial variability exists in Cd concentration among the three sampling sites and between top and sub soil layers. While at KMA and KDB sites, Cd concentration was least variable at both top and sub soil, the concentration of Cd at KSC exhibited a high variability (Table 3.1.1). This could be associated to the predominance of several metal related activities around the neighborhood. Being close to Nigeria Customs Services (NCS) premises, where seized and mostly second-hand vehicles were being kept for long period of time. This was also coupled with the presence of some petrol filling stations and diverse local handcraft industries among others.

3.2 Lead (Cd)

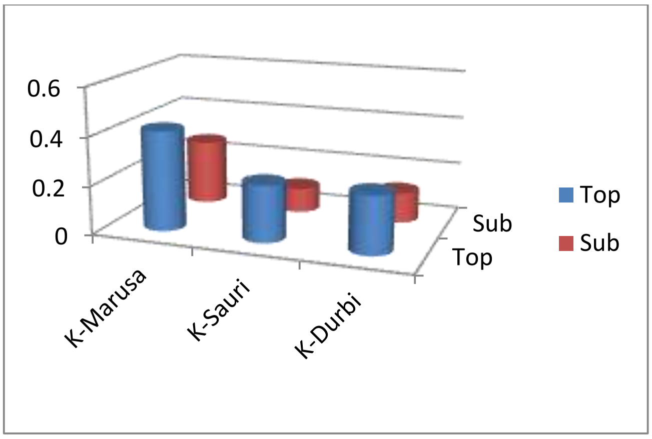
Tables3.2.1 presents results of Lead (Pb) in soil samples at top and sub-surface layers from the three investigated sampling sites. These tables all reveal decrease of lead content with soil depth at the three main sampling sites: KMA, KDB and KSC. At Kofar Marusa sampling site, lead concentration ranges between 0.139 Mg/kg to 0.241Mg/kg at the surface layer, with a mean of 0.413Mg/kg and a standard deviation of 0.175 and coefficient of variation of 42.37.

Table 3.2.1: Descriptive statistics of Lead (Pb) Content in soil samples

Sampling sites	Depths	Range	Mean	St. Dev.	CV%
KMA	Top	0.139 – 0.241	0.413	0.175	42.37
	Sub	0.218 – 0.402	0.268	0.122	45.52
KDB	Top	0.102- 0.422	0.238	0.052	21.85
	Sub	0.112 – 0.261	0.125	0.036	28.80
KSC	Top	0.101 – 0.231	0.233	0.154	66.09
	Sub	0.127 – 0.330	0.202	0.117	57.92
Maximum Allowable Concentration for Lead: 5.0					

MAC (Ayer and Westcot, 1985)
Note: The mean values are for 60 soil samples

Mean lead concentration at the two other sampling sites exhibit similar trend at both surface and subsurface soil layers. The only difference was in their spatial variability as indicated by coefficient of variability percentages. At KMA sampling site, variability among sampling points was estimated as high at both surface and subsurface layers of the soil (Table 3.2.1). Similarly, at KDB sampling site, a similar trend was exhibited with spatial variability ranging from low to medium between surface and subsurface layers of the soil. At KSC sampling site, the same trend was also exhibited between top and sub soil layers. At this particular site, spatial variability between top and sub soil was also similar to Kofar Marusa sampling site. Spatial variability was estimated as high at the top soil while low at the sub sol layers.



Mean Top and sub soil Lead Concentration among sampling sites

According to the Ayers and Westcot, 1985, Maximum Allowable Concentration of Pb for urban irrigated soil was5.0 mg/kg. This was far higher than results obtained in this study. Pb input in Katsina urban irrigated soils may probably come from vehicles that use gasoline additives generated from motor cycles repairs, repairs of car batteries and petrol filling stations at the upstream part of Ginzo drainage. Mean Pb level observed were similar to those reported by Balogun (2013) in Kaduna metropolis; Ibrahim et al., 2011 and Chibuike et al., 2014 in urban irrigation soils. They are well below the permissible limits in soils set by USEPA (1986).

3.3 Copper (Cu)

It is known that Cu is an essential element in human and animals; yet, it may be toxic when its concentration exceeds the safe limits.

Table 3.3.1: Descriptive statistics of Copper (Cu) Content in soil samples

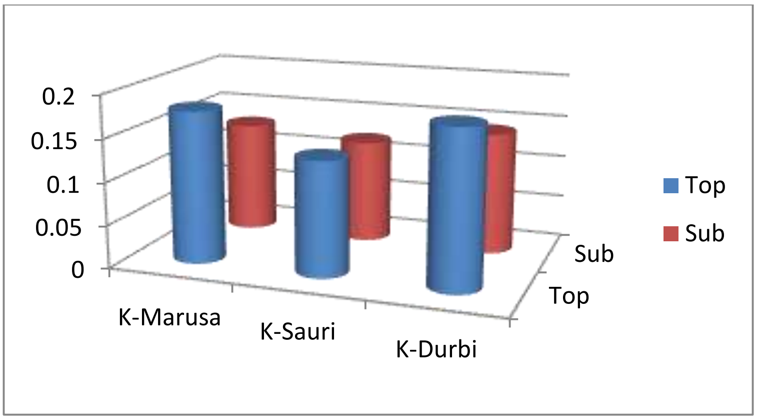
Sampling sites	Depths	Range	Mean	St. Dev.	CV%
KMA	Top	0.157 – 0.201	0.183	0.102	55.74
	Sub	0.101 – 0.207	0.143	0.148	103.49
KDB	Top	0.116 – 0.214	0.134	0.116	86.56
	Sub	0.101 – 0.167	0.121	0.131	108.26
KSC	Top	0.143 – 0.231	0.178	0.013	7.30
	Sub	0.184 – 0.359	0.133	0.024	18.05
Maximum Allowable Concentration for Copper: 0.2					

MAC (Ayer and Westcot, 1985)

Note: The mean values are for 60 soil samples

Mean top soil copper concentration in the present study range from 0.133 at KSC to 0.183 mg/kg at KMA. Data contained in Table 3.31 indicates that mean Cu concentration exhibits decrease with soil depth in all the three sampling sites. The property exhibits very high co-efficient of variation values in the two investigated locations (KMA and KDB) and at both top and sub-surface layers of the soil. At KSC, the coefficient of variation exhibits least variability at both layers (Table 3.3.1).

The result of this finding was lower than reported by Ibrahim et al., 2011 in a study of soil in Billiri with a range of 4.04 to 8.43 for Cu. This variation might be due to differences in the composition of the basement complex rocks between the two study sites. However, the results of this finding appear similar to those obtained for Cu (Kapungwe, 2011) in Zambia.Cu concentration found in this study were lower than in soil samples reported by other literatures such as Ladigbolu and Balogun (2011) who reported the profiles of Cu in sediments as (249.5mg/kg). This appeared outrageous due to wide variations in terms of the volume and diversity of human activities responsible for this metal in urban irrigation soils. The most probable source of copper in irrigated soils under study might be from corrosion of metallic parts, wear and tear of car engines, and spillage of lubricants.



Mean Top and sub soil Copper Concentration among sampling sites

4.0 Conclusions

The data obtained in this study demonstrate that metal concentrations in soils can serve to portent the presence and volume of human activities so as to monitor the impact of anthropogenic activities in an area, provided that background levels of the metals under study have been correctly established and interpreted. Generally, the results obtained in this study agreed with the following conclusions:

- There are evidences of accumulation of the metals under study in soils samples in the three sampling locations.
- Both Pb and Cd have comparatively lower accumulation tendencies than Cu in all the three sampling locations.
- There is no consistent variation of the metals under study with soil depth in the study area. This suggests that continuous application of wastewater to irrigate the soils has resulted into build-up of the metals down into the sub-surface soil layers.
- There exists a high spatial variation in levels of Cu in the three sampling locations than in the two other considered metals (Cd and Pb).
- The extent of build-up of the considered metals in soils of the study area is however below the maximum tolerable limit set by USEPA (1986).

In light of the above, it was recommended that though the extent of accumulation of the considered metals is below the tolerable limits, there is nonetheless a good basis to show much concern since some of the observed metals (especially Pb and Cd) are not wanted at all in human body systems. In fact, there is yet no known lower threshold level of Pb tolerance in human body system. Therefore, there is the need to embark on frequent monitoring of levels of the metals in soil and crop samples so as to ensure that they do not reach the higher limits than have presently been observed in the area. Since some metals exhibit high spatial variation over the study area, there is the need to ensure that any measure aimed at controlling heavy metal pollution in soils in the area take into account this issue in order to ensure that locations with higher extent of accumulation of the metals were given greater attention than locations that were not. There is the need for a feasibility study to be conducted of the viability of providing alternative irrigation water for use by farmers since it was obvious that over long term, continuous usage of wastewater in irrigation could result into serious heavy metal accumulation problems in the area. Since no attempt was made to examine the quality of wastewater and other agricultural inputs like municipal solid waste, pesticides and inorganic fertilizer being used by the farmers, it was possible to identify other sources of the accumulation of the considered heavy metals in soil and crops being produced in the area under study. Therefore, further researches were needed that shall establish the relative contribution (or otherwise) of such other sources of heavy metals accumulation in soil and crop samples in the study are

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