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Evaluating Water Quality of Lower River Gongola for Irrigation

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ABSTRACT
The quality of water in the lower Gongola River was tested for irrigation. Index scores were determined for fifteen parameters: pH, EC, HCO_3, Cl, SAR SSP, RSC, Cr, Cu, Fe, pb, Mn, Ni and Zn. The results show that the values of pH varied from 6.77 to 7.33 for all sites, which indicate that the water is almost neutral to sub-alkaline in nature. Ec values of the investigated samples varied from 0.55 to 0.75ms/cm for all sites which suggests that this type of water is good for irrigation. The SAR value of the sample ranged from 1.49 to 3.61 and the calculated sample values of SSP for all sites varied from 36.2% to 54.53% which represent medium to high degree of limitations for irrigation. The RSC values of the tested samples varied from -1.63 to -1.01 for all sites. The results indicated that all samples have RSC less than zero and are suitable for irrigation uses. For heavy metals the results indicated that the value of cd and cr concentration exceed the permissible level (1.0051 meg/l and 0.008meg/l) respectively. The overall water quality index CCME WQ1 that ranged from 43.17 to 45.11 indicate that the water quality for irrigation uses can be rated as marginal conditions.

Key Words: Water, Quality, Index

I. INTRODUCTION

Water a precious gift from God is being polluted with the increase in the use of chemical in crop production. Changes in water quality are primarily the result of human activities that would discharge water pollutants or alter water availability(Alobaidy 2005) and (Pescod 1985). However, the major source of water pollution is domestic sewage, industrial wastewater and agricultural runoff.The term water quality was developed to provide an indication of how suitable the water is for human consumption and is generally used in numerous scientific researches related to the necessities of suitable management (Ayers 1985).A water quality index (WQI)is a single value indicator of the water quality determined through summarizing multiple parameters of water test resultsin a simple term for management and decision makers (Tatawat 2008). A number of indices have been proposed to summarize water quality data in an easy expressible and understood format.

Significant irrigation water quality parameters consist of a number of specific properties of water relevant in relation to the yield and quality of the crops maintenance of soil productivity and protection of the environment (Todd 1980) These parameters mostly consist of certain physical and chemical characteristics of water that are used in the assessment of irrigation water quality. Parameters such as EC, PH, HCO3, CL, Sodium Adsorption Ratio (SAR), soluble sodium percentage (SSP) and Residual sodium carbonate (RSC) wereused to evaluate the suitability of water for irrigation. Numerous water quality guidelines have been recommended by many researches for using water in irrigation under different soil condition. However, this research was conducted to evaluate the water quality of lower river Gongola.

II. MATERIALS AND METHODS

Study Area

The Gongola River is in Northeastern Nigeria, the principal tributary of the Benue River. The upper course of the river as well as most of its tributaries are seasonal streams, but fill rapidly in August and September. The Gongola rises on the eastern slopes of the Jos Plateau and falls to the Gongola Basin, running northeasterly until Nafada. At one time, the Gongola continued from here in the northeast direction to Lake Chad. Today it turns south and then southeast until it joins the Hawal River, its main tributary. The Gongola then runs south to the Benue river, joining it opposite the town of Numan.

The lower reaches of the river are impounded by the Dadin Kowa Dam near Gombe, and lower down by the Kiri Dam. After the Kiri

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dam was constructed, downstream flood peaks dropped from 1,420 cubic metres per second (50,000 cu ft/s) to 1,256 cubic metres per second (44,400 cu ft/s), while flows in dryer seasons increased from 5.7 cubic metres per second (200 cu ft/s) to 21 cubic metres per second (740 cu ft/s). The river downstream from the dam also narrowed and became less winding, with fewer separate channels.

Sampling and Analysis

Water sample collection was made from two seasons, dry and rainy of 2015 from six selected sites in thelower GongolaRiver. Water samples were collected in stopper fitted polyethylene bottles and refrigerated at 40^{o}C in order to be analyzed as soon as possible. Conductivity and pH were measured on the site using portable measuring devices. Procedures followed for analysis have been in accordance with the Standard Method for examination of Water and Wastewater.

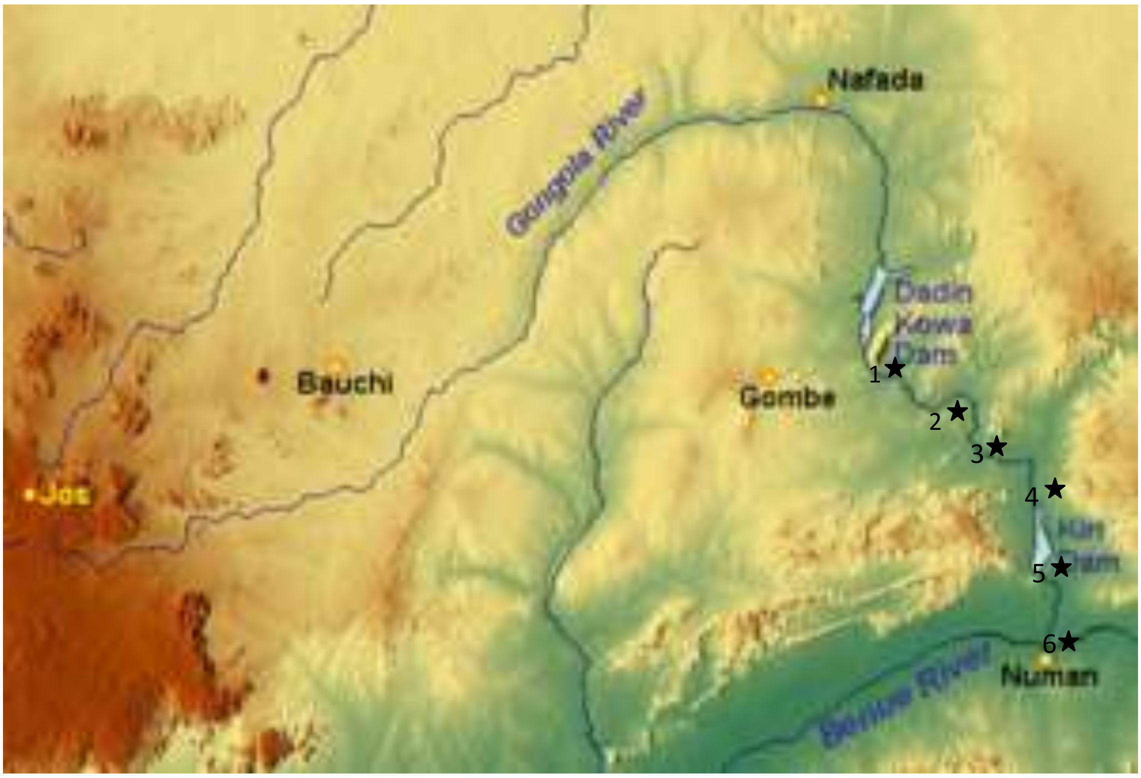

Figure (1):Map of lower GongolaRiver illustrates the study sites.

In this study, the water quality index (CCME) was applied and tested for the lower Gongola River using the values guidelines for irrigation. Index scores were determined for fifteen parameters: pH, EC, HCO_3. Cl, Sodium Absorption Ration (SAR), Soluble Sodium Percentage (SSP), Residual Carbonate (RSC), Cd, Cr, Cu, Fe, Pb, Mn, Ni, and Zn. Several irrigation water quality guidelines have been developed. However, these guidelines were used as objective values in applying the water quality index.

Calculations of the WQI

The WQI equation is calculated using three factors as follows:

$$WQI = 100\left[\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}\right]$$

F1 represents Scope: The percentage of parameters that exceed the guideline.

$$F_1 = \left(\frac{\text{Number of failed parameters}}{\text{Total number of parameters}}\right) \times 100$$

F_2 represents Frequency: The percentage of individual tests within each parameter that exceeds the guideline.

$$F_2 = \left(\frac{\text{Number of failed test}}{\text{Total number of tests}}\right) \times 100$$

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F_3 represents Amplitude: The extent (excursion) to which the failed test exceeds the guideline. This is calculated in three stages. First, the excursion is calculated by:

$$\text{Excursion} = \left(\frac{\text{failed test value}}{\text{guideline value}}\right) \text{x } 1$$

Note: in the case of pH where the minimum and the maximum guideline are given, the excursion equation must be run in equation 4 as well as in reverse i.e. guideline value/failed value.
Second, the normalized sum of excursion (nse) is calculated as follows:

$$\text{nse} = \frac{\sum \text{excursion}}{\text{total number of tests}}$$

At the third stage F_3 is then calculated using formula that scales the nse to a range between 1 to 100:

$$F_3 = \left(\frac{\text{nse}}{0.01\,\text{nse} + 0.01}\right)$$

The index equation generates a number between 1 to 100, with 1 being the poorest and 100 indicating the best quality. Table 2 shows the CCME WQI categorization schema.

Table (1): Objective Values used in applying WQI

Parameters	Values	References
pH	6.5-8.4	10
EC (mS/cm)	2.25	12
HCO_3 (mg/L)	91.5	10
Cl (mg/L)	100	16
Na (SAR)	18	12
Na (SSP)	40	12
RSC (meq/L)	2.5	12
Cd (mg/L)	0.0051	16
Cr (mg/L)	0.008	16
Cu (mg/L)	0.2	16
Fe (mg/L)	5	16
Pb (mg/L)	0.2	16
Mn (mg/L)	0.2	16
Ni (mg/L)	0.2	16
Zn (mg/L)	1	16

Guide to Interpreting irrigation water analysis

Table (2). CCME-WQI Categorization Schema

Rank	WQI Value	Notes
Excellent	95-100	All measurement are within the objectives virtually all of the time
Good	80-94.9	Conditions rarely depart from natural or desirable levels
Fair	65.9-79.9	Conditionssomething depart from natural desirable levels
Marginal	45-64.9	Conditions often depart from natural desirable levels
Poor	0-44.9	Conditions usually depart from natural desirable levels

Guide to Interpreting irrigation water analysis

III. RESULTS AND DISCUSSION

Descriptive statistics of all measured parameters have been presented in Table 3.

	Winter				Summer			
Parameters	Min	Max	Mean	SD	Min	Max	Mean	SD
pH	6.77	7.33	7.03	0.25	7.07	7.33	7.20	0.11
EC (mS/cm)	0.55	0.58	0.56	0.01	0.68	0.71	0.69	0.01
HCO_3 (mg/L)	14.24	16.27	15.05	0.96	1.03	3.47	2.10	0.97
Cl (mg/L)	5.00	12.50	8.47	3.22	158.82	283.60	223.09	49.01

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Na (SAR)	3.06	3.61	3.32	0.18	1.49	1.59	1.53	0.03
Na (SSP)	51.64	54.53	52.59	1.02	36.16	37.57	36.79	0.64
RSC (meq/L)	-1.09	-1.01	-1.04	0.03	-1.63	-1.55	-1.59	0.03
Cd (mg/L)	0.01	0.02	0.003	0.01	0.01	0.01	0.009	0.001
Cr (mg/L)	0.85	1.02	0.95	0.05	0.50	1.08	0.77	0.19
Cu (mg/L)	0.03	0.05	0.04	0.006	0.00	0.06	0.018	0.02
Fe (mg/L)	0.13	0.19	0.16	0.02	0.13	0.22	0.18	0.03
Pb (mg/L)	0.01	0.08	0.04	0.02	0.22	0.33	0.28	0.03
Mn (mg/L)	0.07	0.09	0.08	0.009	0.03	0.05	0.04	0.007
Ni (mg/L)	0.12	0.17	0.15	0.020	0.09	0.11	0.09	0.008
Zn (mg/L)	0.00	0.01	0.0038	0.003	0.00	0.01	0.006	0.002

Statistical summary of water quality data for all sites

The normal pH value for irrigation water is in the range of 6.5 to 8.4 . Irrigation water with a pH outside the normal range may cause nutritional imbalance or may contain toxic ions. The values of pH varied from 6.77 to 7.33 for all sites, which indicate that the water is almost neutral to sub-alkaline in nature and in agreement with the pH values of fresh waters .

Electrical Conductivity (EC) is the most significant issue in determining the suitability of water for irrigation. Irrigation water with conductivity less than 2.25 Ms/cm is allowable for irrigation . The primary effect of high EC reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil . EC values of the investigated samples varied from 0.55 to 0.75 Ms/cm for all sites which suggests that this type of water is good for irrigation and widely used.

The most regular toxicity is from chloride (Cl^-) in the irrigation water. Cl^- is not absorbed or held back by soils, therefore it moves readily with the soil-water, and taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. The Cl^- ion concentration for the irrigation water is 100 mg/L . With exception in winter season, the obtained Cl^- concentrations of the tested samples were higher than the acceptable level recommended by the CCME for irrigation . The possible sources of these ions may be anthropogenic and natural.

Sodium content is the major constituent and an import aspect of irrigation water quality assessment, extreme sodium concentrations lead to development of an alkaline soil that can cause soil physical problems and reducing soil permeability . Sodium hazard is typically expressed in terms of Sodium Adsorption Ratio (SAR) and Soluble Sodium Percentage (SSP), which can be calculated as follows:

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

Where
Na^+, Ca^{2+} and Mg^{2+} are in meq/L

SAR is a significant parameter for the determination of the suitability of irrigation water because it is responsible for sodium hazard . The SAR value of the sample ranged from 1.49 to 3.61. the comparison between SAR values and the standard value which is 18 recommended by US Salinity. Laboratory reflects water is suitable for irrigation. The Soluble Sodium Percentage (SSP) was calculated by the following equations.

$$SSP = \frac{(Na^{+}) \times 100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}}$$

Where
All the ions are expressed in meq/L.

The standard value of SSP is 40 percent recommended by US Salinity Laboratory. The calculated sample values of SSP for all sites varied from 36.26% to 54.53%, which represent medium to high degree of limitations for irrigation. Water high percent of SSP may cause sodium accumulation in the soil profile and affect the physical properties of soil .

To qualify the effect of CO_3^- + HCO_3 in water over the sum of Ca^{2+} and Mg^{2+}, an experimental parameter termed as Residual Sodium Carbonate (RSC) could be used. It can be calculated as follows:

$$RSC = (CO_3^{2+} + HCO_3^-) + (Ca^{2+} + Mg^{2+})$$

All ion concentrations are reported in meq/L.
US Salinity Laboratory , reported that RSC value less than 2.5 meq/L is safe for irrigation; a value between 1.25 nd 2.5 meq/L is of acceptable quality and value more than 2.5 meq/L is unsuitable for

irrigation RSC values of the tested samples varied from (-1.63 to -1.01) for all sites. The results indicated that all samples have RSC less than zero and are suitable for irrigation uses.

For the heavy metals the results indicated that the mean value of Cd and Cr concentration exceed the permissible level (0.0051 meq/L and 0.008 meq/L respectively) recommended by the CCME for irrigation all sites. While the mean value of Pb concentrations exceeded the permissible level (0.2 meq/L) recommended by CCME for irrigation in the summer season only.

Average values of CCME WQI ranged from 43.17 to 45.11 indicating that the water quality index for irrigation can be rated as marginal condition in the 1st site which is situated at the north of the study area while in the other sites it is rated as poor conditions (Table 4). This may reflect the Discharge of pollutants to the water resources system from domestic sewers, storm water discharges, industrial waste discharges, agricultural runoff and other sources, all of which may be Untreated and can have significant effects on the river system causing low water quality for irrigation.

Table 4: CCME WQI Values of Lower River Gongola.

Locations	WQI Values
Site 1	45.11
Site 2	44.42
Site 3	44.11
Site 4	44.36
Site 5	43.17
Site 6	43.50

IV. CONCLUSIONS

The overall CCME WQI values, which ranged from 43.17 to 45.11 indicate that the water quality for irrigation uses can be rated as marginal conditions in the 1st site which is situated at the North of the study area while the water quality of the other sites can be categories as poor conditions. This may reflect the Discharge of pollutants to the water discharges, agricultural runoff and other sources, all of which may be untreated, can have significant effect of a river system.

RECOMMENDATIONS

It is recommended that further studies should be made to evaluate the effect of pollution on the quality of water in the river.

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