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Heavy Metals in Soils Used For Irrigation of Crops along River Tatsawarki in Kano, Nigeria.

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Abstract:- Irrigation along River Tatsawarki involves the application of stream water and/or groundwater from tube wells believed to be recharged by the stream that flows through industrialized and residential areas. In the use of these sources of water for irrigation, of major concern is the concentration of heavy metals that are neither rapidly removed, nor readily detoxified by metabolic activities. Soil samples are collected from three irrigated farmlands (A, B and C) along the river banks and control samples (D) were also collected at the control farms located away from the river bank. The samples were collected at 0 – 15cm depth, placed in polyethylene bags and taken to laboratory for analysis. Two samples were collected from each zone, one from farmland using surface water as the only source of irrigation water, and another sample from farmland using groundwater as its sole source of irrigation water. The samples were analysed for pH, texture, and heavy metals (Cr, Cu, Co, Cd, Fe, Zn, Mn, and Pb). It was found that Irrigation with the polluted water has a significant effect on the soils heavy metals content. This eventually affects the groundwater as the soils were prone to high metals mobility because of its acidic nature and very low clay content which increases the porosity and poor retention capacity. In comparison with the EU limits only cadmium (Cd) was found to be out of the set limits. It was concluded that heavy metals accumulate in the soils and if the source of pollution is not checked, it will gradually reach and subsequently pass, the standard limit set. Urgent steps required to control this gradual accumulation is recommended.

Keywords:- Heavy Metals, Soil Pollution, Irrigation, Kano.

I. INTRODUCTION

Human activities have introduced potentially hazardous metals to the environment since the onset of the industrial revolution [1]. Aquatic ecosystems are polluted with high levels of toxicants (organic and inorganic substances), from wastewater and effluents generated from industrial enterprises [2]. Contaminated air, soil, and water by industrial effluents are associated with disease burden and this could be reasons for the current shorter life expectancy in developing countries [3] when compared with developed nations. In Kano, the current practice is the discharge of effluents into streams or canals after the retention period of some hours in the stabilization ponds without secondary or tertiary treatments [4]. Heavy metal toxicity adversely disrupts growth and other physiological processes of plant, specifically leading to great economic and ecological trauma [5].

If heavy metals move too rapidly in a particular soil, they can pollute ground water supplies, especially in areas with high water tables [6]. While it has generally been assumed that these metals are retained in agricultural soils [7], some factors that reduce their retention, and therefore enhance their mobility, can result in more plant uptake or leaching of these metals to ground water. These factors include the properties of the metals, soil texture, pH and competing cations in the soil solution. Reference [8], in an extensive review of heavy metal movement in sewage sludge-treated soils, concluded that movement most likely occurred where heavy disposal of sewage sludge was made on sandy, acidic and low organic matter soils, receiving high rainfall or irrigation water.

The mode of heavy metal transportation to roots and supply mechanism for ions in soil has been studied by [9]. The researchers assessed the nutritional status and trace element contamination of holm oak tree woodlands in Vesuvius National Park by analyzing Quercus ilex leaves and surrounding soils. The concentrations of Cd, Cr, Fe, K, Mg, Mn, Na, Ni, Pb, and Zn were measured in 1-year-old leaves and in the soils at 0-5 and 15-20 cm depths. The potentially available concentrations were also measured for the soils. Cadmium and Pb showed higher soil concentrations at surface layers than at deep layers. Cadmium, Pb and Zn percentages of available soil concentrations with respect to the total soil concentrations of each element was high and considerable translocation of Zn from soils to leaves was noted. They concluded that the uptake by root of crops was according to the root morphology as metal distribution in the soil profile decreases with depth.

The solubility of metal in soil solution is strongly influenced by some soil properties such as organic matter content, pH and clay content. Reference [10] showed pH to be a consistent predictor of the extractability of soil metals by reagents accepted as surrogates for bioavailability. They concluded that because metals formed complexes with soluble as well as solid phase organic matter, it might be the reason for low incidence of organic matter as a predictor variable.

Previous studies ([11], [12], [13], and [14]) have established the presence of some heavy metals in excess of the permissible limits set by FEPA and WHO in some of the effluents that are being discharged into the streams and the waters of the stream. If this is the case the use of industrial liquid waste for irrigation poses great danger to the soil and the crops. An assessment carried out by [15] showed high levels of manganese, lead and iron in water application as well as in the irrigated soil. A similar study by [16] attempted an assessment of the effect on ground water pollution. The study showed tolerable levels of mercury (0.05mg/l) and lead (less than 1 mg/l) in River Salanta (a tributary of River Tatsawarki) upstream of the site where effluent is discharged into the river. At the point of effluent discharge, the levels increased above the permissible limits of 17.5mg/l of mercury and 20.5mg/l of lead. The water used for irrigation had the highest concentration of lead (28.5 mg/l) and mercury (405mg/l). However, samples of shallow well water showed low levels of mercury and lead suggesting limited or no groundwater pollution [16]. Also, [17] identified concentration of heavy metal (iron, lead, manganese and chromium) in excess of the permissible limits set by FEPA. In this paper, an assessment of the level of heavy metals in soils used for irrigation of vegetable crops along the Tatsawarki River in Kano is presented, and the suitability of the soil for irrigation determined.

II. MATERIALS AND METHODS

A. The Project area

Kano is one of the three industrial zones of Nigeria. Reference [18] indicated that Kano is a booming industrial center with over 320 industrial establishments comprising of chemical and cosmetic industries, tanneries, textiles, and food processing factories which release waste water into streams. This has lead to the deterioration of water quality in the state. Reference [19] had earlier carried out industrial survey which showed that 60 industries discharged untreated effluent into rivers and only 6 industries surveyed (10%) had primary treatment plants ranging from oxidation tanks, to sedimentation tanks. Many of these factories were observed to dispose of their wastes either at the nearby bushes or directly into a neighboring stream or rivers such as River Salanta in south central Kano metropolis which empties into River Tatsawarki and eventually into River Challawa (Figure 1). This was in spite of the government efforts to curve out the menace. The nefarious activity was thought to have adversely affected the vegetation including crops and animals around the river basin, perhaps throughout the course of River Challawa, Wudil and Hadejia –Jama'are rivers where such water finally entered [13].

Irrigation along River Tatsawarki involves the application of stream water and/or groundwater from tube wells believed to be recharged by the stream that flows through industrialized and residential areas to irrigate crops. In the use of these sources of water for irrigation, of major concern is the concentration of heavy metals that are neither rapidly removed, nor readily detoxified by metabolic activities [20]. Farmers had often complained of the toxic effect apart from the poignant odour of the effluents against human skin and with a potential of killing wild and domestic animals – fish, birds and rodents [21].

B. Soil Sample Collection and Preservation

The soil samples are collected from three irrigated farmlands (A, B and C) along the river banks and control samples (D) were also collected at the control farms located away from the river bank (Figure 2). Zone C is located upstream of the River at Magami Village. Zone B is located mid-way downstream at Gidan Kwanso Village just before the confluence with the channel that discharges effluents from the Tamburawa Water Works. Zone A is located around Tsafe Village just before the confluence with the Challawa River, which immediately empties in to the Kano River. The samples were collected at 0 – 15cm depth, labeled, placed in polyethylene bags, and taken to laboratory for analysis. Two samples were collected from each zone, one from farmland using surface water as the only source of irrigation water and another sample from farmland using groundwater as its sole source of irrigation water.

Sample collection was done using the standard procedure described by the Department of waters affairs and forestry Pretoria (SA) [22]. The following parameters were recorded at the site of collection: name of sample, zone and time and date of collection.

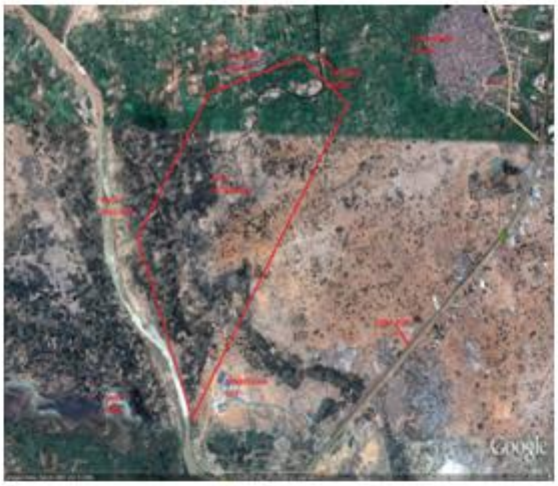

Figure 1: Project Area Location (Google, 2011).

Figure 2: Location of Sampling Points

C. Determination of Soil Texture

This was determined using Bouyoucos Hydrometer and Calgon (sodium hexametaphosphate) reagent [22]. 50g of air dried 2mm sieved soil was weighed into a flask and 100ml of solution of calgon and sodium carbonate was added and kept for 30minutes. Stirring was done with a mechanical end-over-end shaker for 15 minutes after which the suspension was transferred into the measuring cylinder and distilled water added to 1000ml mark. Stirring was done with a plunger and at 40 seconds the hydrometer reading was taken and the temperature determined. The cylinder was then left on a stable surface undisturbed, after 5 hours, the hydrometer and temperature readings were taken. The texture was determined using equations (1), (2), and (3).

Clay (g/100kg) = [(H x 1000)/W] – 1 (1)

Silt + Clay (g/kg) = [(M x 1000)] – 1 (2)

Silt (g/kg) = (Silt + Clay) – Clay (3)

Where 1 = is the calgon correction factor
W = Weight of soil (oven dry basis (gm)
M = Hydrometer reading at 40secs (g/l)
H = Hydrometer reading after 5hrs (g/l)

D. Determination of soil pH

This was determined using Soil pH in distilled water and 0.01M $CaCl_2$ and buffer solutions at pH 4, 7 and 9.2 [22]. 20g of air dried 2mm sieved soil was weighed in duplicate into 50ml beaker. One 20ml of distilled water was added into the duplicate 20ml of 0.01M $CaCl_2$. They were allowed to stand for 30minutes and stirring was done occasionally with a glass rod. The pH meter was standardized with buffer solutions of pH 4, 7 and 9.2, the pH of the soil in water and $CaCl_2$ was then read in the pH meter.

E. Pre-treatment of Soil Samples for Analysis of Heavy Metals

The double acid extraction method was employed [22]. The extraction reagent (0.05M HCl in 0.125M H_2SO_4): 80ml of 6M hydrochloric acid (HCl) and 7ml of conc sulphuric acid (H_2SO_4) were diluted to a final volume of 10liters with deionized water. 5g of soil sample was weighed into an acid washed 50ml extraction bottle. 25ml of the extraction reagent was then added and then shaken for 15minutes on reciprocating shaker at a minimum of 180 oscillations per minute. The suspension was filtered through Whatman No. 42 filter paper. The filtrate was then used for the determination of the metals.

F. Determination of Heavy Metals

Analysis of heavy metals was conducted using Atomic Absorption Spectrophotometer (AAS). The heavy metal concentrations were determined using the absorbance made with air-acetylene flame [23]. Eight working solutions were prepared from the stock solutions for each of the metals (Cr, Cu, Co, Cd, Fe, Zn, Mn, and Pb) by successive serial dilution and each of the standard solutions was then aspirated into the flame of AAS and the absorbance recorded in each case. A plot of the concentration against the corresponding absorbance gives the calibration curve of each metals. The samples, after aspirated into the flame and the absorbance obtained were then extrapolated from the calibration plot to get the corresponding concentration.

III. RESULTS AND DISCUSSIONS

A. Soil Classification Based on pH and Texture

The results of the analysis of Soil pH and Texture are presented in Table 1. The soil classification is discussed based on the pH and Texture.

1) *Soil Texture:* The soils from all the three irrigated farmlands have very low clay contents with high sand – silt content (Table 1) which implies reduced retention by agricultural soils. This thus enhances mobility of the metals which results to leaching of these metals to the ground water more especially with the low pH values exhibited by most soils in the research area (Table 2). This also applies to the soil from the control farmland at Kwarin Matage.

Table 1: Soil Classification Based on pH and Texture

S/N	Soil Samples	Soil pH	Sand %	Silt %	Clay %	Textural Class
	Control sample	6.6	73.10	24.80	2.10	Loamy Sand
1	Sample MS	5.5	71.10	26.82	2.08	Loamy Sand
2	Sample GS	6.0	69.10	27.78	3.12	Loamy Sand
3	Sample TS	6.0	51.20	46.60	2.20	Sandy Loam
1	Sample MG	6.1	33.10	64.56	2.34	Silty Loam
2	Sample GG	6.9	73.10	23.76	3.14	Loamy Sand
3	Sample TG	6.0	53.00	44.80	2.18	Sandy Loam

2) *Soil pH:* Generally, soils from all the three irrigated farmlands shows pH values within the acidic class ranging from strongly acidic to neutral pH classes (Tables 1 and 2). The soil in the Magami farmlands in zone C, which is irrigated with the surface water (MS), is strongly acidic with a pH of 5.5. The soils irrigated with surface water (GS) from Gidan Kwanso (Zone B) as well as the surface (TS) and ground water (GS) samples from Tsafe (Zone A) farmlands are moderately acidic with pH of 5.6 – 6.0. The ground water samples (MG) from Magami farmlands (Zone C) is slightly acidic with a pH of 6.1 while the ground irrigation water from Gidan Kwanso farmlands (GG) was neutral with a pH of 6.9. In comparison, the soil from the control farmland in Kwarin Matagi village is neutral with a pH of 6.6. The general acidity of the soils implies enhanced mobility of metals which in-turn poses the danger of contaminating the groundwater.

Table 2: Most Common Classes of Soil pH [24]

S/N	**Class**	**pH**
1	Extremely acid	3.5 – 4.4
2	Very strongly acid	4.5 – 5.0
3	Strongly acid	5.1 – 5.5
4	Moderately acid	5.6 – 6.0
5	Slightly acid	6.1 – 6.5
6	Neutral	6.6 – 7.3
7	Slightly alkaline	7.4 – 7.8
8	Moderately alkaline	7.9 – 8.4
9	Strongly alkaline	8.5 – 9.0

Source: [24]

B. Heavy Metals in Soil Samples

The results of the analysis of heavy metals in soils are presented in Table 3. These results are compared with the Limiting Values for Concentration of Heavy Metals in Soils (Table 4) prescribed by the European Union [25]. These are discussed according to each of the heavy metal analyzed.

Table 3: Results of the Analysis of Heavy Metals in Soils

SN		PARAMETERS (mg/kg)							
		Pb	Cr	Cd	Fe	Mn	Co	Zn	Cu
	Control sample	**11.2**	**6.8**	**2.8**	**2.2**	**1.5**	**3.8**	**7.7**	**4.0**
1	Sample MS	10.4	10.9	4.0	2.0	3.0	8.0	13.6	8.7
2	Sample GS	9.8	13.6	4.0	2.0	4.5	2.3	13.6	8.7
3	Sample TS	9.9	14.5	10.0	3.0	3.0	1.9	13.1	6.0
	Average	**10.0**	**13.0**	**6.0**	**2.3**	**4.7**	**4.1**	**13.4**	**7.8**
1	Sample MG	8.7	7.3	2.0	1.6	2.5	1.5	8.2	2.7
2	Sample GG	8.4	9.1	5.0	2.6	3.0	2.7	10.5	6.7
3	Sample TG	8.3	14.5	2.0	2.2	1.5	1.9	10.9	6.7
	Average	**8.5**	**10.3**	**3.0**	**2.2**	**2.3**	**2.0**	**9.9**	**5.4**

MS – Magami farmlands – Surface water irrigated soils
GS – G/kwanso farmlands – Surface water irrigated soils
TS – Tsafe farmlands – surface water irrigated soils

MG – Magami farmlands – Groundwater irrigated soils
GG – G/kwanso farmlands – Groundwater irrigated soils
TG – Tsafe farmlands – Groundwater irrigated soils

Table 4: Limiting Values for Concentration of Heavy Metals in Soils [25]

Elements	Limit Values (mg/Kg)			
	6<pH<7	5≤pH<6	6≤pH<7	pH≥7
Cd	1 – 3	0.5	1	1.5
Cr	-	30	60	100
Cu	50 – 140	20	50	100
Hg	1 – 1.5	0.1	0.5	1
Ni	30 – 75	15	50	70
Pb	50 – 300	70	70	100
Zn	150 - 300	60	150	200

Source: [25]

1) Chromium, Cr: The concentration of metal chromium in the irrigated soils is within the limiting values for concentration of heavy metals in soils (Table 4). However, all the values obtained are higher than the values obtained from the control site (6.8 mg/kg), with the soils irrigated with surface water exhibiting higher values (13.0 mg/kg on average) than those irrigated with groundwater averaging 10.3 mg/kg (Table 3).

2) Cadmium, Cd: The concentration of the metal cadmium in the soil samples from the irrigated farmlands irrigated with surface water is out of the set limit values for concentrations of heavy metals in soils by EU (Table 4), though all values obtained are found to be higher than the values obtained in the soils irrigated with groundwater which are within the set limits of 1 – 3 mg/kg on average. All values obtained showed higher values in relation to the control soil cadmium content of 2.8 mg/kg (Table 3).

3) Zinc, Zn: The concentration of the metals Zn in the soils in the irrigated farmlands was found to be within the limiting values for concentration of heavy metals in soils (EU Standard) with soils irrigated with surface water showing higher zinc content value (13.4 mg/kg average) more than soils irrigated with groundwater of (9.9 mg/kg average) (Table 3 and 4). All values obtained showed higher values than the control sample.

4) Cupper, Cu: The concentration of the metals Cu in the soils in the irrigated farmlands was found to be within the limit values for concentration of heavy metals in soils (EU Standard) with soils irrigated with surface water showing highinger copper content value (7.8 mg/kg avg) more than soils irrigated with groundwater of 5.4 mg/kg average (Tables 3 and 4). All values obtained showed higher values than the control sample (4.0 mg/kg average).

5) Lead, Pb: The concentration of the metal lead in all the soil samples collected from the irrigated farmlands is within the limiting values (Tables 3 and 4), so also samples irrigated with surface water exhibits higher concentration of lead (10.0 mg/kg average) than those irrigated with groundwater (8.5 mg/kg average). However, the samples lead concentration is lower than that of the control sample. This could be attributed to the proximity of the control irrigated farmland to the Kano – Kaduna highway which bears heavy traffic, and thus discharges high lead concentration from their exhaust emission in to the surrounding air environment.

6) Iron, Fe: The concentration of the metal iron is in conformity with the concentration of the metal in the control sample averaging 2.2 mg/kg, with samples irrigated with surface water showing slightly higher value of 2.3 mg/kg average (Tables 3 and 4).

7) Manganese, Mn: The concentration of the metal manganese in the soil samples is higher than the concentration obtained in the control sample of 1.5 mg/kg (Table 3) and the results shows the concentration of the metal as 4.7mg/kg average in the surface water irrigated soils and the groundwater irrigated samples shows an average concentration of 3.3 mg/kg.

8) Cobalt, Co: The concentration of the metal cobalt in the soils irrigated with surface water shows higher value of 4.1 mg/kg average which is higher than the concentration obtained in the control sample (3.8 mg/kg) while the concentration obtained in the sample irrigated with groundwater shows a lower concentration than the control sample of 2.0 mg/kg average (Table 3). This may mean low leaching of Cobalt in to the ground water.

IV. CONCLUSION

Irrigation with the polluted water has a significant effect on the soils heavy metals content which eventually affects the groundwater as the soils were prone to high metals mobility because of its acidic nature and very low clay content which increases the porosity and poor retention capacity. In comparison with the EU limits only cadmium (Cd) was found to be out of the set limits. However, heavy metals accumulate in the soils and if the source of pollution is not checked, it will gradually reach and subsequently pass the standard limit set. Thus urgent steps are required to control this gradual accumulation. A holistic understanding of the linkage between health and environment is urgently needed in order for improved management techniques to be implemented as such more researches in the area are recommended to be able to establish the linkages. The authorities and other stakeholders should start planning the means and methods to clean the soils off the heavy metals before they reach the threshold level of serious environmental damage. All stakeholders should also ensure that all defaulting industries are sanctioned for violating industrial effluent standards.

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