APPRAISAL OF THE SUITABILITY OF RIVER RIDO FOR IRRIGATION IN KADUNA STATE, NIGERIA

BUGGU, L. T.[1], ABENU, A.[2], YUSUFU, F. A.[3], YAHAYA, T. I.[4]., & AUDU, E. B.[5]
[1]Nigerian National Petroleum Corporation, Abuja
[2]Department of Civil and Environmental Engineering,
Air Force Institute of Technology, Kaduna, Nigeria
[3]Department of Geography, College of Education, Akwanga, Nasarawa State, Nigeria
[4]Department of Geography, Federal University of Technology, Minna, Nigeria
[5]Goverrnment Secondary School, Abuja@30, Pegi, Federal Capital Territory, Nigeria
Email: ltbuggu@yahoo.co.uk **Phone No:** +2348033084433

Abstract
The suitability of River Rido for irrigation purpose was determined through the assessment of the water quality. Twelve water samples were collected and tested for pH, electrical conductivity (EC), total dissolved solids (TDS), sodium (Na), calcium (Ca), magnesium (Mg) potassium (K), ammonium nitrogen (NH_4-N), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu) and iron (Fe). Sodium Adsorption Ratio (SAR) was derived from some of the measured parameters. EC and Mg had relatively higher values at the upstream compared to values observed downstream. The downstream was the section where the highest values of Na, Ca, K, NH_4-N and SAR were found. The mean of EC was 122.1, PH 6.8, TDS 83.8, Na 14.7, Ca 14.5, Mg 6.5, K 17.3 and NH_4-N 0.2. The values of pH, EC, TDS, Na, Ca, K and NH_4-N were within the allowable limits. The mean value of SAR was 4.55 meq/L; which indicated that the adsorption of sodium is excellent. The values obtained showed that the use of the water from River Rido for irrigation will not expose the soil to salinity and alkalinity hazards. However, the concentrations of heavy metals in the water makes it unsafe for irrigation, as it contaminates the crops cultivated and endangers the health of both man and animals that consume the crops. The highest values of As, Cd, Cr and Fe were observed downstream with content levels of Cu being the only exception, out of the five heavy metals tested. To reduce the level of contamination, effluents discharged into the river by the Kaduna Refinery and Petrochemical Company (KRPC) should be treated to meet standard set by the World Health Organisation and regulatory bodies; and the Kaduna Environmental Protection Authority (KEPA) should monitor the activities of KRPC and make it comply with guidelines of industrial effluent discharge.

Keywords: Irrigation, water quality, salinity, alkalinity and effluents

Introduction
The available fresh water on the earth's surface has three basic uses: industrial, agricultural and domestic uses. The largest use of it is for agricultural activities mostly, irrigation which accounts for 70%; industrial activities 20%, while the remaining 10% is for various domestic uses (Cunningham & Cunningham, 2004; Wright & Nebel, 2004). The pattern presented in Nigeria is similar to the global statistics as Orubu (2006) observed that, the largest water use in Nigeria is for agriculture, as it accounts for 54% of the total freshwater withdrawal in the country. This scenario implies that, uncontaminated water is required for irrigation, as according to Habbari *et al*., (2000) cited in Odigie (2017); without adequate safeguards, wastewater irrigation can cause serious drawbacks to public health and environment.

Irrigation farming is a farming system commonly carried out in areas characterized by seasonal rainfall as well as regions of soil moisture deficit like the arid and semi-arid regions, where water deficit hampers agricultural productivity. It is an artificial application of water to the topsoil that serves as the root zone, for the immediate and subsequent use of the crop. The increased soil moisture promotes cropping, and in some cases multiple cropping (FAO, 1997; Mutsvangwa & Doranalli, 2006).

Irrigation practices in Africa take a large portion of the fresh water available because of the dry climate in many areas. The seasonality of rain that characterizes the tropical climate, which is the predominant climate in many parts of Africa is seen as a big factor in the large amount of water withdrawn for the traditional flood method of irrigation; which is the most common irrigation method used in the continent (Wright & Nebel, 2004). Other factors which call for the use of irrigation for agricultural activities in the zone are dry spells and droughts as rainfall is not always favourable for adequate crop production even during the wet season. According to Ita (2005) cited in Ojoye (2013), precipitation is the primary factor controlling the impact of occurrence and persistence of drought along with other variables such as evapotranspiration.

In southern region (forest ecological zone) of Nigeria, a high annual rainfall of over 2000 mm is experienced. This high amount of annual rainfall coupled with the fact that it lasts for most of the year means rainwater is available most of the time for rain-fed agriculture. According to Audu *et al.*, (2014), rain-fed agriculture is the major form of crop production in Nigeria. Rainfall amount in the northern region is relatively lower and the duration of the rain is shorter. The rainfall pattern in the North is characterized by a single peak of rainfall occurring usually in August. Thus, all year-round farming is only possible in the northern region (mostly in the sudano-sahelian zone) with the adoption of irrigation, which makes use of water from streams, rivers, lakes and underground aquifers (Federal Ministry of Water Resources, 2004; Akpabio & Ansa, 2013).

Increased human activities, as a result of rapid population growth has adversely affected the quality of water in streams, rivers, lakes, lagoons and underground aquifers globally, with most fresh water currently contaminated (Christopherson, 2006; Enger & Smith, 2006). This is because, in most cases; both untreated domestic and industrial wastes are carelessly dumped into these water bodies. UN-Water (2007) reported that close to 70% of untreated industrial wastes in developing countries are discharged into water where they contaminate existing water supplies. Thus, the discharge of industrial waste into surface water will often impact negatively on water resources and livelihoods. According to Oluyori *et al.*, (2019), the high concentration of pollutants in the soil have potential to reach and contaminate water resources, agricultural processes and thus threatening sustainable development.

Kaduna Refinery and Petrochemical Company (KRPC) Limited, one of the 11 subsidiaries created by Nigeria National Petroleum Corporation (NNPC), refines 110, 000 barrels per day (BPD) into high quality petroleum products and the manufacturing of petrochemical and packaging products. KRPC is primarily engaged in the manufacturing of fuel, lubricants and petrochemical intermediates, using petroleum as a principal input material (Austin, 2010). The activities of KRPC generates effluents which are disposed into River Rido (Amin, 2006; Oyewoye, 1964, cited in Buggu, 2018). According to Edokpayi *et al.*, (2017), wastewater consists of various classes of pathogens which can cause diseases of various magnitude to man by causing immediate negative health impact on people that use contaminated surface water resource for domestic, agricultural and recreational purposes. According to Ayotunde *et al.*, (2019), in Nigeria; nearly all abattoir facility disposes their waste on the land or stream with or without pretreatment. This, however, destroys the life in the aquatic environment.

The assessment of the suitability of River Rido for irrigation in Kaduna State is, therefore, timely as the inhabitants of Rido in Kaduna state are majorly farmers who rely on the water source for irrigation particularly in the dry season.

Research Questions

(i) What is the level of chemical concentrations in River Rido, Kaduna State?

(ii) Does the level of chemical concentrations in irrigation water fall within acceptable ranges recommended by FAO/WHO?

The Study Area

The study area is located some 16 kilometers south of Kaduna metropolis. It lies between longitudes 7° to 8° east and latitudes 10° to 11 ° North. KRPC facility lies between latitudes 10° 24' 36.18"N and 1.6.2 area of the region (Figure 1). The study area has distinct wet season (May-September) and dry season (October-April) which are features of the tropical continental climate that prevails in the area. The rainfall characteristics include mean of about 1202.4 mm; maximum of 1658.9 mm recorded in 2014; range, 865.5 mm and minimum of 793.4 mm which was observed in 2008 (Audu *et al.,* 2018a). According to Audu *et al.*, (2018b); Audu *et al.,* (2019); both rainfall and heavy rainfall over Kaduna are on the increase. Single maximum heavy rainfall is experienced in August and September (Audu *et al.,* 2019). The study area is drained by River Rido, one of the tributaries of River Rigasa, which drains into River Kaduna. Its vegetation is made up grassland (savanna). Farming is one of the major occupations in the area.

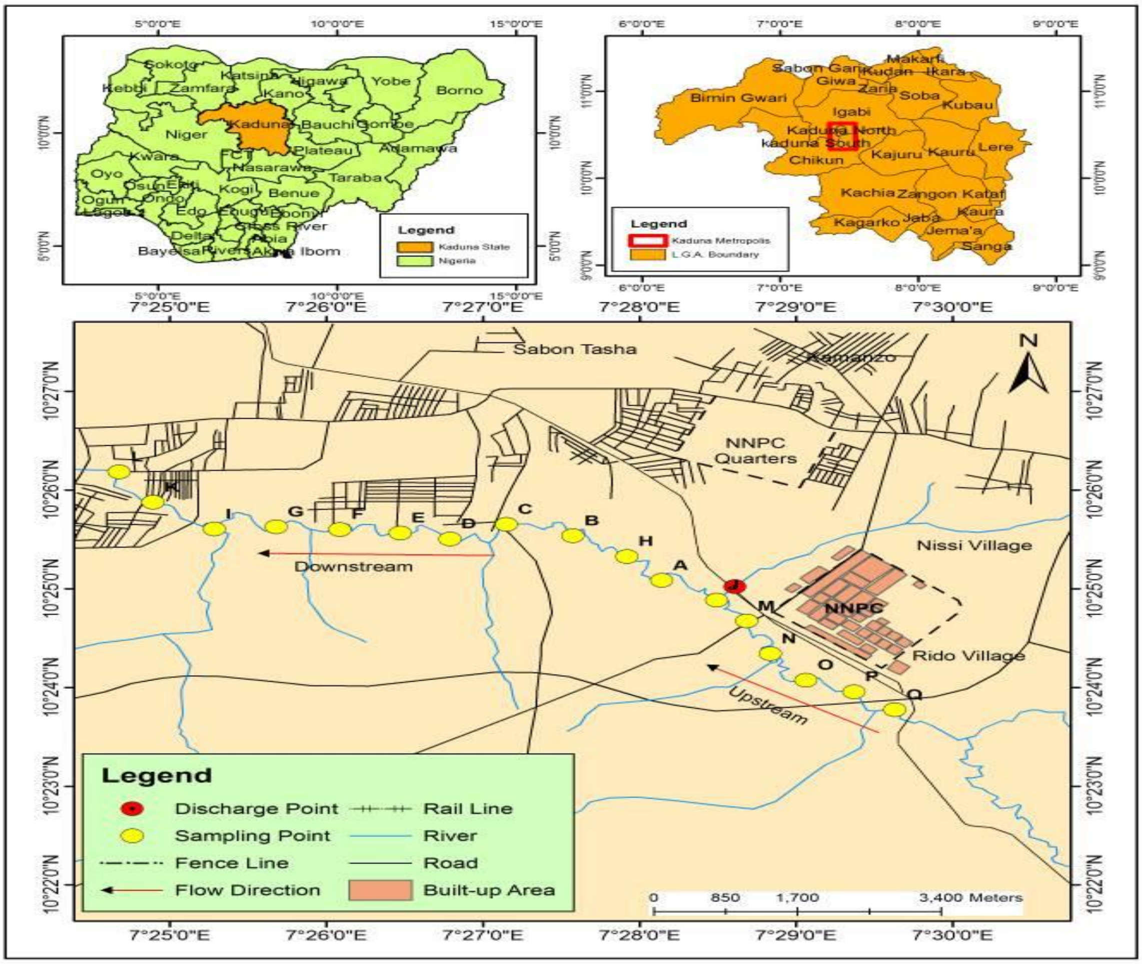

Figure 1: Map of the study area

Source: Department of Geography, Nasarawa State University, Keffi, Nigeria (2019)

Materials and Method

Transient method was used to determine sampling points along River Rido. This was done to allow flexibility in fixing of the points in the river at which water samples were taken. A total of twelve samples were taken for the study; at interval of 1km from each other during the dry season in the months of January, February and March; when farmers mainly relied upon the river for irrigation. The first four (1-4) sampling points which were closest to KPRC were designated as the upstream section of the river in the study area, while the remaining eight (5-12) were tagged as the downstream. Collection of water samples along the river took take place in the morning between 8-10 am, when the temperature was low because high temperature might alter the level of pollutants by enhancing chemical reaction. Grab method was adopted, which involves dipping a sampling container (plastic cup) from one or more points in a stream along the cross section. Grab sampling technique used in this study was consistent at each sampling point.

The samples were collected by immersing a plastic container midway of the width of the river and allowed to overflow before withdrawing with the opening pointing directly downward to maintain a volume of air in the container thereby avoiding the collection of any surface films. The samples were all collected in clean 1.5 litres white polyethylene stopper containers which had been soaked overnight in dilute HNO_3 solution. The containers were first rinsed with distilled water and filled with distilled water to the sampling points. The containers were emptied at the sampling points and rinsed severally with the samples to be collected and eventually, the collection of samples and the containers covered (airtight) with their lids immediately. Each bottle was labeled for clear identification. Preservations of the samples were carried out by the addition of a little quantity of Nitric acid (APHA, 2002). The samples were labeled accordingly and then placed in a plastic container with ice and transported to the laboratory and stored thereafter at $4^{o}C$ in the refrigerator.

Field sheet was used to record information of samples collected from the field. Such information included location and position of sampling points, date and time of collection of samples. Information also included results of in-situ parameters measured, instrument used and methods of sampling treatment.

Each sample was tested for pH, electrical conductivity (EC), total dissolved solids (TDS), sodium (Na), calcium (Ca), magnesium (Mg) potassium (K), ammonium nitrogen (NH_4-N), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu) and iron (Fe). Sodium adsorption ratio (SAR) was derived from some measured parameters using the formula:

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \quad 1$$

To calculate the mean chemical concentrations for all the parametres across the twelve (12) data collection points, the following equation was used:

$$\bar{x} = (\sum x_i)/_n \quad 2$$

Where:

$\bar{x}$ = sample mean, $\sum$= summation, x_i= all the x values, n = no of points

Table 1: Location of sampling points on the River Rido, Kaduna State

	Sample point	Longitude	Latitude
	1	10° 19' 7.3" E	7° 16' 06.9" N
Upstream	2	10° 21' 23.12" E	7° 16' 18.8" N
	3	10° 18' 8.9" E	7° 16' 19.3" N
	4	10° 19' 09.19" E	7° 17' 20.14" N
Downstream	5	10° 22' 09.64" E	7° 17' 20.5" N
	6	10° 19' 15.19" E	7° 17' 21.31" N
	7	10° 21' 2.1" E	7° 17' 21.6" N
	8	10° 22' 7.9" E	7° 17' 22.5" N
	9	10° 18' 24.8" E	7° 17' 22.7" N
	10	10° 24' 0.6419" E	7° 17' 26.0" N
	11	10° 20' 30.1" E	7° 18' 15.8" N
	12	10° 20' 26.11" E	7° 18' 17.18" N

Results and Discussion

Tables 2 and 3 shows the values (range and mean) for the parameters tested in each water sample and the sodium adsorption ratio (SAR) which was derived from some of the measured parameters. The pH values in the water samples from the River Rido varied from 6.21 to 7.31 and this fell within the range of 6.00–8.50 as recommended by FAO (1985). Total water salinity is assessed as total dissolved solids (TDS) in mg L^{-1}, or the electrical conductivity in µS m^{-1}. For TDS, FAO (1985) recommended threshold is 0–2000 mg/L, the mean value obtained for water samples at both upstream and downstream of River Rido is about 83.8 and falls within safe limit permitted for irrigation purpose. These are important parameters used to determine the suitability of irrigation waters (Sudhakar & Narsimha, 2013). Total water salinity brings about the buildup of salts in soils after irrigation. It increases in direct proportion to the salinity of irrigation water and total depth of water applied. Plant growth is retarded, and crop yield is also reduced due to the increase in osmotic potential of soil solution which takes place due to addition of excessive salts through irrigation water.

For irrigation, EC values of 20–70, 70–300 and >300 µS/m are categorized as normal, slight to moderate and severe with respect to salinity hazards (Schoeneberger, 1998). The values of EC recorded in water sample taken from River Rido varied from 89.40 µS/m to 134.60 µS/m with the mean of 122.1. At the upstream, the values were relatively higher than values observed downstream. These values could be categorized as having slight to moderate EC and there was no occurrence of values >300 µS/m which would have presented a severe case of EC. The use of water from River Rido will therefore not make the soil saline, hence recommended for irrigation.

The level of Na ions in water is an indication of the sodicity danger of the water (Singh *et al.,* 2012). Na^+ in water is one of the important criteria for its suitability for irrigation due to its effects on soil permeability and the infiltration of water (Ajayi *et al.*, 1990). The level of sodium in water determines its total salinity and this may be toxic to sensitive crops if it is at elevated levels. It also causes deflocculation of soil particles, closing the pores and thereby preventing water infiltration (Sudhakar & Narsimha, 2013). Sodic water makes the excess of the sodium ions to be adsorbed on the exchangeable complex and therefore, causing dispersion of aggregate of soil particles, blocking the pores and reducing or completely preventing water infiltration (Davis & Dewest, 1966). The values of sodium in water samples from River Rido ranged from 10.56 to 23.14 meq/L (with the mean of 14.7) at both upstream and downstream. The maximum value, 23.14 meq/L, was found at the downstream; an indication that the use of inorganic fertilizer may be responsible for the increased presence of Na ions in water. Overall, the values of all the water samples fell within the range of 0–40 meq/L recommended by FAO (1985).

The values of calcium and magnesium ions in water considered to be the normal ranges by FAO (1985) for irrigation water are 0–20 meq/L and 0–5 meq/L respectively. The lowest concentration of calcium in River Rido water samples was 10.68, the highest was 18.31 meq/L while the mean is 14.5. The highest value was at the downstream portion of the study area, an indication that other source(s) outside the industrial wastewater discharged from KPRC contributed to the comparatively high value of calcium ion. All these values fell within tolerable limit. However, the magnesium contents from almost all the sampling points are relatively higher than the recommended range of 0–5 meq/L as the values recorded were from 4.66–9.70 meq/L with the mean of about 6.5. Values of magnesium at the upstream were relatively higher than those at the downstream section. High magnesium content causes deterioration of soil structure particularly in soil with high level of sodium, and it also adversely affect crop yields because the soil becomes alkaline (Adamu, 2013). According to Bond (1999) cited in Odigie (2017), farmers are affected by direct contact with contaminated wastewater and its use in agriculture causes negative externalities both to public health through the consumption of agricultural produce irrigated with wastewater and to the environment by always polluting the ground water and soils.

Potassium ions in water do not constitute any danger in irrigation water when it is within the threshold values of 0–50 meq/L as recommended by FAO (1985). In the study area, the level of potassium in water samples from River Rido varied from 15.61 to 18.49 meq/L; at the upstream all the values were < 18 meq/L while some values downstream were slightly > 18 meq/L with a mean of about 17.3. The values were within the range recommended by FAO (1985).

According to FAO (1985), when ammonium nitrogen (NH_4-N) exceeds 5.00 mg/L, it portends danger or risk factor to irrigation water quality. For all the water samples from River Rido, the level of ammonium nitrogen at both the upstream and downstream was found to be negligible as their values ranged from 0.00 mg/L to 0.04 mg/L with the mean of about 0.2, thus it is safe for irrigation.

Generally, magnesium and calcium are in equilibrium state in most waters and their combined effect in countering the negative effect of sodium ion lowers SAR. The range of SAR in water samples from River Rido at the upstream and downstream was found to be 3.38–6.52 meq/L with the mean of about 4.5 which was within the recommended range of 0–15 meq/L by FAO (1985). Therefore, the higher contents of magnesium would not be of much problems since it is part of SAR, which actually determines the salinity of irrigation water.

The mean concentrations of arsenic, cadmium, copper, chromium and iron in the water samples of River Rido were 0.0337 mg/L, 0.0094 mg/L, 0.2789 mg/L, 0.0098 mg/L and 1.0282 mg/L respectively. The values of arsenic from upstream to downstream presented a fluctuating pattern, with the highest value, 0.0826 mg/L observed downstream. Cadmium values were lower at the upstream compared to downstream. The two highest values (0.5946 mg/L and 0.4419 mg/L) of copper in the study area were observed at the topmost part of the upstream, which lies within close proximity of KPRC, thereafter, a downward trend was observed to the end of the last point in the upstream. At the downstream section, the values of copper fluctuated and were not as high as the two highest recorded at the upstream. Chromium was comparatively higher at the downstream than the upstream in places where the heavy metal was detected. While a regular pattern was not seen from upstream to downstream in the values of iron, some of the highest values were found at the downstream. When the values were compared with the recommended thresholds set by WHO (2011) the results revealed that mean values of arsenic, cadmium and iron were all above the tolerable limits. However, the values of copper and chromium were within the tolerable levels.

Table 2: Comparison between sampled water parameters from River Rido and FAO/WHO recommended thresholds

Samples	pH	EC (µS/m)	TDS (mg/l)	Na^+ (meq/l)	Ca^{2+} (meq/l)	Mg^{2+} (meq/l)	K^+ (meq/l)	NH_4-N (mg/L)	SAR (meq/l)
1	7.3	134.6	101.2	16.3	10.7	6.1	17.2	0.01	5.6
2	7.2	133.5	86.4	13.0	15.6	5.1	17.8	0.02	4.0
3	6.2	133.1	94.7	12.6	14.5	9.7	15.6	0.04	3.6
4	7.0	129.3	89.6	15.2	14.8	6.0	17.2	0.03	4.7
5	6.2	129.1	79.6	15.2	15.6	6.0	18.3	0.00	4.6
6	7.2	128.4	87.5	15.3	14.0	6.5	18.5	0.00	4.8
7	6.2	128.3	98.4	10.6	13.2	6.3	16.2	0.02	3.4
8	6.3	124.6	94.6	11.5	18.3	4.7	17.7	0.03	3.4
9	7.2	114.6	95.6	15.3	12.2	8.2	15.7	0.01	4.8
10	6.9	112.0	85	15.3	12.3	5.1	17.6	0.04	5.2
11	7.2	108.6	56.5	12.9	14.8	7.1	18.1	0.03	3.9
12	7.2	89.4	36.2	23.1	17.6	7.6	17.3	0.03	6.5
Range	6.2 7.3	89.4–134.6	36.2–101.2	10.6–23.1	10.7–18.3	4.7–9.7	15.6–18.5	0.0–0.04	3.4–6.5
Mean	6.8	122.1	83.8	14.7	14.5	6.5	17.3	0.02	4.5
FAO/ WHO recommended Thresholds	6.0 – 8.5	70–300	0–2000	0– 40.0	0– 20.0	0– 5.0	0 – 50	0– 5.0	0– 15.0

Sources: FAO (1985) and WHO (2011)

Table 3: Comparison between Level of Heavy Metal Contents in Water Samples from River Rido and FAO/WHO recommended thresholds

Samples	As	Cd	Cu	Cr	Fe
1	0.0645	0.0031	0.5946	-	0.5799
2	0.0463	-	0.4419	-	1.5134
3	0.0717	-	0.2946	-	0.7946
4	-	0.0217	0.1349	0.0019	1.1095
5	0.0112	0.0090	0.2134	-	0.8946
6	-	0.0231	0.3645	-	0.8134
7	0.0514	0.0112	0.1064	-	1.0137
8	0.0121	0.0179	0.3015	-	1.2493
9	0.0648	0.0121	0.2564	0.0910	0.4183
10	-	0.0021	0.3016	0.0245	1.4216
11	-	0.0131	0.1056	-	1.2146
12	0.0826	-	0.2316	-	1.3164
Range	0.0- 0.0826	0.0- 0.0231	0.1056 - 0.5946	0.0- 0.0910	0.4183 - 1.5134
Mean	0.0337	0.0094	0.2789	0.0098	1.0282
FAO/WHO recommended thresholds	0.01	0.003	2.000	0.050	0.300

Sources: FAO (1985) and WHO (2011)

Conclusion

The appraisal of the suitability of River Rido for irrigation showed that the means of pH (6.8), electrical conductivity (EC) (122.1), total dissolved solids (TDS) (83.8), sodium (Na) (14.7), calcium (Ca) (14.5), potassium (K) (17.3) and ammonium nitrogen (NH_4-N) (0.2), were all within the allowable limits set by FAO (1985); except for magnesium (Mg) with the mean of about 6.5 which presented values at both upstream and downstream that were much higher than the required value in irrigation water. However, the high magnesium content helped to counter the effects of sodium; which reduced the value of sodium adsorption ratio (SAR) with the mean of about 4.5. The calculation of SAR showed values that indicated that the adsorption of sodium is excellent. The low values of EC and TDS thus indicate that the soil is not exposed to salinity hazard and what was derived for SAR showed the soil is not in imperil of alkalinity hazards. The water quality would not negatively affect plant yield, the physical soil structure and soil permeability. All the heavy metals tested showed irregular patterns of contamination from upstream to downstream. Arsenic, cadmium, chromium and iron showed comparatively higher values downstream, with only copper having relatively higher values upstream. These results are clear indications that several sources of pollutants occur along river Rido beside the KPRC. Generally, the levels of heavy metals in the water makes it unsafe for irrigation. It would contaminate the crops cultivated and the ingestion of such crops would lead to major diseases in man and animals. As crops produced finds its way into markets and are consumed by people within and outside Rido, the impact would transcend the local community.

Recommendations

This study recommends that, Kaduna Refinery and Petrochemical Company (KRPC) should ensure that the effluent quality being discharged into the river meets standards since it is used for irrigating farms during the dry season in order to avoid bioaccumulation of toxic pollutants in the agricultural products. In addition, Kaduna Environmental Protection Authority (KEPA) should ensure that Kaduna Refinery complies with guidelines of industrial effluent discharge. Wastes should be treated before been discharged into the river. To reduce the effect of magnesium in the river in order to make it more suitable and harmless for irrigation, water softening should be adopted by applying magnesium hydroxide as a flocculant.

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