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THE EFFECTS OF HEAVY METALS DISCHARGED INTO RIVER KADUNA ON THE QUALITY OF IRRIGATED FARMLANDS AT KADUNA METROPOLIS, KADUNA STATE

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Abstract

The farmlands along River Kaduna used for irrigation farming, suffer enormous pollution as a result of addition of water from the River Kaduna that had become contaminated. The study determines the concentration of selected heavy metals of the surface waters, the soil physico-chemical characteristics of the irrigated farmlands and examines the implications of the surface water pollution on the soils of farmlands used for irrigation along River Kaduna. The water samples were collected using grab method along River Kaduna at five points – Bypass, Barnawa, Down quarters, Kakuri-Makera drains and Kudendan at rainy season and dry season. Soil samples were also collected at the irrigated farmlands alongside the points. The water samples were taken to the laboratory and analyzed for Cr, Ag, Fe, Cu, Be, Al, Cd, Cyanide and Zn using Atomic Absorption Spectrophotometer and the soil samples were analyzed for pH, EC, OC, N, Ammonia, P, K, Ca, Na, Mg, Fe, Cu, Zn and Al. The concentrations of the parameters were observed to be higher than WHO acceptable limits. This revealed that the soils have become contaminated by heavy metals discharged into the farmlands from the River Kaduna and may cause serious ecological and health hazards. The paper recommends that there should be proper monitoring of effluents and there is the need for mass education of people on the impact of indiscriminate waste discharge on the water quality.

Keywords: Heavy metals, Pollution, Farmlands, Industrial wastes, Effluents.

Introduction

Heavy metals are among the major contaminants of food supply and are considered as problem to the environment (Zaidi, Asrar and Farooqu, 2005). Heavy metals contamination may occur due to irrigation with contaminated water, the addition of fertilizers, metal-based pesticides, industrial emissions, transportation, harvesting process and storage. Advancement in technology has led to high levels of industrialization leading to the discharge of effluents bearing heavy metals into our environment. The various activities by man in recent years have increased the quantity and distribution of these heavy metals in the atmosphere, land and water bodies (Zaidi et al., 2005). Human exposures to heavy metals occur primarily through inhalation of air and ingestion of food and water. The concentration of these metals in the environment varies considerably depending in the soil concentration and proximity to sources of emission (Muchuweti, Biekett, Chiyanga, Scrimshaw and Lester, 2006).

Excessive accumulation of heavy metals in agricultural soil through wastewater irrigation may not only result in soil contamination but also lead to elevated heavy metal up take by crops and thus affect food quality and safety (Muchuweti et al., 2006). Heavy metal accumulation in soil and plants is of increasing concern because of the potential human health risk. This food chain contamination is one of the important pathways for the entry of these toxic pollutants into the human body. Heavy metal accumulation in plant depend upon plant species and soil to plant transfer factors of the metal (Rattan, Dattan, Chhonkar, Shuribabu, and Sigh, 2005).

There are many sources of trace metals contaminants that can be accumulated in soils. Lead, nickel and

boron are gasoline additives that are released into the atmosphere and carried to the soil through rain and snow (Igwe, Ogunewa and Abia, 2005).

Farmlands were irrigated with water from Kaduna River and drainages within Kaduna Metropolis. For the past decades, water from these rivers was clean, however, with the increase in urban population and industrialization it now becomes contaminated with various pollutants among which are heavy metals (Igwe et al., 2005).

River Kaduna is a major source of water supply to the Kaduna city. The river basin is a booming crop farming area in both dry and raining seasons. The bank of River Kaduna is predominantly used for peasant vegetable crop farming of lettuce, cabbage and dry season fresh corns. Fertilizers, herbicides and insecticides are used on these crops – and are eventually washed into the river. Most of the industries (textile factories, NNPC Refinery and Peugeot Automobile Assembly Plants among others) located in the southern part of the city derive their water requirements from the river and discharge their wastes directly into the river (Federal Ministry of Environment, 2002). Trade wastes (from auto-mechanics, metal fabrication/finishing and abattoirs among others) are also directly or indirectly discharged into the river. Domestic sewage and refuse also found their way into the river from many settlements along the river via leaching, direct discharge. These suggest that there is every possibility of contamination of water, sediments and fish of River Kaduna by heavy metals since industrial effluents and municipal wastes are known to contain high amounts of heavy metals (Federal Ministry of Environment, 2002).

It has been demonstrated by Ali, Oniye, Balarabe and Auta (2005) that the use of industrial effluents and wastewaters for growing of crops have serious impacts in contamination of soils by heavy metals. A number of research have been carried out on the concentration of heavy metals of certain crops around the Makera Drain (Ali et al., 2005; Dadi-Mamud, Oniye, Balarabe, M.L, Auta and Gudugi 2011; Etonihu and Lawal, 2011), but none have considered the effects of heavy metal from the river on the irrigated farmlands along river Kaduna.

The aim of the paper is to examine the concentration of some of the River Kaduna heavy metal pollutants and the effects on the irrigated farmlands. The study determines the concentration of the heavy metals of the surface water of River Kaduna, the soil physico-chemical characteristics of the irrigated farmlands and examines the implications of the surface water pollution on the soils of the irrigated farmlands along the River Kaduna.

The study area

Kaduna Metropolis has a total land area of about 3,080km^2. It is located between Latitudes 10^0 52' and 10^0 30'N and Longitudes 7^0 15' and 7^0 45' east, (Figure 1)

The area is situated on a relatively low plain liable to flood (Bureau for Land and Survey Kaduna, 2010). The topography of the area consists of a rolling park-like terrain with little relief situated about 100ft (33m) above sea level (Adetola, 2000). The soils of the study area fall within the tropical ferruginous soils. The topsoil is coarse sandy loamy to clay loamy (Adetola 2000). The area was initially characterized by over 80% agricultural land-use. However, owing to the petroleum industry, the land-use pattern is fast changing.

The climate of the study area is part of the tropical wet and dry climate of Nigeria. The climate is characterized by the wet and dry seasons. The wet season begins in April and ends in October. Though, there are fluctuations in the beginning and the ending of the seasons from year to year in some years it begins early May (Adetola, 2000). The area has a mean annual rainfall of about 1204 to 1567mm, mean daily temperatures of between 27^{0}C and 33^{0}C, and relative humidity of about 99% during the wet season and less than 55% in the dry season (Adetola, 2000).

The river Kaduna took its source from Jos Plateau. The river divides the Kaduna metropolis into two major areas, thus: Kaduna north and Kaduna south. The north houses mostly the commercial centers, residences and business activities and the south is mostly the industrial area.

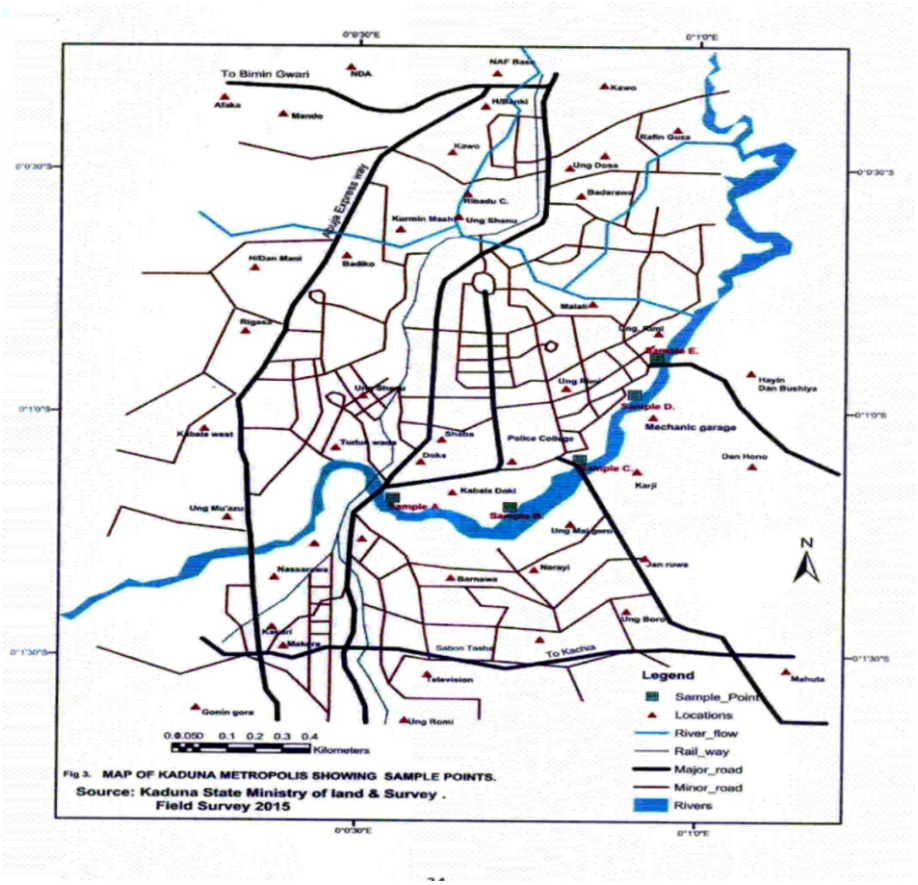


Fig. 3. MAP OF KADUNA METROPOLIS SHOWING SAMPLE POINTS.
Source: Kaduna State Ministry of land & Survey .
Field Survey 2015

Fig. 1: Map of Kaduna Metropolis showing sample points

Materials and methods

Water samples collection

For this research, five water sampling points were chosen along the river Kaduna. The surface water samples were collected at the mid-stream using grab method. The collections were done at the depth of 20 - 30cm directly into clean 1 litre plastic bottles at the intervals of two kilometers each. The samples were marked A, B, C, D and E. The samples were collected for two seasons (rainy and dry). The first samples were collected on the 25th of July and 3th August, 2015 when the volume of the water had increase in the rainy season. The same procedure of collection of samples was repeated on 28th February and 3rd of March, 2015 when the volume of the water had reduced during the peak of dry season. Sample **A** was collected along the Kaduna eastern by-pass, sample **B** at Barnawa area, sample **C** was collected at Down quarters, sample **D** was collected at Kakuri – Makera drains and the last sample **E** was collected at downstream of Kaduna river at Kudedan. The samples were immediately taken to the Kaduna State Water Board laboratory for analysis.

Soil samples collection

Five soil samples were also collected at the irrigated farmlands alongside the points of water samples collected along the River Kaduna. The collections were done at the depth of 30cm using Auger at a distance of 40meters from the river bank. The samples were marked A, B, C, D and E and were taken to the Institute of Agricultural Research, Zaria for analysis.

Water samples analysis

The collected samples were analyzed for Lead (Pb) Chromium (Cr) Arsenic (As) Iron (Fe), copper (Cu), Berium (Be), Aluminium (Al), Cadmium (Cd), Cyanide and zinc (Zn) which are considered as those very critical for water quality. The Atomic Absorption Spectroscopy (AAS) method was employed in the analyses of the parameters. The results of the analysis were compared with the World Health Organization (WHO) Water Quality Standard.

Soil samples analysis

In carrying out the soil analyses, emphasis was placed on those soil properties directly affecting soil quality and served as the support pillar for plants survival. The parameters analyzed were pH, Electrical conductivity, Organic Matter, Nitrate, Ammonia, Phosphorus, Potassium, Magnesium, Calcium, Sodium, Copper, Zinc and Iron. The pH was determined using pH meter and for nitrate and phosphorus Iceldak method was adopted. The Atomic Absorption Spectroscopy (AAS) method was employed in the analyses of the heavy metal parameters. The results were plot in Bar graph using FEPA recommended Standard as control parameter to compare the concentration level of the observed parameters.

Results

Water sample results of the rainy season heavy metals of River Kaduna

The result shows that the concentration of Chromium at all the observed points A, B, C, D and E are above the standard limit of WHO. At point A, the value of Chromium was 144mg/l, 1.65mg/l, at B and at C is 1.55mg/l. The value increases at point D and E to 3.72mg/l and 3.69mg/l respectively due to the addition of metal content from the industrial wastes. The lowest value (144mg/l) was recorded in sample A.

The results of Iron obtained during the rainy season indicate that the values show a progressive increase from point A with the values of 0.976mg/l and 0.986mg/l at point C. The Samples D and E also shows a sharp increase of 5.20mg/l and 2.57mg/l at Makera-Kakuri drain and downstream respectively. All these values observed are above 0.3mg/l the limit standard of WHO. It was observed that the lowest value (0.97mg/l) was recorded in sample A and highest in sample D (5.20mg/l), with a mean of 2.14.

Copper values at points A, B and C as observed from the analysis are within the acceptable limit of 1.0mg/l of WHO standard. But at points D and E, the values were to 3.16mg/l and 1.22mg/l above the 1.0mg/l of WHO acceptable limit. The lowest value (0.502mg/l) was recorded in sample A and highest in sample D

Table 1: Rainy Season Water Samples Results along River Kaduna

Parameters	Point A (Bypass)	Point B (Barnawa)	Point C (D/qtrs.)	Point D (Kakuri - Makera Drains)	Point E (Kudedan)	WHO Standard
Chromium (mg/l)	1.44	1.65	1.55	3.72	3.69	0.1 mg/l
Iron(mg/l)	0.976	0.976	0.986	5.20	2.57	0.3 mg/l
Copper (mg/l)	0.502	0.502	0.614	3.16	1.22	1.0 mg/l
Zinc(mg/l)	0.408	0.427	0.434	2.32	1.19	1.0mg/l
Arsenic (mg/l)	0.448	0.467	0.765	2.59	1.01	0.5 mg/l
Lead(mg/l)	0.627	0.648	0.765	3.67	1.45	0.1 mg/l
Cyanide (mg/l)	0.0004	0.0014	0.009	0.007	0.006	0.1mg/l
Barium (mg/l)	3.01	3.2	3.2	8.1	7.89	0.1mg/l
Aluminium (mg/l)	0.15	0.37	0.37	0.14	0.9	0.1mg/l
Cadmium(mg/l)	0.002	0.002	0.03	0.2	0.01	0.01mg/l

Source: Authors, 2017

Table 2: Dry Season Water Samples Results along River Kaduna

Parameters	Point A (Bypass)	Point B (Barnawa)	Point C (D/qtrs.)	Point D (Kakuri - Makera Drains)	Point E (Kudedan)	WHO **Standard**
Chromium (mg/l)	1.94	1.76	1.75	3.97	3.96	0.1 mg/l
Iron(mg/l)	1.676	1.876	1.986	5.45	2.95	0.3 mg/l
Copper (mg/l)	0.704	0.704	0.714	3.61	1.42	1.0 mg/l
Zinc(mg/l)	0.218	0.627	0.644	2.43	1.20	1.0mg/l
Arsenic (mg/l)	0.648	0.967	0.965	2.99	1.13	0.5 mg/l
Lead(mg/l)	0.827	0.828	0.965	3.97	1.67	0.1 mg/l
Cyanide (mg/l)	0.0006	0.0016	0.011	0.009	0.008	0.1mg/l
Barium (mg/l)	3.42	3.42	3.14	8.10	7.89	0.1mg/l
Aluminium (mg/l)	0.15	0.77	0.77	0.97	0.92	0.1mg/l
Cadmium(mg/l)	0.00	0.004	0.04	0.3	0.11	0.01mg/l

Source: Authors, 2017

Table 3: Mean and Range (max. and min.) values of the Rainy Season Heavy Metals characteristics of the River Kaduna

Parameter	Rainy season	Dry season
Chromium mg/l	2.41(3.69-1.44=2.25)	2.68(3.97-1.75=2.22)
Iron mg/l	2.14(5.20-0.976=4.22)	2.79(5.45-1.68=3.77)
Copper mg/l	1.20(3.16-0502=2.66)	1.43(3.61-0.704=2.91)
Zinc mg/l	0.96(2.32-0.41=1.91)	0.91(2.43-0.218=2.22)
Arsenic mg/l	1.06(2.59-0.448=2.14)	1.34(2.99-0.648=2.34)
Lead mg/l	1.43(3.67-0.63=3.04)	1.65(3.97-0.827=3.14)
Cyanide mg/l	0.024(0.009-0.004=0.005)	0.006(0.011-0.006=0.006)
Barium mg/l	5.08(8.1-3.0=5.09)	5.19(8.10-3.14=0.01)
Aluminium mg/l	0.39(0.9-0.37=0.53)	0.72(0.97-0.15=0.82)
Cadmium mg/l	0.244(0.2-0.002=0.20)	0.091(0.11-0.004=0.11)

Source: Authors, 2017

The results of zinc obtained during the rainy season from the analysis indicate that the values at points A, B and C are within the accepted limit of 1.0mg/l of WHO standard. The values at points D and E did not conform to the standard of 1.00mg/l as stipulated by WHO. There is a sharp rise of 2.32mg/l and 1.19mg/l respectively. The lowest value (0.408mg/l) was recorded in sample A and highest in sample D (2.32mg/l),

The rainy season samples at points A, B, and C show that Arsenic parameter values are within the acceptable limit of WHO standard except at the point D and E where the values are 2.59mg/l and 1.01mg/l above the accepted limit of WHO.

As observed from the table, the values of Lead increases from point A, to the last point E where the values are above the acceptable limit of WHO standard of 0.1mg/l.

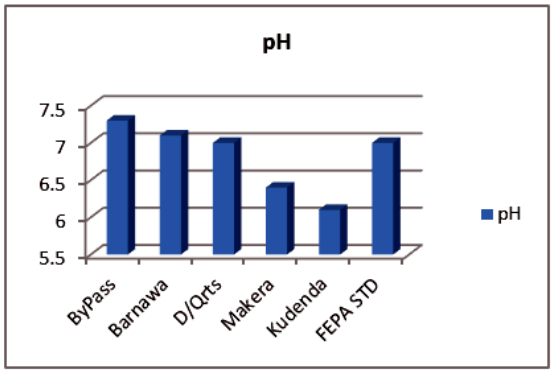
Cyanide, zinc, aluminum and copper with the exception of Iron, were observed to be low and are in agreement with FEPA standard. However their concentrations decreased both upstream and downstream from the discharge point.

Barium at sample point A was 3.01mg/l, point B 3.2mg/l, point C 3.2mg/l point D 8.1mg/l and point E recorded 7.89mg/l. the record observed is above the limit 0.1mg/l stipulated by FEPA. Aluminium was above the FEPA standard at all point of samples collected.

Cadmium was also observed to have the lowest value (0.002mg/l) recorded in sample A, B.

***Water sample results of the dry season heavy metals of river Kaduna*:**

The dry season sample results vary with the rainy season results because of the reduction in the volume of effluents discharged and the volume of water. It was observed that the results of the dry season water sample of River Kaduna in table1 shows a sharp increase in the concentration of the heavy metal parameters determined. The concentration of chromium in the river Kaduna is observed to be as high as 3.96mg/l at Kakuri – Makera drain and Kudenda above the permissible limit of WHO of 0.1mg/l. Other parameters observed such as iron, copper, zinc arsenic, lead, Barium Aluminium and Cadmium are highly concentrated in the water sample above the permissible values of WHO standard.



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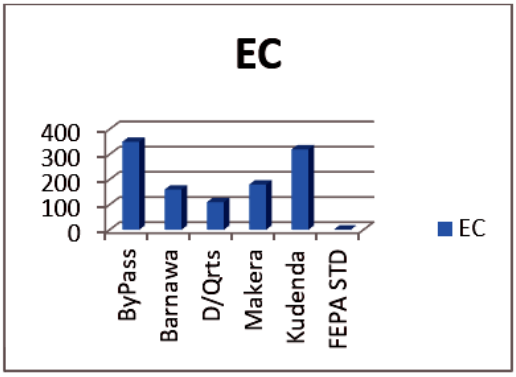

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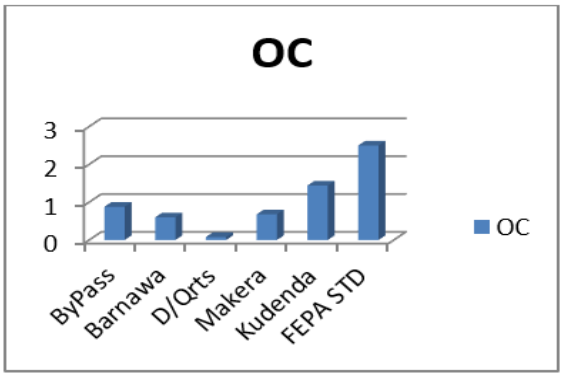
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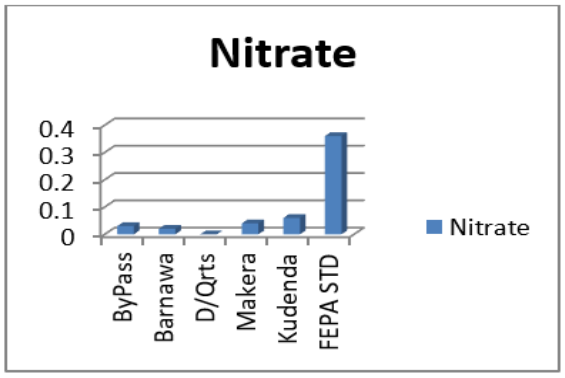
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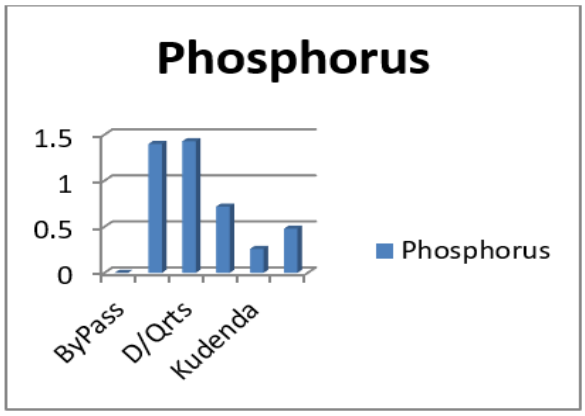
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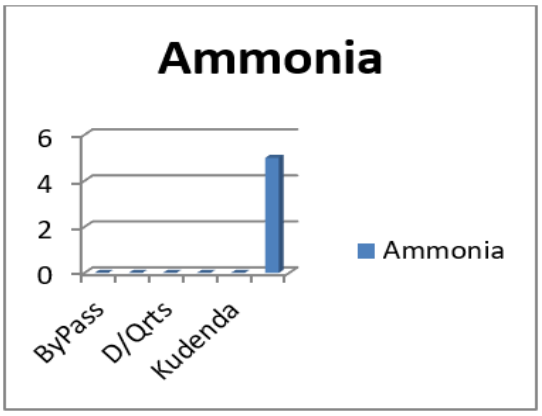
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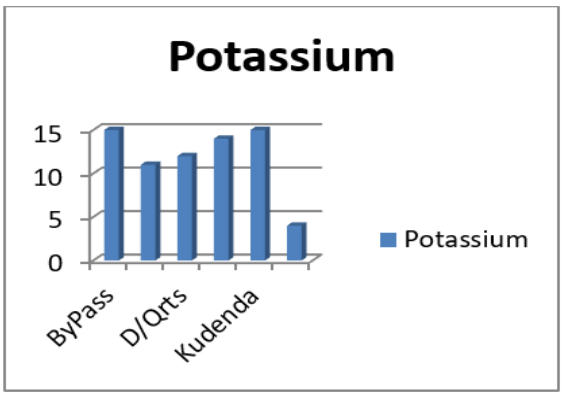
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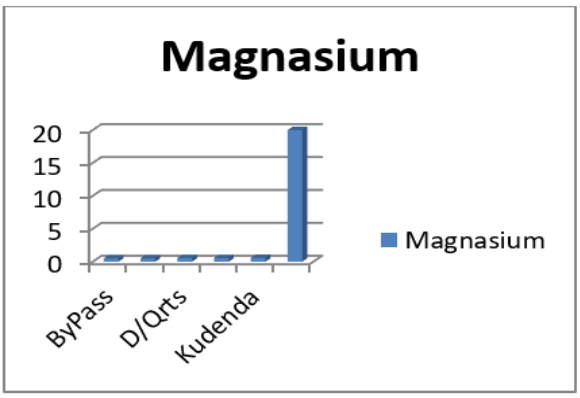
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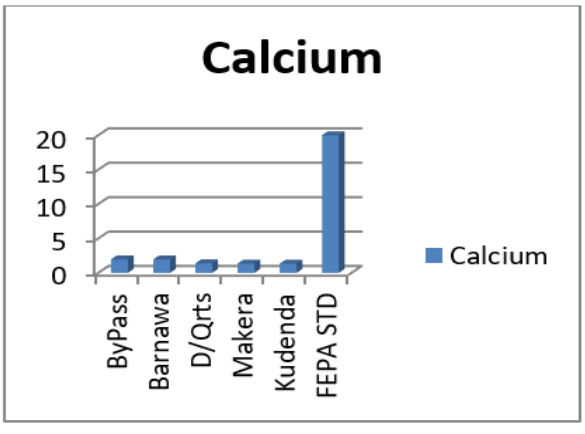
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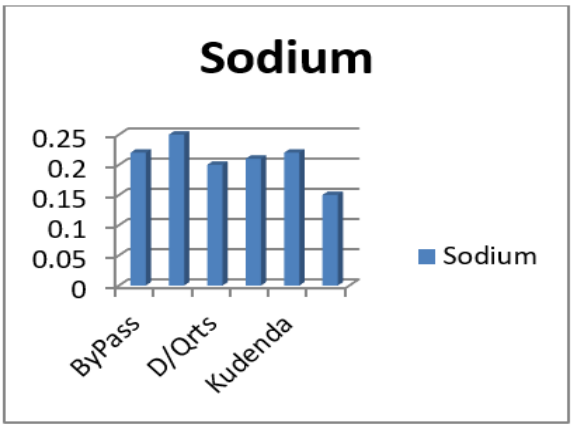
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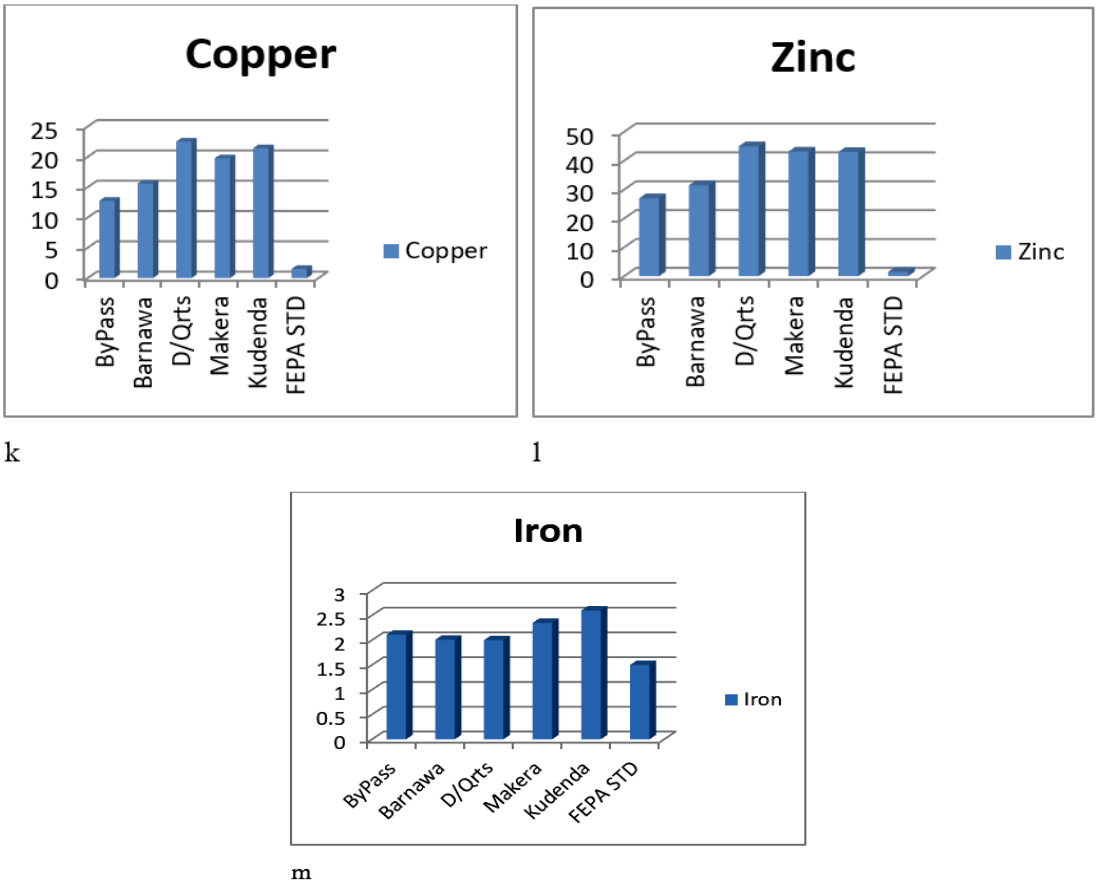

Fig. 2: Concentration values of soil parameters

Discussion

The results of the soils samples of the farmlands in figure 2 – 14 along river Kaduna used for irrigation have been revealed to be significantly altered. The quality of the soils may have been altered due to the addition of the water from the river used for irrigation over time.

From the results of the water samples parameters investigated in table 1, it shows that river Kaduna had become contaminated and its contaminants may be due to the content of the industrial and municipal effluents and waste discharges into the river. As observed the water samples parameters show that with the exception of Cyanide, the values of all other parameters were significantly higher. The dry season results values of all the parameters shows higher concentration than the rainy season due to the reduction in the volume of the water (Table 2)

As observed, the soils pH of the study area in figure 1 falls within the range of neutral to slightly acidic. It is indicative that the soil pH range was optimum for the most crops but with proper management. According to Yunana, Siaka and Danjuma (2014), soil with high acidity is detrimental not only to plants but also to other elements in the environment. An appreciable amount of micronutrients such as Zinc and Copper become toxic to plants

It was observed in figure 3 and 4, that the Organic carbon and Nitrate in the soils of the irrigated areas along river Kaduna is low. According to Yunana, et al, (2014), the slightly acidic values obtained in soils may affect the nitrifications and decomposition activities of the soils organisms. Hence, the effect is noticed in the low concentration of the organic and nitrate component of the soils. The mineralization of organic residues by bacteria and fungi, i.e. "microorganisms", releases inorganic nutrients such as nitrate, sulphate and phosphate that can then be utilized again by plants and other organisms. According to Purse glove, (1976), Nitrate seems to have the quickest and most pronounced effects on the yield of crops. It encourages the percentage of protein in the crops.

The micronutrients (Copper, Zinc and Iron) have been observed to exceed the permissible limits of FEPA standard. These micronutrients are needed in small quantity by the plants and therefore, if high in the soils they become harmful to the crops. Soil contamination by heavy metals is one of the problems threatening soil fertility and element cycling most seriously in many areas (Kandeler, Tscherko, Bruce, Stemmer, Hobbs, Bardgett, and Amelung, 2000). If present in sufficiently high concentrations, tend to reduce the size of the microbial populations, to destruct their community structure and to reduce their activity (Kandeleret al., 2000; Wang, Luo , Wei and Hua , (2004).

The results show that two of the exchangeable cations concentration (magnesium, and calcium) in the soils of irrigated farmland along river Kaduna is low. These elements are required in sufficiently large quantities for crops production because of the role they play in plant growth. For example, magnesium is an important constituent of chlorophyll and is needed in process of photosynthesis, while potassium encourages the developments of a strong fibrous root system. Similarly, calcium plays a role during photosynthesis process.

The results obtained in this study confirm the study carried out by Yunana *et al* (2014) who observed that the effluent discharge into the environment is detrimental to the farmers who cultivate the land by polluting the soils and creating certain conditions, which make essential nutrients, such as Nitrogen unavailable to the plants.

Conclusion and recommendation

The study has shown that the soil along river Kaduna used for irrigation have been revealed to be significantly altered due to the addition of the water from the river Kaduna over time. The used of the river for irrigation result to low nitrogen, phosphorus and increase the values of the Micronutrients in the soil. It is obvious that the river cannot be relied upon as a good source of water for irrigation. The farmers have been experiencing decline in crops outputs from their farmlands over the years. It is obvious the deteriorating crop outputs may be attributed to the nature of the water from river.

The study therefore, recommends that good soil management can improve the soil condition and build up soil fertility. The proportion of the organic matter can be increased by adding manure, compost and green materials.

Reference

Adetola, K. 2000. Notes and Model Answers on Geography for Secondary School Certificate

Ali, N., Oniye S.J., Balarabe M.L. and Auta, J. (2000). Concentration of Fe, Cu, Cr, Znand Pb in Makera – Drain, Kaduna, Nigeria. *Chemical Class Journal,* 2: (6973).

Bureau for Land and Survey Kaduna (2010). Map of Kaduna State Showing the Local Government Areas.

Dadi-Mamud, N.J., Oniye, S, Balarabe, M.L, Auta J, Gudugi I.A.S (2011). Toxicological Implications of Polluted Water from Makera Drain, Kaduna on Some Cereals and Horticultural Crops, Mediterranean *J. Social Sci. Vol. 3(16).*

Etonihu A.C, Lawal, K (2012). Continental J. Water, Air and Soil Pollution 4 (1): 1-7.

Igwe, J.C., Ogunewa, D.N., and Abia, A.A, (2005). Conmparative Adsorption of Zinc, Cadmium and Lead ions from aqueous solutions and non-aqueous solution by maize cob and husk. *Africa Journal of Bioechnology*. 4(10): 1113-1116

Kandeler E., Tscherko D., Bruce K. D., Stemmer M., Hobbs P. J., Bardgett R. and Amelung D. (2000). Structure and function of soil microbial community in microhabitats of a heavy metal polluted soil. Biology and Fertility of Soil. 32(5): 390 –400.

Muchuweti, M., Biekett, J.W., Chiyanga, E. Zvanya, R. Scrimshaw, M.D., and Lester, J.N., (2006). Heavy metal content of vegetables irrigated with mixture of wastewater andsewage sludge in Zimbabwe; the implication for human health. *Journal of Ecosystem Environment.* 112: 41-48

Purse glove, C.F,. (1976). Environmental Impact Assessment of Soils- Apractical Guide: St. Lugia Brishore, University of Queens Land Press.

Rattan, R.K., Dattan, P.K., Chhonkar, K., Shuribabu, K. and Sigh A.K., (2005). Long-term impact of irrigation with sewage effluent on the heavy metal content in soil, crops and ground water. A case study. Agricultural Ecosystem and Environment. 109: 310-322

Wang L. Q. Luo L, Ma Y. B, Wei D. P. and Hua L. (2004). In situ immobilizationremediation of

heavy metals-contaminated soils: a review, *Chinese Journal of Applied Ecology*. 20(5): 1214–1222.

Yunana M. A., Siaka S. and Danjuma, P (2014). Effects of Refinery and Petrochemical Effluents on the Vegetation of Romi River Area of Kaduna State. *Journal of Agricultural Sciences and Policy Research. Vol.4(1)*. Pp 21-33

Zaidi, M. I., Asrar, A. M., Farooqu, M. A, (2005). The heavy Metal concentration along roadside trees of Quetta and its effects on public health. *Journal of Applied Science*. 4: 708-711