Abstract
Irrigation water from Kano River Irrigation Project (KRIP) was assessed to determine its suitability for irrigation and to determine variation of water quality parameter at different points and seasons. Sample collection was done from KRIP east and west in the month of April 2013, November 2013, and February 2014. At each period, 12 samples were collected. The parameters analyzed are pH, Electrical Conductivity (EC), Sodium, Potassium, Calcium, Magnesium, Carbonate, Bicarbonate, Boron, Chloride, Sulphate, nitrate nitrogen and ammonium nitrogen. Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Exchangeable Sodium Percentage (ESP) and Permeability Index (PI), were determined using appropriate relationship. Result obtained has shown that the water is suitable for irrigation when compared with standard. EC increases progressively from reservoir downstream, highest values of 0.92dS/m was recorded in April. An ESP of 15.65% was recorded in February and this has detrimental effect on sodium sensitive and semi-tolerant crops. The SAR and RSC have shown that the water is of good quality for irrigation as highest values observed for these parameters are 0.33 and -0.50 meq/l respectively. Statistical analysis using Generalized Linear Model (GLM) has shown significant variation of parameters between points and seasons within the scheme at p<5%. Management practices such as gypsum application, choice of sodium tolerant crops and occasional testing of water to assess sodium hazard are recommended.

Keywords: Variability, irrigation, water, quality, river

Introduction
The major challenges confronting the world nowadays is achieving food security, poverty alleviation, rural stabilization and improving the quality of life. This is more pronounced in the third world countries (Jibrin et al, 2006). From earlier times, the vital importance of irrigated agriculture has been recognized worldwide, especially in areas where rainfall during growing season is not sufficient for dependable crop production (Makama, 2003).

In areas where the amount and timing of rainfall is inadequate to meet moisture requirement of crops, irrigation is necessary if enough food is to be produced. Irrigation on individual basis had been practiced for time immemorial in the fadama areas of Northern Nigeria. This had been particularly around Kano and Sokoto States (Olu, 2003). Kano State has the largest irrigated area in the country with more than 3 million hectares of cultivated land. It is the largest and most populous city in Nigeria (Mohammed et al, 2014). The population of the city is estimated to over 10 million during the 2006 national population census (Dan’azummi and Bichi, 2010).

Water is one of the most abundant resources to man. The importance of water cannot be over-emphasized as there are no substitute to it many uses (Dike et al, 2013). It is the most valuable asset of irrigated agriculture. The quality of water is as important as its quantity for a successful irrigation. The physical and chemical properties of irrigated soils depend to some extent on chemical composition of water. Poor quality of irrigation water affects the yield of crops, fertility needs and irrigation system performance. It is therefore important that irrigation water be free from ions which are toxic to plants or composition that has detrimental effects on soil physical condition. Knowledge of water quality is critical to understanding of what management changes are necessary for long term productivity (Bauder et al, 2013).

This paper studied and compared water quality in reservoir and different areas of Kano River Irrigation Project (KRIP). Kano River
Irrigation Project is a large scale agricultural project in Nigeria. The project commenced in 1969 with construction of Bagauda dam supplying Kadawa irrigation sector as a pilot Scheme and Tiga dam between 1970-1974. The paper also studied the possible change in water quality from the reservoir to tertiary canals due to various human activities such as washing, bathing, fishing, watering of livestock, and the effect of insecticides, pesticides, fertilizer etc. which gets into the canals, and reservoir through runoff water.

**Material and methods**

**The study area**

The Kano River Irrigation Project (KRIP) includes the Kano River Project Phases I and II, with a total area of about 62,000 ha. The main source of water for irrigation in the region is the Tiga Dam and Ruwankanya reservoir (Maina et al, 2012). Tiga dam was constructed across River Kano between 1970 and 1974 and has a capacity of 1.968 billion m$^3$, a length of 6km and a height of 48m. It is the largest irrigation dam in Nigeria. The dam is the corner stone of water resources development in Kano River valley in the state and Hadejia in Jigawa state (Maina, et. al,. 2012). It was constructed to irrigate the KRIP area in two phases.

Under phase one, 22,000 ha were to be developed while 40,000ha were to be developed under phase two. The developments of two phases were to be completed in 1982. The two irrigation project KRIP east and west are both located at GarumMallam, Kura, and Bunkure Local Government Areas (Othman et.al. 2006). There are two main canals that convey water from the dam to irrigation area and each is 25km long. One to kura irrigation area westward and the other to Bunkure irrigation areas eastward (Danbuzu, 2011). The Kano River Irrigation Project Phase I Extension lies about 30 km south of Kano city, on either side of the Kano-Zaria express way. The plan of the federal government of Nigeria was to transform the agriculture from low technology, semi-subistence farming into modern market oriented sectors which was not achieved. However, despite setbacks (KRIP) is one of the most successful irrigation projects in Nigeria (Maina, et,al 2012).

**Sample collection**

Samples were collected in plastic containers from Reservoir, Primary canal at Munture, secondary canals at Bunkure and tertiary canals at Kura. At each point of collection; three (3) samples were collected to ensure accuracy by replication. The collections were done in the months of April 2013 (late dry season), November 2013 (beginning of Dry season) and February 2014 (mid dry season). Out of the samples collected, thirty six (36) samples were used for statistical analysis. The plastic bottles used for the sample collection were washed with detergent and rinsed 3 times with distilled water and then with the sample water.

**Laboratory works**

The pH was determined by electrometric method with pH meter M200, the electrical conductivity was determined with conductivity meter 4071, Sodium and potassium were determined using flame photometer 400, Volumetric method was used for the determination of Chloride, Carbonate and Bicarbonate. Magnesium and calcium were determined by bycomplexometric titration, boron by Azomethine-H method, nitrate and ammonium by Nessler’s Calorimetric Method. The test procedure was in accordance with APHA standard method for the examination of water and waste water -20th editions.

**Calculation of some parameters from laboratory result**

The sodium adsorption Ratio (SAR) was calculated from the values of sodium, calcium and magnesium from the following relationship (Michael, 2008):

\[
SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}
\]

The values of the elements in mg/l were converted to meq/l using the equations below:
\[
\text{Meq/l} = \frac{\text{mg/l}}{\text{eq.wt}}
\]  \hspace{1cm} \text{.............................eq2}

\[
\text{eq.wt} = \frac{\text{at.wt}}{\text{valency}}
\]  \hspace{1cm} \text{.............................eq3}

The exchangeable sodium percentage (ESP) was also calculated from this expression:

\[
\text{ESP} = \frac{\text{Na}^+}{\text{Na}^+ + \text{Ca}^{2+} + \text{Mg}^{2+} + \text{K}^+} \times 100
\]  \hspace{1cm} \text{.............................eq4}

\[
\text{RSC} = \left( \text{CO}_{2-3} + \text{HCO}_3^- \right) - \left( \text{Ca}^{2+} + \text{Mg}^{2+} \right)
\]  \hspace{1cm} \text{.............................eq5}

The permeability index was calculated as follows:

\[
\text{PI} = \left( \frac{\text{Na}^+ + \text{HCO}_3^-}{\text{Na}^+ + \text{Ca}^{2+} + \text{Mg}^{2+}} \right) \times 100\%
\]  \hspace{1cm} \text{(Dhirendia, 2009) \hspace{1cm} Eq 6}

**Statistical analysis**

Generalized Linear Model (GLM) procedure in Statistical Package for the Social Science (SPSS) was used in the analysis of data. GLM of two way Analysis of Variance (ANOVA) was used to analyze parameters between time and points within the dam. The mean of each parameter was compared using Least Significant Difference (LSD) post Hoc test.

**Result and discussion**

Variation of parameters between sampling points are shown in Table 1 and Figure 1, the values of all parameters varied significantly at P<0.05. The pH at all location is within the normal range for irrigation but the mean values increase progressively from reservoir to the farms as highest value of 6.90 was recorded in Kura canal downstream of the dam. The mean pH values of 6.48 to 6.90 recorded differ from the range of values of (6.40-7.83) reported in Tiga dam by Akindele et al., (2013). The electrical conductivity increases from reservoir to downstream and the mean values ranges from 0.90-0.86 dS/m.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Reservoir</th>
<th>P.canal</th>
<th>S.Canal</th>
<th>T.Canal</th>
<th>SE</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH</td>
<td></td>
<td>6.48c</td>
<td>6.75b</td>
<td>6.85a</td>
<td>6.90a</td>
<td>0.031*</td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>dS/m</td>
<td>0.87ab</td>
<td>0.86b</td>
<td>0.90a</td>
<td>0.90a</td>
<td>0.01  *</td>
<td></td>
</tr>
<tr>
<td>HCO&lt;sub&gt;3&lt;/sub&gt;</td>
<td>mg/l</td>
<td>24.74b</td>
<td>24.01c</td>
<td>23.93c</td>
<td>27.87a</td>
<td>0.263 *</td>
<td></td>
</tr>
<tr>
<td>Boron</td>
<td>mg/l</td>
<td>0.16bc</td>
<td>0.14c</td>
<td>0.16bc</td>
<td>0.25a</td>
<td>0.004 *</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/l</td>
<td>13.00d</td>
<td>13.58c</td>
<td>15.71</td>
<td>14.43b</td>
<td>0.103 *</td>
<td></td>
</tr>
<tr>
<td>NO&lt;sub&gt;3&lt;/sub&gt;-N</td>
<td>mg/l</td>
<td>7.00d</td>
<td>7.14c</td>
<td>7.30b</td>
<td>8.33a</td>
<td>0.047 *</td>
<td></td>
</tr>
<tr>
<td>NH&lt;sub&gt;4&lt;/sub&gt;-N</td>
<td>mg/l</td>
<td>1.01a</td>
<td>0.90b</td>
<td>0.8ab</td>
<td>1.03a</td>
<td>0.01  *</td>
<td></td>
</tr>
<tr>
<td>Sulphate</td>
<td>mg/l</td>
<td>4.21c</td>
<td>4.38c</td>
<td>5.12</td>
<td>5.34a</td>
<td>0.077 *</td>
<td></td>
</tr>
</tbody>
</table>

Note: NS (Not Significant), * significant at ≤ 5%, LOS= Level of Significance , Means followed by the same letter in the same row are not significantly different from each other.

The highest value of EC (0.90 dS/m) was recorded in Bunkure and Kura and the lowest value of 0.86 dS/m was observed at Munture. This implies slight to moderate restriction in the use of this water for irrigation as the values are above 0.7dS/m. With
crops like potatoes, corn, onion, beans, maize, lettuce, tomato, cucumber, wheat etc. which are grown under irrigated condition in the study area, no yield reduction will be recorded and maximum production potential of crops irrigated with this water can be achieved as the salinity level is below the threshold values of these crops. Damage to plants with low tolerance to salinity will occur. Plant growth and quality will be improved with excess irrigation for leaching and or periodic use of low salinity water and provision of good drainage. Successful use of water with EC above 0.75 dS/m depends upon soil condition and tolerance to salinity (Camberato, 2001).

Other parameters such as bicarbonate, boron, sulphate, and chloride are also within normal range. The effect of bicarbonate is more pronounced on sprinkler irrigation when concentration exceeds 1.5 meq/l (91.4 mg/l) whereas in the entire scheme, surface method of irrigation is practiced. No restriction on the use of water for irrigation with respect to bicarbonate composition as all the values are less than 1.5 meq/l. Chloride concentration at all points is less than 70 mg/l and a value below this concentration is generally safe for all plants (Bauder et al, 2013). Nitrate and ammonium mean values are also within acceptable limit but unusual of fresh water where activities of domestic animals as well as runoff from farmlands (where nitrate fertilizers and manure are applied) are common.

Variation of parameters at different periods of sampling is shown in Table 2, the mean pH values in the months of April and November had no significant difference but was significantly lower than mean value of 6.95 recorded in the month of February. Mean values of EC in April, November and February differed significantly in descending order. The conductivity of water in the reservoir declines after the rainfall as salt concentration becomes more dilute and decreases from November and reached lowest value in February.

Mean values of bicarbonate observed in the months of April and February had no significant difference but they were significantly higher compared to mean value of 23.18 mg/l recorded in the month of November as shown in Figure 2.
Boron mean values differ significantly in all months, a significantly higher mean value of 0.22 mg/l was recorded in the month of April and the mean value of 0.17 mg/l recorded in the month of February was significantly higher than that recorded in the month of November. Chloride mean values in November and February have no significant difference but are significantly lower than the value observed in April. Nitrate, sulphate and ammonium nitrogen all varied between the seasons (Table 2).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Apr-13</th>
<th>Nov-13</th>
<th>Feb-14</th>
<th>SE</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>6.77b</td>
<td>6.79b</td>
<td>6.95a</td>
<td>0.026</td>
<td>*</td>
</tr>
<tr>
<td>EC</td>
<td>mS/cm</td>
<td>0.92a</td>
<td>0.89b</td>
<td>0.83c</td>
<td>0.009</td>
<td>*</td>
</tr>
<tr>
<td>HCO₃</td>
<td>Mg/l</td>
<td>26.12a</td>
<td>23.18b</td>
<td>26.04a</td>
<td>0.228</td>
<td>*</td>
</tr>
<tr>
<td>Boron</td>
<td>Mg/l</td>
<td>0.22a</td>
<td>0.15c</td>
<td>0.17b</td>
<td>0.003</td>
<td>*</td>
</tr>
<tr>
<td>Chloride</td>
<td>Mg/l</td>
<td>15.57a</td>
<td>13.34b</td>
<td>13.55b</td>
<td>0.089</td>
<td>*</td>
</tr>
<tr>
<td>NO₃-N</td>
<td>Mg/l</td>
<td>8.23a</td>
<td>7.52b</td>
<td>6.57c</td>
<td>0.041</td>
<td>*</td>
</tr>
<tr>
<td>NH₄-N</td>
<td>Mg/l</td>
<td>1.19a</td>
<td>0.90b</td>
<td>0.79c</td>
<td>0.009</td>
<td>*</td>
</tr>
<tr>
<td>Sulphate</td>
<td>Mg/l</td>
<td>4.72b</td>
<td>4.52c</td>
<td>5.04a</td>
<td>0.066</td>
<td>*</td>
</tr>
</tbody>
</table>

Note: NS (Not Significant), * significant at ≤ 5%, LOS= Level of Significance
Means followed by the same letter in the same row are not significantly different from each other.

The mean values of SAR at different periods shows that the water is of low sodium hazard as all the values are less than 9 as shown in Table 3. This implies that the water has low potentials for permeability problem but the use of sodium sensitive crop must be cautioned. RSC values have shown that the water is safe for irrigation as all the values are less than 1.25 meq/l.
Table 3: SAR, RSC, ESP and PI

<table>
<thead>
<tr>
<th></th>
<th>April, 2013</th>
<th>November, 2013</th>
<th>February, 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAR</td>
<td>0.26</td>
<td>0.2</td>
<td>0.33</td>
</tr>
<tr>
<td>RSC (Meq/l)</td>
<td>-0.5</td>
<td>-0.64</td>
<td>-0.87</td>
</tr>
<tr>
<td>ESP (%)</td>
<td>13</td>
<td>9.92</td>
<td>15.65</td>
</tr>
<tr>
<td>PI</td>
<td>32.13</td>
<td>35.6</td>
<td>43.48</td>
</tr>
</tbody>
</table>

An ESP value above 15% was observed in February, and this might be from the soap, detergent and other laundry items used for washing in some areas within the scheme. Sodium sensitive and semi-tolerant crops such as carrot, lettuce, onion, rice, tomato etc are affected by an ESP greater than 15%. The PI suggest infiltration problem as all the values are less than 75%. However, the SAR and RSC have shown that the water poses low sodium hazard. Application of gypsum and some management strategies are needed to prevent impoverishment of soil structure due to high ESP which may cause soil dispersion and crusting. Leaching and choice of sodium tolerant crops will help in the management of the water.

**Conclusion**

Analysis has shown that the water is of good quality for irrigation with respect to most of the parameters. The EC increased from the reservoir downstream and reached highest value of 0.9 dS/m at Bunkura and Kura (Table 1). The conductivity of the water decreases after the rainfall as salt concentration becomes more dilute as the mean value declined from 0.92 dS/m in April to 0.89 dS/m in November (Table 2). Other parameters such as bicarbonate, boron, chloride and nitrate are within acceptable limit for irrigation. All parameters varied significantly between location within the scheme and seasons at p< 5%. The SAR and RSC have shown that the water is of low sodium hazard as the mean values observed for these parameters are less than 1.0 and 1.25 meq/l respectively. However, an ESP greater than 15% was recorded in February and this has detrimental effect on sodium sensitive and semi-tolerant crops. Management practices such as gypsum application, and choice of sodium tolerant crops and occasional testing of water to assess sodium hazard are recommended.

**References**


Environmental Science and Technology, 3(4):122-129.


