Physico-Chemical Properties of Water for Irrigation in River Dura Catchment Area of Benue State, Nigeria

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Abstract

Physical and chemical properties of water in the river and handdug wells were assessed for irrigation purposes along river Dura catchment area of Benue State (longitude 8^045 ' and 9^015 'E and latitudes 6^040 ' and 7^010 'N). Topographical map was used for physiographical evaluation of the study areas. Water samples from the river and handdug wells were collected in air-tight plastic containers, analyzed for quality- related parameters and compared with the FAO (1994) Water Standards for Irrigation. The investigation was carried out in the wet and dry seasons of 2017. Water qualities were found to be suitable for irrigation as the values of the parameters related to the general irrigation problems of salinity, permeability, toxicity and 'miscellaneous' fell within the FAO water 'tolerable' limits.

Key Words: Water quality, Irrigation, Salinity, Permeability, Toxicity

Introduction

Benue State lies within the Southern Guinea Savanna agro-ecological zone of Nigeria where rainfall is often erratic and inadequate in amount and distribution for production of some crops (Ajon *et al.*, 2014). In Nigeria, annual rainfall varies from about 500 mm in the extreme North to about 3000 mm in the south and the rainfall is high in intensity (Ojeniyi, 1995). Annual rainfall in Benue varies from about 900 to 1200 mm (Jimba and Adegoye, 2000).

In Benue State, rainfed agriculture has suffered varying lengths and intensities of agricultural drought, thus necessitating irrigation in order to satisfy the moisture requirements of crops needed to meet the demands for food and fibre. Although irrigation is useful for sustaining agricultural production in any locality, it is imperative that only good quality water be used. Poor quality water affects both soil quality and crop production adversely (Bello, 2001; USDA, 2001). In irrigation water evaluation, emphasis is placed on chemical and

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physical characteristics of the water and only rarely is any other factors considered important (Rogers *et al.*, 2003; Ajon *et al.*, 2014).

Considering large hectares of land which are agriculturally productive within River Dura catchment area, there is a felt need to encourage irrigated agriculture. This can support year round crop production on medium scale and will alleviate the present food shortage in the state and consequently alleviate poverty.

River Katsina-Ala, is the tenth most important river in Nigeria (The National Atlas of the Federal Republic of Nigeria, 1978). It has a length of about 346 km (Welcomme, 1976) and river Dura is one of its tributaries. Notwithstanding its relevance to socio-economic development of the area, there is dearth of knowledge on surface and ground water qualities in its catchment areas. It is necessary, therefore, to investigate and evaluate the qualities of the surface and ground water within river Dura catchment area for irrigation purposes. This will sustainably increase agricultural productivity and income (food security) in Nigeria.

Materials and Methods

Study Area

River Dura catchment area is located at Dura along Katsina-Ala road, near Ugbema town in Buruku Local Government Area of Benue State. The study areas are bounded by longitudes 8⁰45' and 9⁰15'E and latitudes 6⁰40' and 7⁰10'N (Fig. 1). Dura relief ranges from 90 to 262 m above mean sea level. The study areas are undulating plains. The main river that drains rivers Dura is river Katsina-Ala. Then, river Benue drains river Katsina-Ala. River Dura is the tributary of river Katsina-Ala (Fig. 1). The climate of the study area is tropical savanna. The minimum temperature is 9.7°C and maximum is 33.5°C. The mean monthly temperature is 27.3°C. The total annual rainfall varies between about 900 and 1200 mm. The study area has distinct dry and wet seasons. Rainy season starts in March/April and ends in October/November. The vegetation in the study area is Guinea Savannah type, characterized by grasses with few scattered shrubs and trees. There are forests along the river of the study area. The study areas are underlain by the rock units of the undifferentiated basement complex. The following rocks units were also observed; the alluvium, Ezeaku shale, sandstone and the tertiary basalt are found in Dura.



Figure 1. Location and Drainage Map of the Study Area **Source:** Ministry of Land and Survey, Makurdi (The NAFRN, 1978)

Field and Laboratory Methods

This research was carried out in 2017. Water samples were collected from three (3) different handdug wells. In each well, water sample was collected using air-tight plastic container after the well had operated for more than 15 minutes. River water samples were collected in three different points namely; the upper, middle and lower positions of river Dura in both wet and dry seasons (6 samples). A total of 12 samples (wet and dry seasons) were labeled, transported to laboratory for immediate chemical analysis: The pH of water was measured electrometrically using glass electrode pH meter (Udo et al., 2009). Electrical conductivity was measured with electrical conductivity meter. Sodium, potassium, chlorine and boron were determined using flame photometer, while calcium, magnesium, iron and manganese were determined using atomic absorption spectrophotometer (AAS) (Udo et al., 2009). Bicarbonate was determined by the titrimetric method using naphthalene and methyl orange as indicator (Udo et al., 2009). Total dissolved solids in water were determined by evaporation-drying (Udo et al., 2009). The temperature of the water samples was measured by thermometer (mercury-in-glass). Sodium adsorption ratio was calculated to determine the concentration of cation in water (Udo et al., 2009). All the parameters were determined based on the FAO water quality standards for irrigation.

Water Quality Evaluation

The mean values of the chemical parameters of the river and well water along river Dura catchment area were compared with FAO (1994) water standards for irrigation (Table 1). Water quality problems were presented in four general categories namely: salinity, permeability, toxicity and miscellaneous effects as described by the FAO (1994) water standards.

Results and Discussion Salinity Effects;

The pH values are presented in Table 1. The pH values of the well and river water indicated slightly alkaline condition. The pH of the river water in the dry season (7.37) was higher than in the wet season (7.05) due to high degree of saturation with base-forming cations (Ca, Mg, K and Na) in the dry season. The pH values of the well water were higher in the wet season (7.73) compared to the dry season (6.71). The cations were expectedly leached down the soil profile thereby increasing the base concentration in the well water. All the values fall within the recommended standards range of 6 - 8.5 (FAO, 1994; Ayers and Westcot, 1994).

Electrical Conductivity (ECw) of the river water in the dry season (0.09 ds/m) was higher than that of the wet season (0.07 ds/m) (Table 1). River water quality is often related to flow. The dilution due to runoff in the rainy periods usually keeps total salt concentration low. For the well water, the ECw values were higher in wet season (0.11 ds/m) compared to the dry season (0.09 ds/m). Generally, the EC values for the water samples were low. Based on the FAO (1994) standards, the value of 3.0 ds/m is the highest safe limit of EC for irrigation water. The water is, therefore, very safe for irrigation.

The river water had higher concentration of calcium in the dry season (0.26 meq/l) than in the wet season (0.22 meq/l). In well water, high calcium concentration was noticed in the wet season (0.43 meq/l) compared to the dry season (0.41 meq/l) (Table 1). The high amount of calcium in the water could be due to the presence of limestone within the lithology. Calcium, also being a biophile element, when bush is burnt; more calcium gets into the surface water. The ratio of Ca/Mg is greater than one. Therefore, potential effect of sodium is reduced. The SAR and ESP would also decrease. The values are generally low and fall within the safe limit (0 - 20 meq/l) for irrigation as suggested by FAO (1994).

Magnesium (Mg²⁺) concentration in river Dura were higher in the dry season than in the wet season (Table 1). The ratio of Ca/Mg is greater than one. Generally, the result shows low concentration of magnesium in the water. This would not cause salinity problem. The FAO (1994) safe range is 0 - 5 meq/l.

The concentration of sodium in water was generally very low. The values ranged from 0.21 to 0.31 meq/l in the river and well water (Table 1). The values were below 3 meq/l which means that sodicity problem is not expected.

The values of pH, EC, Ca, Mg and Na indicate that the water has no salinity problems. The water in the catchment area is, therefore, good quality for irrigation.

Permeability Effects;

Factors to determine soil permeability are sodium content relative to calcium and magnesium; bicarbonates and carbonate content, and the total salt concentration of the water (FAO, 1994).

The Sodium Adsorption Ratio (SAR) of the river and well water is generally low. The SAR of the water ranged from 0.41 to 0.55 meq/l (Table 1). Such low SAR values are expected in view of the fairly low sodium content.

The water analysis shows lower concentration of bicarbonate, it ranged from 0.83 - 1.01 meq/l (Table 1). The values of HCO₃ are below 1.5 meq/l indicating 'no degree of restriction of use'. A permeability problem, therefore, is not expected to occur.

The values for total dissolved solids in the water ranged from 58.24 to 171 mg/l (Table 1). The study area has values of TDS below 450 mg/l indicating 'No problem' which means the water could be used for irrigation without permeability problem.

The concentration of calcium and magnesium in the water is generally low (Tables 1). The values of SAR, HCO₃, TDS, ECw, Ca and Mg of the water fall within the 'usual range' and indicating 'no degree of restriction of use'. The water is, therefore, highly suitable for irrigation.

Toxicity Effects;

A toxicity problem may occur when certain constituents in the water are taken up by the crop and accumulate in amounts that would result in a reduced yield. This is usually related to one or more specific ions in the water namely, boron, chloride and sodium. Other trace elements which may cause toxicities are iron and manganese.

The concentration of sodium in water is very low (0.21 - 0.31 meq/l) and could not lead to sodium toxicity. Therefore, the water is highly suitable for irrigation.

Chloride concentration in water ranged from 0.55 to 2.24 me/l (Table 1). Generally, chloride concentration in the study area is low and falls within the safe limit for irrigation. The safe limit for chloride is <30 meq/l (FAO, 1994).

Boron concentration in the river water ranged from 0.09 to 0.12 mg/l (Table 1). High concentration was noticed in the river and well water during the wet season compared to dry season. Generally, the concentration of boron is low and falls within the tolerable range. The FAO (1994) safe range is 0 - 2 mg/l. The water has no boron toxicity problem.

Iron and Manganese were generally low in water (Table 1). The values fall below 1.5 mg/l and 2 mg/l considered as safe limits for Fe and Mn respectively. This implies that the water has no Fe and Mn toxicity problems.

In evaluating the potential for a toxicity problem in river Dura catchment area for irrigation, the values of Na, Cl, B, Fe and Mn fall within the values of the tolerable limits set by the FAO (1994). Toxicity, therefore, is not expected to be a problem.

Miscellaneous Effects;

Nitrate (NO₃) concentration in both the river and well water ranged from 0.0003 to 0.003 mg/l. The concentration is very low. The values are within the recommended range.

Turbidity is caused by suspended solids in water. The turbidity of the water ranged from 16.9 to 42.23 mg/l. The higher values were observed in the wet seasons. These may be due to runoff from the nearby fields to the rivers during the rainy periods. Higher turbidity of the well water in the wet season could be due to suspended matter, silt and clay particles mainly from the soft overburden. The values in both the dry and wet season fall within the recommended limit of 50 - 100 mg/l.

Sulphate (SO₄) concentration in the water ranged from 0.20 to 0.72 meq/l (Table 1). The values in the dry season were lower than the wet season values. The sulphate concentration of water is within the tolerable limit for irrigation, the recommended standard being 0 - 2 meq/l (FAO, 1994).

Potassium (K) concentration in water ranged from 1.05 to 6.97 mg/l (Tables 1). The high values could be as a result of contamination from inorganic fertilizers (as farmers within the area make large use of NPK), feldspar, micas and clay. Leaching of these minerals into water could cause the high concentration of K in water. The FAO (1994) safe range is 0 - 2 mg/l. Potassium is not toxic. The value of K is above the standard range in the water, but could be used for irrigation.

In miscellaneous problem evaluation, the values of NO₃, turbidity, SO₄ and K in water fall within the safe ranges for irrigation.

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Parameters	River Water	River Water	Well Water	Well Water	FAO
	(Wet Season)	(Dry Season)	(Wet Season)	(Dry Season)	Irrigation
					Water Limits
Temp. (°C)	27.0	26	28.2	28	_
Turbidity	44.33	25.9	23.0	20.0	50 – 100
mg/l					mg/l
pН	7.05	7.37	7.73	6.71	6.0 - 8.5
EC ds/m	0.09	0.07	0.10	0.09	0 - 3 ds/m
Ca me/l	0.22	0.26	0.43	0.41	0 - 20 me/l
Mg me/l	0.30	0.37	0.47	0.39	0-5 me/l
Na me/l	0.21	0.31	0.30	0.28	0 - 40 me/l
K mg/l	4.17	1.05	6.97	2.07	0 - 2 mg/l
Cl me/l	0.60	0.55	2.24	1.03	0 - 30 me/l
B mg/l	0.12	0.09	0.15	0.10	0 - 20 mg/l
Fe mg/l	0.74	0.63	1.34	1.49	0 - 1.5 mg/l
Mn mg/l	0.17	0.14	0.21	0.12	0 - 2 mg/l
NO ₃ mg/l	0.0004	0.003	0.0005	0.0003	0 - 10 mg/l
SO ₄ me/l	0.72	0.41	0.54	0.20	0 - 20 me/l
HCO ₃ me/l	1.01	1.09	1.00	0.85	0 - 10 me/l
TDS mg/l	171	98	140	58.24	0 – 2000
					mg/l
Hardness	55.0	46.0	36.0	36.00	<80 mg/l
mg/l					
SAR me/l	0.41	0.55	0.45	0.44	0 - 15 me/l

Table 1: Chemical Composition of the River and Well Water

Conclusion

An evaluation of the quality of water along the river Dura catchment area reveals that the water is highly suitable for irrigation. The water parameters investigated for salinity, permeability, toxicity and miscellaneous fall within the tolerable limit for irrigation purposes.

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