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WATER QUALITY ASSESSMENT OF DELIMI RIVER FOR IRRIGATION ON THE JOS PLATEAU OF NIGERIA

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Irrigation, river, salinity, sodium adsorption ratio, suitability assessment, water quality, and total dissolved salts.

ABSTRACT

Water from the Delimi River has been used for irrigation farming since the onset and development of the Jos metropolis. However there are concerns over the quality of the water for irrigation farming due to pollution resulting from anthropogenic activities. The objective of this study was to determine the suitability of water from Delimi River for irrigation purposes in the study area. Water sampling was carried out over a period of six months during the dry season when irrigation farming is usually practiced. The parameters analyzed included pH, Electrical conductivity, Magnesium, sodium, calcium, chloride, nitrate, sodium adsorption ratio and boron. The result of the water analysis shows that the mean pH values were within acceptable range in most cases for irrigation farming. Effect of water on sodicity, permeability and salinity were rated as slight to moderate. Similar rating was observed for nitrate. Calcium, magnesium, boron and chloride contents were within acceptable limits for irrigation.

INTRODUCTION

Irrigated farming depends majorly on natural water resources for production of crops in semi-arid to arid areas or to ensure an all year round production of crops in semi humid areas. Water for irrigation can be gotten from surface water sources, groundwater sources, municipal water supplies, grey-water sources, and other agricultural and industrial process wastewaters. Irrigation has been reported to have adverse effects on soil properties if the quality of the source of water is not regularly monitored. Al-Ghobari [1] observed increased salt content of irrigated soils in Saudi Arabia due to salinity of water sources. Similar results were noted by Ahmed and Sherif [2] who observed that irrigation with water with high pH significantly increased the pH and electrical conductivity of sand and calcareous soils.

The presence of heavy metals has also been a great concern in irrigation water sources. Patel [3] have reported higher concentration of extractable cadmium, lead, copper and iron in soils irrigated with untreated drain water. Similarly Kibria et al [4] observed that total Cd, Pb, Zn and Cu contents of surface soil in waste water irrigated locations were above the normal ranges of these metals for soils. Furthermore Singh et al [5] noted that the metal pollution index were higher at wastewater-irrigated sites when compared to the clean water–irrigated ones.

Consequently there has been a lot of concern over anthropogenic influences on the water quality of the Delimi River. Such influences as reported by Njoku and Keke [6]; and Sabo et al [7] includes: uncontrolled wastewater seepage from mining and industrial activities, dumping of refuse and sewage into the river. Sabo et al [7] reported that Cd and Cu contents of the Delimi River were above the critical limits of 0.01 and 0.20 mg/L recommended by FAO. Similarly Njoku and Keke [6] reported that contents of Fe (0.6-3.0 mg/L), Cd (1.5-2.1 mg/L), Pb (0.8-1.25 mg/L), Cu (2.6-3.8 mg/L), Zn (8.5-18.0 mg/L) and Cyanide (0.005-0.4 mg/L) significantly violated the internationally recommended water quality criteria for drinking purposes, domestic use and aquatic life. These studies notwithstanding, it is imperative to ascertain the water quality of the Delimit River as it pertains to meeting irrigated farming needs. About 224 hectares of land in Jos metropolis rely on the Delimi River as source of irrigation water. Furthermore very little has been reported on its suitability for irrigation purposes. Therefore, the objective of this study was to determine the suitability of water from Delimi River for irrigation purposes in the study area.

MATERIALS AND METHODS

Study Area

The Jos Plateau is a high land region in North Central Nigeria. The watershed of three major river systems of Nigeria meets on the Jos Plateau and includes the Delimi River which drains into Chad. River Delimi is the major drainage system in Jos Metropolis. The river serves as a source of water for domestic use, fishing and irrigation. The climate is a variant of the tropical Continental climate with distinct wet and dry season. Furthermore the climate is characterized by a mean annual temperature of about 22^0C and a mean annual rainfall of 1260 mm [8]. Figure 1 shows that dry season on the Jos Plateau commences in the month of October and terminates in the month of March.

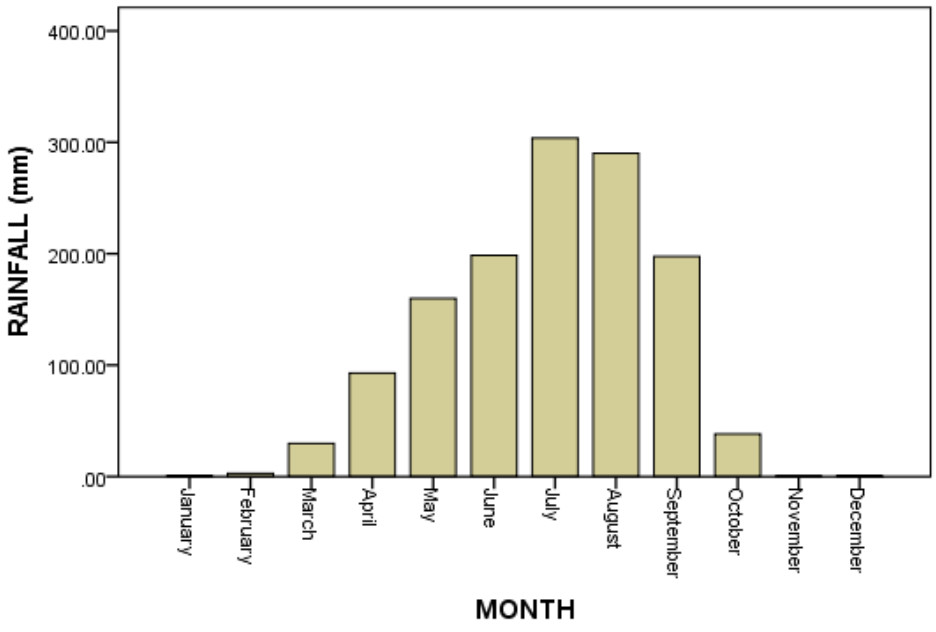

Figure 1: Long Term Monthly Distribution of Rainfall over the Jos Plateau [8]

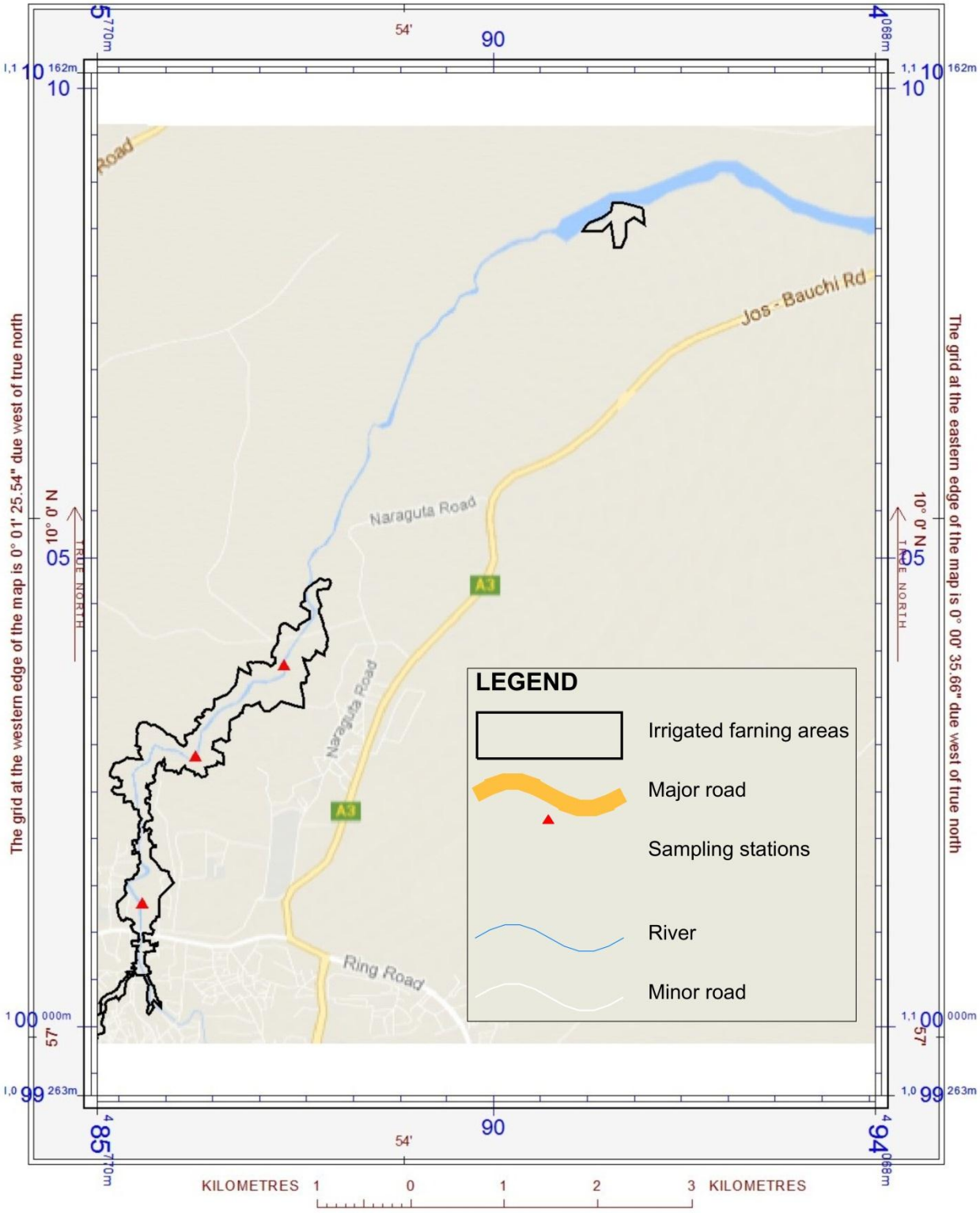

Figure 2: Map of the study site

Sampling Strategy and Statistical Analysis

Samples of water were collected randomly from three different sampling stations along the river as shown in Figure 2. The sample stations were located along the stretch of the river where dry season farming were majorly carried out due to suitability of the loca-

tion. The samples were collected monthly during the period November 2017 to April 2018 when irrigation activities are extensively carried out. At each of the sampling stations three samples of water were collected at the depth of 30 cm below the surface using 1 litre polyethylene bottles with screw caps which were acid washed and rinsed with distilled water prior to the sampling.

Laboratory Analysis

Data from laboratory analysis was interpreted using Figure 3. Electrical conductivity (EC) and pH of water samples were determined with the aid of an EC and pH meter respectively. Total dissolved salts were assessed by multiplying EC by 640. Sodium was determined using a flame photometer while calcium and magnesium determined with the aid of an atomic absorption spectrophotometer. Nitrate and Boron were determined by Kjeldahl distillation and azomethine-H Procedure as described by Agbenin [9]. Chloride was determined by titrating with silver nitrate. Sodium adsorption ration (SAR) and Magnesium adsorption ratio (MAR) were assessed using the following equations [10]:

SAR = Na+/ 0.5Ca2+ + Mg2+ .....equation 1
MAR = Mg2+ Ca2+ + Mg2+ .....equation 2

Potential Irrigation Problem		Units	Degree of Restriction on Use		
			None	Slight to Moderate	Severe
Salinity (affects crop water availability)					
EC (or)		dS/m	< 0.7	0.7 - 3.0	> 3.0
TDS		mg/l	< 450	450 - 2000	> 2000
Infiltration (affects infiltration rate of water into the soil. Evaluate using EC and SAR together)					
SAR	= 0 - 3 and EC	=	> 0.7	0.7 - 0.2	< 0.2
	= 3 - 6 *	=	> 1.2	1.2 - 0.3	< 0.3
	= 6 - 12	=	> 1.9	1.9 - 0.5	< 0.5
	= 12 - 20	=	> 2.9	2.9 - 1.3	< 1.3
	= 20 - 40	=	> 5.0	5.0 - 2.9	< 2.9
Specific Ion Toxicity (affects sensitive crops)					
Sodium (Na)					
	surface irrigation	SAR	< 3	3 - 9	> 9
	sprinkler irrigation	mg/l	< 69	> 69	
Chloride (Cl)					
	surface irrigation	mg/l	< 142	142 - 355	> 355
	sprinkler irrigation	rng/l	< 106	> 106	
Boron (B)		mg/l	< 0.7	0.7 - 3.0	> 3.0
Nitrogen (NO_3 - N)		mg/l	< 5	5 - 30	> 30
pH				Normal Range 6.5 - 8.4	

Figure 3: Guidelines for interpretation of mater quality for irrigation [11]

RESULTS AND DISCUSSION

pH and Salinity

Table 1 shows the descriptive statistic of pH, EC and TDS of water samples collected at 3 different location of the Delimi River. The values across the months the not follow any particular trend. Analysis of variance shows that there was significant difference in the distribution of pH EC, and TDS among the months. The pH obtained in the month of November 2017 to April 2018 ranged from 6.38 to 10.44 with a mean of 7.51. In most cases pH values were within the normal range. EC and TDS values ranged from 0.26 to 0.88 (ds/m), and 166.40 to 563 (mg/l) respectively. Their corresponding mean values were 0.55(ds/m) and 352.00 (mg/l). EC values were within the acceptable range for irrigation whereas occasional slightly high TDS values were observed. These observations were similar to that reported for surface water of the Kosovo plain [12] which also had EC and pH within permissible limits for irrigation.

Table 1: Descriptive statistic of pH and EC in Delimi River

Parameter	Month	Mean	Std. deviation	Minimum	Maximum	CV
pH	November	9.15[a]	0.67	8.25	10.44	0.07
	December	7.47[b]	0.94	7.28	7.62	0.13
	January	6.84[c]	0.04	6.81	6.88	0.01
	February	7.20b[c]	0.12	6.94	7.35	0.02
	March	7.08[cd]	0.17	6.81	7.29	0.02
	April	6.85[cd]	0.41	6.38	7.66	0.06
	Total	7.51	0.89	6.38	10.44	0.12
EC (ds/m)	November	0.36	0.07	0.26	0.46	0.19
	December	0.53[e]	0.02	0.50	0.57	0.04
	January	0.83[d]	0.05	0.80	0.88	0.06
	February	0.74[a]	0.09	0.50	0.79	0.12
	March	0.62[b]	0.02	0.59	0.65	0.03
	April	0.38[c]	0.02	0.36	0.43	0.05
	Total	0.55[e]	0.17	0.26	0.88	0.31
TDS (mg/l)	November	230.40	44.80	166.40	294.40	0.19
	December	339.20[e]	12.80	320.00	364.80	0.04
	January	531.20[d]	32.00	512.00	563.20	0.06
	February	473.60[a]	57.60	320.00	505.60	0.12
	March	396.80[b]	12.80	377.60	416.00	0.03
	April	243.20[c]	12.80	230.40	275.20	0.05
	Total	352.00	108.80	166.40	563.20	0.31

NOTE: means with the same letter are statistically similar (P>0.05)

Sodicity and Permeability

Sodium obtained from November 2017 to March 2018 ranged from 18 – 30 mg/l with a mean of 23.44mg/l. Consequently, sodium adsorption ratio obtained within the period ranged from 3.70 – 6.32mg/l. while the mean was 4.93mg/l. Analysis of variance shows that there was no significant difference in the distribution of sodium among the months. The degree of restriction of the water for irrigation with respect to sodium is classified as slight to moderate. In contrast it was reported [10] that SAR values of surface water in the Jalagon urban area of India did not pose any threat to irrigation farming. SAR and EC were used to assess impact of irrigation water on infiltration rate using guidelines in Figure 3. SAR and EC values were within the range 3 to 6 and 0.3 to 1.2 (ds/m), permeability rating was therefore classified as slight to moderate.

Specific Ion Toxicity

Contents of nitrate, chloride and boron in the Delimi River within the period of study are presented in Table 2. Mean contents of chloride, nitrate and boron ranged from 42.00 – 52.00, 13.00 – 17.00, and 0.20 - 0.2 mg/l respectively. Analysis of variance shows that there was no significant difference in the distribution among the month except for chloride. Boron and chloride values were nonetheless within acceptable range for irrigation however the degree of restriction with respect to nitrate was classified as slight to moderate. Similar observation was reported for boron and chloride in suface waters of the Kosovo plain [12].

The calcium and magnesium contents obtained within the period ranged from 27.00 – 35.80mg/l and 12.00 – 16.00mg/l while the mean total was 3.8881 and 13.7778mg/l respectively. The month of January had the highest level of calcium while November had the lowest. Analysis of variance shows that there was significant difference in the distribution of Calcium among the month. In contrast, there was no significant difference in the distribution of magnesium among the months. The content of calcium and magnesium were within the normal ranges found in irrigation water [13] and therefore serve as a source of enrichment to soils irrigated from the river. The MAR values were =< 50, hence, suitable for irrigation [10]. However the Ca: Mg being less than 3.1 indicates that Ca deficiencies may develop in soils irrigated with the water in the long-term [13].

Table 2: Descriptive statistics of chemical properties of Delimi river.

Parameter	Month	Mean	Std. deviation	Minimum	Maximum	CV
Ca	November	28.00[b]	1.00	27.00	29.00	0.0
	January	33.33[a]	1.53	32.00	35.00	0.0
	March	31.33[ab]	2.52	29.00	34.00	0.1
Mg	November	13.00[a]	1.00	12.00	14.00	0.1
	January	14.67[a]	1.53	13.00	16.00	0.1
	March	13.67[a]	1.53	12.00	15.00	0.1
MAR	November	31.71[a]	50.00	30.77	32.56	1.6
	January	30.56[a]	50.00	28.89	31.37	1.6
	March	30.38[a]	37.78	29.27	30.61	1.2
Ca:Mg	November	2.15[a]	1.00	2.25	2.07	0.5
	January	2.27[a]	1.00	2.46	2.19	0.4
	March	2.29[a]	1.65	2.42	2.27	0.7
Na	November	20.00[a]	2.00	18.00	22.00	0.1
	January	26.67[a]	4.93	21.00	30.00	0.2
	March	23.67[a]	3.51	20.00	27.00	0.1
SAR	November	4.31[a]	0.54	3.70	4.70	0.1
	January	5.48[a]	1.12	4.20	6.32	0.2
	March	5.01[a]	0.87	4.04	5.70	0.2
B	November	0.27[a]	0.06	0.20	0.30	0.2
	January	0.37[a]	0.07	0.29	0.42	0.2
	March	0.31[a]	0.06	0.24	0.36	0.2
NO3	November	12.00[a]	1.00	11.00	13.00	0.1
	January	15.00[a]	2.00	13.00	17.00	0.1
	March	13.67[a]	1.53	12.00	15.00	0.1
Cl	November	43.67[b]	1.53	42.00	45.00	0.0
	January	49.67[a]	2.08	48.00	52.00	0.0
	March	46.33[ab]	1.52	45.00	48.00	0.0

NOTE: Mean with the same letter are statistically similar (P>0.05)

Conclusion

Water quality parameters assessed during the period of study did not follow any particular trend across the months. Furthermore despite the anthropogenic influences on the water, values for coefficient of variation for water quality parameters across the months were in most cases less than 1. Signifying that monthly variation during the period of study was minimal. The degree of restriction of water from the Delimi River for irrigation during the period of study with respect to salinity, sodicity, permeability and nitrate content is rated as slight to moderate. Boron and chlorine contents were within acceptable limits. However to avert long-term environmental effects it is imperative that regulatory agencies control or prevent further pollution of the river. In addition, mechanisms should be set up to ensure regular monitoring of water quality from the river on a long-term basis.

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