IJAAR PUBLISHING®
DOI: 10.46654

African Journal of Sustainable Agricultural Development | ISSN: **2714-4402**
Vol. 4, Number 1 (January-March, 2023) | www.ijaar.org/ajsad

ASSESSING THE QUALITY OF PERI-URBAN AND URBAN IRRIGATION WATER AND IRRIGATED SOILS USING HEAVY METALS AS INDICATORS IN MINNA, NIGERIA.

[1]BELLO, A., [2]DAPELLUM, A.U, [3]ALIYU, A.A. and [4]AWELE OSAMUDIAME OSA-AFIANA[4]

[1&2]Department of Agric Tech. Adamawa State Polytechnic, Yola, Nigeria.

[3]Department of Crop Science, University of Jos, Nigeria.

[4]National Oil Spill Detection and Response Agency, Abuja Nigeria.

Authors' Correspondence (email:abubakarbello663@gmail.com)

Abstract

This research work aimed at assessing the quality of Peri-urban and Urban irrigation water and irrigated soils using heavy metals as indicators in Minna, Nigeria. Water sample from five (5) irrigation sites namely: Kanfanin Kutare, Gidan Mongoro, Opposite Federal Secretariat, Morris and Ketaren Gwari all within peri-urban and urban Minna were collected and their heavy metal pollutants concentration were determined, expected annual loading rate in the soil and their values in the irrigated soil. The results revealed that only cadmium at site Ketaren Gwari was discovered to be above permissible limit (0.023 mg L^{-1}) and at the same vein exceeding the expected annual loading rate in almost all the study sites while for analyzed soil values only zinc and copper were recorded in all the sites but in small quantity. Therefore, it is recommended that periodic monitoring of the water and the irrigated soil analytically and agronomic approach (bio-remedy) with sound legislation should be adopted.

Keywords: Heavy metals, Irrigation water, Minna, Quality, Soils

1. INTRODUCTION

Irrigation is the artificial application of water to supplement rainfall as an aid to crop production. It is practiced during brief dry spells to supply all or nearly all the water required by the crops on farms in regions of low rainfall. There are various sources of water for irrigation but surfaces stream is the most popular (Bennett, 2009). Water quality is a measure of the condition of water relative to the requirements of one or more biotic species. The water quality used especially for irrigation is essential for soil quality and productivity (Lennteh, 2017). Human activities such as urbanization, agricultural practices, poor land management and sewage disposal have directly or indirectly affected the quality of water and making it unsuitable for some or all agro ecosystem component. Agricultural water sources may be of poor quality as a result of natural causes, contamination or both, hence, the need for improvement becomes paramount for the water to stand the test of any given use (Tsado *et al.*, 2016). Parameter use in evaluating quality of water is numerous, depending on the purpose for which the water is intended to be used for: aquaculture, drinking or irrigation. For purpose of this study some heavy metals pollutant (Lead, Cadmium, Chromium, Zinc and Copper) were used as indicator for evaluating the quality of the irrigation water as well as their rate of loading on soils irrigated by the water. Heavy metal are metal with density greater than $4gm^{-3}$ or the density of water, some of which are natural constituents of the earth crust while others are discharged into soil by irrigation with waste water as demonstrated by Nyamangara and Mzezewa (1999). A number of the heavy metals are essential, example: iron, manganese, cobalt (Omar and Al-Khashaman, 2004). However, there are also heavy metals like Arsenic (As), Cadmium (Cd), Chromium (Cr), Mercury (Hg), Lead (Pb) which are non essential for living component of agro ecosystem and are toxic even at low concentration (Alloway and Ayers, 1993; Pulford, 2007).

These water sources that were evaluated in this work comes from drainage channels that runs through the city of Minna, north central Nigeria receiving waste discharged at various points along its length from both domestic and commercial areas that include industrial effluents as well as waste from automobile mechanic workshops, thereby substantially affecting the quality of the water that is ultimately used for irrigation. According to Nyamangara *et al*., (2005), the quality of irrigation water is affected through discharges of partially and untreated effluents into rivers or stream that supply water for agriculture. Studies have been performed to assess quality of irrigation water within and around Minna (Tsado *et al*., 2014). But, there is dearth of information on quality of irrigation water with respect to heavy metals and their level of concentration on farming soil. The aim of this research was to ascertain the quality of the irrigation water using the following heavy metals: Lead (Pb), Cadmium (Cd), Chromium (Cr), Zinc (Zn) and Copper (Cu) as variables and to determine their level of concentration on the irrigated soil.

2. MATERIALS AND METHODS

2.1 Study Area

The study area was Minna (9^0 14' N, 6^0 30' E) in the Southern Guinea savanna of Nigeria. The climate is sub-humid tropics with mean annual rainfall of about 1200 mm (90 % of the rainfall is between June and August). The mean daily temperature rarely falls below 22 ^{0}C with peak of 40 ^{0}C and 36 ^{0}C between February to March and November to December respectively. The soils of Minna are predominantly Alfisols (USDA) developed from Basement Complex rocks ranging from shallow to very deep soils overlying deeply weathered gneisses and magmitites with some underlain by iron pan to varying depths (FDALR, 1990; Adeboye *et al.*, 2011).

2.2 Study Site

The study was conducted at five (5) selected irrigation sites namely: Kanfanin Kutare (opposite IBB Specialist Hospital), Morris Fertilizer site, Ketaren Gwari (Mechanic village), Opposite Federal Secretariat and Gidan Mongoro all within Minna and its environs. These fields are under continuous cultivation both during the rainy and dry seasons. However, Kanfanin Kutare has a natural body of water as its source of water for irrigation which serves as the control because it was presumed to have been devoid of so much contamination, the other four sites have drainage channels used as sources of water for irrigating the vegetables produced during the dry season farming. The drainage channels run through residential areas and places of various activities. There geo reference were captured as follows: **Kanfanin kutare** (09^{0} 31$'$ 54.7$''$ N / 006^{0} 35$'$ 16.3$''$ E, 09^{0} 31$'$ 55.9$''$ N/ 006^{0} 35$'$ 17.3$''$ E and 09^{0} 32$'$ 00.9$''$ N/ 006^{0} 34$'$ 56.0$''$ E), **Morris Site** (09^{0} 35$'$ 44.4$''$ N/ 006^{0} 32$'$ 14.4$''$ E, 09^{0} 35$'$ 53.5$''$ N/ 006^{0} 32$'$ 13.4$''$ E and 09^{0} 35$'$ 53.3$''$ N/ 006^{0} 32$'$ 12.9$''$ E), **Ketaren Gwari** (09^{0} 36$'$ 14.9$''$ N/ 006^{0} 32$'$ 16.1$''$ E, 09^{0} 36$'$ 16.1$''$ N/ 006^{0} 32$'$ 16.5$''$ E and 09^{0} 36$'$ 12.9$''$ N/ 006^{0} 32$'$ 16.9$''$ E), **Opposite Federal Secretariat** (09^{0} 37$'$ 31.9$''$ N/ 006^{0} 31$'$ 34.0$''$ E, 09^{0} 37$'$ 32.0$''$ N/ 006^{0} 31$'$ 34.2$''$ E and 09^{0} 37$'$ 33.6$''$ N/ 006^{0} 31$'$ 34.9$''$ E) and **Gidan Mongoro** (09^{0} 33$'$ 40.3$''$ N/ 006^{0} 30$'$ 29.0$''$ E, 09^{0} 33$'$ 40.3$''$ N/ 006^{0} 30$'$ 30.0$''$ E and 09^{0} 33$'$ 40.5$''$ N/ 006^{0} 30$'$ 28.9$''$ E).

2.3 Sampling and Analysis of Irrigation Water

Water samples at each site three (3) times at intervals during irrigation potential period in a year (December, March and June), considering the fact that water sample from the same source do differ in quality with time. Composite water samples at each sampling period were collected in the morning with polyvinyl chloride (PVC) bottles that were first rinsed 3-4 times with the water at the exact site of sampling before taking samples and finally kept in dry cool shaded place prior to analysis (Pennstate, 2018). In the water samples, heavy metals (cadmium, chromium, lead, copper and zinc) were determine using atomic absorption spectrophotometer after digesting with 5 mL concentrated nitric acid plus per chloric acid in 3:1 as described by Rodajevic and Bashkin (1999), concentration of total heavy metals (lead, cadmium, chromium, zinc and copper) were determined in the sampled water by digesting the water with 5mL concentrated nitric acid plus per chloric acid in 3:1 and analyzed by atomic absorption spectrophotometer (AAS) at a wavelength of 283.3 nm (Pb), 228.8 nm (Cd), 357.9 nm (Cr), 213.9 nm (Zn) and 324.7 nm (Cu). Total metals were determined by digesting and analyzing unfiltered sample.

2.4 Soil Sampling and Analysis

Composite soil samples were collected from the five (5) selected farmlands whose size ranged between 0.5-1.5 hectares that were irrigated with the sampled water. Three (3) soil samples from each of selected farmlands were collected using augering method at a uniform depth of 0-15 cm amounting to fifteen (15) soil samples which were air dried, disintegrated with wooden mortar and pestle and sieved with 2mm sieve for heavy metals determination according to standard methods as follows; Heavy metals (cadmium, chromium, lead, copper and zinc) were determined using atomic absorption spectrophotometer after digesting the soil samples using aqua regia digest method (Baker and Amacher, 1982). Soil samples were digested for heavy metal analysis using the aqua regia digest method. One gram of soil for each sample, in duplicates, were transferred into a 100 ml digestion flask to which 10 ml of aqua regia (a mixture of concentrated HCl and concentrated HNO_3 in the HCl:HNO_3 ratio of 3:1) was added before covering the digestion flask with a watch glass and allowing the mixture to react over night (for at least 12 hrs). The next day, the mixture was heated progressively and boiled under reflux for 2 hrs after which the digestion flask was allowed to cool. The cooling column was rinsed with 15 ml of distilled water recovering rinse water in the digestion flask. The mixture was separated using a centrifuge at 1500 rpm for 5 min after which a supernatant solution was collected into a 50 ml volumetric flask before diluting to the mark with hot 2 M HNO_3. The soil extract was analyzed for Pb, Cd, Cr, Zn and Cu using an atomic absorption spectrophotometer (model: Philips AA-10). Standard solutions were prepared in the concentration ranges of 0-5 mg L^{-1} for Pb, Cr, Zn and Cu while 0-1 mg L^{-1} for Cd. A blank determination was also carried out.

Annual heavy metal loading expected in the soil of the study site was estimated using the following equation:

$$ALR = C*Q*D*F*S*10^{-6} \qquad \text{Equation 1}$$

Where: ALR= annual loading rate, C= Elemental concentration in sample water (mg/ L), Q= Quantity of irrigation water (L/ hr/ ha), D= Duration of irrigation (hrs/ day), F= Frequency of irrigation (days/ week), S= Length of season (week/ yr) and 10^{-6}= Conversion factor from mg /L to kg/L.

3. RESULTS AND DISCUSSION

3.1 Irrigation Water Analysis

Concentration of Lead (Pb) in all collected water samples ranged from 0.010-0.017 mg L^{-1} with zero value recorded at the control (Kanfanin Kutare) site, Morris and Opposite federal secretariat (Table 1). The entire results obtained were less than standard permissible limit (0.05 mg L^{-1}) in water set by World Health Organization (WHO) for Pb in water as reported by Zigham *et al.* (2012). Exchangeable Cadmium (Cd) content in water samples from the various sites ranged from undetectable to 0.023 mg L^{-1} (Table 1). The Cd contents in all samples were within the permissible limit of 0.01 mg L^{-1} recommended by WHO (Zingham *et al*., 2012) except that of Ketaren Gwari, which was 0.023 mg L^{-1} a double value to the maximum permissible limit. Similarly, Cr content in the sampled water for the sites ranged from not detected to 0.060 mg L^{-1}. Samples from the control site Kanfanin Kutare and opposite Federal Secretariat recorded noting while concentration in sample from Ketaren Gwari was the highest followed by Gidan Mongoro with the corresponding values of 0.060 mg L^{-1} and 0.057 mg L^{-1} respectively (Table 1). Nevertheless none of the samples fail WHO rating of 0.1 mg L^{-1} (Zigham *et al.*, 2012). Zinc (Zn) concentration in the sampled water varied from 0.023--0.440mg /l (Table 1) for all the water sources, with the control (Kanfanin Kutare) having 0.023mg L^{-1} while Ketaren Gwari has 0.440mg L^{-1}. Reference to permissible limit allowed by WHO for Zinc in water of 5 mg L^{-1} as quoted by (Zigham *et al.*, 2012). One will concluded that these values for the water are by far less than the established maximum limit. Mean concentration of Cu in all the collected water samples for the period of review from the different sites are between 0.043--0.083 mg L^{-1} (Table 3.1). All the values reported were below the permissible limit of 2 mg L^{-1} allowed by WHO for Cu in water (Zigham *et al.*, 2012). Keteran Gwari source takes the lead virtually in almost the analysed variables this may link to its closeness to the mechanic village.

3.2 Expected annual loading rates (ALR) in kg/ha/year of heavy metals

Regarding to Expected annual loading rate (ALR) limits in kg ha^{-1} $Year^{-1}$ by United Kingdom as quoted by Nyamangara *et al.* (2005) of 7.5, 15, 0.15, 15,15 kg ha^{-1} $Year^{-1}$ for Cu, Zn, Cd, Cr and Pb respectively. Cadmium was the only metal found above the set limit in all the sites with exception of Morris (Table 2). The reason for cadmium exceeding limit may be attributed to its high mobility and bioavailability in relation to other metals (Singh and McLaughlin, 1999).

3.3 Heavy metal Concentrations in irrigation water samples at the study area over time (Seasons)

Row results of irrigation water quality indices depicted in the Table 3 show that there were variability between the replications (seasons), this may be partly as a result of differences in the season of sampling.

3.4 Heavy metal content in soils of the study area

All the metals analyzed, (lead (Lb), cadmium (Cd), chromium (Cr), zinc (Zn) and copper (Cu) one will authoritatively said the results presented in table 4 did not exceed limit. Generally, Ketaren Gwari site top the list in concentration for all the analyzed metal across all the locations with exception of Chromium which was higher at Morris but the differences are in close range. These unveiled results may be due to close proximity of Ketaren Gwari site with automobile mechanic workshops whose workers may turn the site as dumping ground for their repairs waste which are mostly metal base. In fact, there were some metals that was not even detected at other sites like Pb in Kanfanin Kutare and Opposite Federal Secretariat, same to Cr at the former. Also, Cu were reported in appreciably amount a cross all the sites even though it did not exceed set limit, this could be as a result of usage of Bordeaux mixture which is copper base in controlling fungi in the study area as attested by farmers during interaction at the cause of the research. Continuous application of Bordeaux mixture on soil could lead to gradual built up of some metals particularly copper to a toxic level for agro ecosystem according to Agbede (2009).

Table 1: Means values of heavy metals in the irrigation water of the study areas.

Properties	Kanfanin Kutare	Gidan Mangoro	Ketaren Gwari	Morris	Opp. Fed. Secretariat
Pb (mg/L)	ND	0.010	0.017	ND	ND
Cd (mg/L)	0.003	0.003	0.023	ND	0.010
Cr (mg/L)	ND	0.057	0.060	0.017	ND
Zn (mg/L)	0.023	0.120	0.440	0.230	0.197
Cu (mg/l)	0.070	0.083	0.057	0.047	0.043

ND: Not Detected

Table 2: Expected annual loading rates (ALR) in kg/ha/year of heavy metals at the study sites

Metal	Sites					ALR Limit in Kg/ha/yr
	A	B	C	D	E	
Pb	0	0.37	0	0	0.56	15
Cd	0.19	0.19	0.56	0	0.75	0.15
Cr	0	1.12	0	0.37	1.12	15
Zn	0.37	2.25	0.94	4.31	8.24	15
Cu	1.31	1.5	0.75	2.62	1.12	7.5

A= Kanfanin Kutare, B= Gidan Mongoro, C= Opposite Federal Secretariat, D= Morris, E= Ketaren Gwari

Table 3: Heavy metal Concentrations in irrigation water samples at the study area over time.

Time	Source	Pb (mg/l)	Cd (mg/l)	Cr (mg/l)	Zn (mg/l)	Cu (mg/l)
December, 2017	Kanfanin Kutare	0	0	0	0.01	0.04
	Gidan Mangoro	0.02	0	0.06	0.13	0.04
	Opp. Fed. Secretariat	0	0	0	0.19	0.01
	Morris	0	0	0.01	0.17	0
	Ketaren Gwari	0.04	0.01	0.08	0.36	0.02
March, 2018	Kanfanin Kutare	0	0.01	0	0.01	0.03
	Gidan Mangoro	0.01	0.01	0.04	0.12	0.03
	Opp. Fed. Secretariat	0	0.03	0	0.17	0.01
	Morris	0	0	0.03	0.22	0
	Ketaren Gwari	0.01	0.03	0.06	0.39	0.01
July, 2018	Kanfanin Kutare	0	0	0	0.05	0.14
	Gidan Mangoro	0	0	0.07	0.11	0.18
	Opp. Fed. Secretariat	0	0	0	0.23	0.11
	Morris	0	0	0.01	0.3	0.14
	Ketaren Gwari	0	0.03	0.04	0.57	0.14

Table 4: Some heavy metal content in soils of the study area

Parameter	Kanfanin Kutare	Gidan Mangoro	Opp. Fed. Secretariat	Morris	Ketaren Gwari
Lead(Pb) (mg/kg)	ND	0.19	ND	0.12	0.41
Cadmium(Cd) (mg/kg)	0.13	0.20	0.11	0.21	0.68
Chromium(Cr) (mg/kg)	ND	2.48	0.17	4.91	4.18
Zinc (zn) (mg/kg)	4.63	8.15	3.09	8.47	13.04
Copper (Cu) (mg/kg)	9.62	18.7	3.50	4.63	24.82

ND: Not Detected

4. CONCLUSION

The results of irrigation water from all the selected sources: Kanfanin Kutare (opposite IBB Specialist Hospital), Morris Fertilizer site, Ketaren Gwari (Mechanic village), Opposite Federal Secretariat and Gidan Mongoro reveals that all the tested variables: Lead (Pb), Cadmium (Cd), Chromium (Cr), Zinc (Zn) and Copper (Cu) are within the permissible limit with exception of cadmium at Ketaren Gwari site exceeded the standard(0.02mg/L) and this could be attributed to known chemistry of the variable for high mobility, perhaps this should be the reason for the estimated expected annual loading rate values showing only cadmium was found to be above the set limit in almost the sites. Conversely, of all the heavy metals evaluated on the soil of the study area zinc and copper were the only two found to be present in all the sites. This may be due the agronomic practices apply in controlling fungi using Bordeaux mixture a copper base substance by farmers of the study area and/or drained water from the zinc roofing since the study area was an urban, to some extent semi-urban settlement. The research suggested periodic monitoring of the irrigation water analytically, addition of organic matter to the soil to stem down cadmium mobility, proper farm sanitation as a means of controlling fungi instead of chemicals and sound legislation on building/town planning and waste disposal.

REFERENCES

Adeboye, M. K. A, Bala, A., Osunde, A. O., Uzoma, A. O., Odofin, A. J. & Lawal, B. A. (2011). Assessment of soil quality using soil organic carbon and total nitrogen and microbial properties in tropical agro ecosystems. *Journal of agricultural sciences*, 2, 34-40.

Agbede, O. O. (2009). *Understanding soil and plant nutrition*. Printed in Nigeria by Petra Digital Press. 38 Pp. ISBN: 978-978-900-087-6.

Alloway, B. J. & Ayres, D. C. (1993). *Chemical Principles of Environmental Pollution.* Blackie Academic and Professional An imprint of Chapman and Hall, Oxford, UK, 291 Pp.

Baker, D. E. & Amacher, M. C. (1982). Nickle, copper, zinc and cadmium. In: Page, A. L., Miller, R. H., Keeney, D. R. (Eds.), *Methods of soil Analysis, Chemical and Microbiology properties*. (pp. 323-336)., NY, USA, ASA Inc. SSSA Inc Publishers

Bennett, H. H. (2009). *Elements of Soil Conservation,* second edition. Biotech Books 1123/74, Tri Nagar, Delhi. 287 Pp.

FDALR (1990). *Literature review of soil fertility investigation in Nigeria* .Publication of the Federal Department of Agriculture and Land Resources, Lagos, Nigeria. 158 Pp.

Lenntech, B. V. (2017). Irrigation water quality. Culled on January 1, 2018 from https://lenntech.com/applications/irrigation/irrigation-water-quality.htm.

Nyamangara, J. & Mzezewa, J. (1999). The effects of long -term sewage sludge application on Zn, Cu, Ni and Pb levels in clay loam soil under pasture grass in Zimbabwe. *Agricultural Ecosystem and Environment,* 73, 199-204.

Nyamangara, J., Mangwayana, E. N., Mapanda, F. & Giller, K. E. (2005). The effects of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. Agriculturae Ecosystem & Environment. www.elsevier.com/locate/agee.

Omar, A. & Al-khashaman, A. (2004). Heavy metal distribution in dust, street dust and soils from the work place in karak industrial Estate . *Atmospheric Pollution*, 38, 6803-6812.

Pennstate (2018). How to collect a water sample-Agricultural Analytical Services Lab. Pennstate College of Agricultural Science. Retrieved January 1, 2018 http://agsci.psu.edu/aasl/water-testing/drinking-water-testing/how-to-collect-a-water-sample.

Pulford, I. D. (2007).The chemistry of the solid Earth. In; R.M. Harrison (Eds.), *Principles of environmental chemistry,* (pp. 100-108) .The Royal Society of Chemistry.

Radojevic, M. & Bashkin, V. N. (1999). *Practical Environmental Analysis.* The royal society of chemistry. 250 Pp.

Singh, B. R. & McLaughlin, M. J. (1999). Cadmium in Soil and Plants. Developments in Plant and Soil Sciences book series volume 85.

Tsado, P. A., Lawal, B. A., Eze. P. C., Afolabi, S. G. & Saidu, O. I. (2014). Assessment of the Suitability of Water Quality for Irrigation in Minna, Niger State. *International Journal of Research in Agriculture and Forestry.* 1(2), 13-17.

Tsado, P. A., Lawal, B.A., Igwe, C. A. & Eze, P. C. (2016). Evaluation of River Water Quality for Irrigation Purpose in Niger State, Nigeria. *Gashua Journal of Irrigation and Desertification Studies*, 2(1), 129-138. ISSN: 2489-0080.

Zigham, H., Zubbair, A., Khalid, U. K., Mazhar, I., Rizwanullah, K. & Jabar, Z. K. (2012). Civic Pollution and it is Effect on Water Quality of River TOi at District Kohat NWFP; *Research Journal of Environmental and Earth Science*, 4(3), 334-339.