Physico-Chemical Analysis of River Benue within Makurdi Reach for Irrigational Use

Aho M.I[1], Ajayi, S.D[2], Lagasi, J.E.[3]
[1,2]*Civil Engineering Department, University of Agriculture Makurdi, Nigeria.*
[3]*Department of Civil Engineering, Federal Polytechnic, Bauchi.*

ABSTRACT

River Benue is one of the largest rivers in Nigeria, second only after River Niger. The reach of the River within Makurdi metropolis is inhabited by farmers, who depend largely on the availability of the water resource for agricultural and irrigational purposes. The sustained human activities within the reach of the River all year round, necessitated the investigation into the physico-chemical status as well as some selected cations, anions, nutrient load and heavy metals for comparism with FAO and WHO permissible limits. One hundred and ten samples (110), collected at ten (10) different locations within the study area were analyzed between December, 2015 to October, 2016. Heavy metals such as cadmium, manganese and lead were undetectable in the study area, except iron and zinc which were found in traces between 0.018 – 0.038 and 0.014 – 0.035mg/L in the dry and rainy seasons respectively. Sodium Adsorption Ratio (SAR), Residual sodium bi carbonate (RSBC) and Permeability Index (PI) were adopted in the assessment of the water quality for irrigation. The SAR and Electrical Conductivity (EC) values ranged from 0.0896 – 0.503epm and 0.163 – 0.281ds/m in the dry and rainy seasons respectively. Following Wilcox classification, the water quality within the reach of River Benue is observed to be of low sodium content, moderate pH, without sodicity challenge for irrigation.

Keywords: *Physico-chemical Parameters, Sodium Adsorption Ratio, Water Quality, Irrigation, River Benue.*

I. INTRODUCTION

Water is the most vital element among the natural resources, and is crucial for the survival of all living organisms', plants and animals inclusive [1]. The economic burden of environmental degradation owing to water pollution is very huge in the Third world countries like Nigeria when it comes to restoring the quality of life and installing controls. The increasing urbanization and industrialization of Nigeria have negative implications on water quality [2]. The pollution from industrial and urban waste effluents and from agrochemicals in water bodies of Nigeria has reached alarming levels. The long-term effects of this water contamination by organic and inorganic substances, many of them are toxic, are incalculable. The marine and aquatic ecosystems are affected, and the chemicals that enter the food chain have public health implications

Irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available. This situation is now changing in many areas. Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental supplies must rely on lower quality and less desirable sources. To avoid problems when using these poor quality water supplies, there must be sound planning to ensure that the quality of water available is put to the best use [3].

The quality of surface waters is very significant. Much attention has being drawn to it, that is why criteria and standards for its evaluation have existed since the late 1800's. Currently, there is much concern about the quality of natural water and about the presence of extremely small amount of potentially harmful substances in them, due to anthropogenic influences from urban, industrial as well as natural processes (changes in precipitation inputs, erosion, weathering of crustal materials). This has degraded surface water and has affected both domestic and irrigational activities making it unsuitable and unsafe [3].

Hence, water analysis is often carried out in areas where surface water are used frequently, and also areas where industries are known for discharging wastes (without adequate treatment measures). These wastes contain chemicals that can potentially affect nearby water sources contaminating these water bodies, making such sources to be unsuitable for irrigation, recreation and other purposes. Its effect when such water is used can be very severe for irrigation. It can go a long way in affecting the rapid growth of the crop producing smaller plants with fewer and smaller leaves, [4].

Therefore, proper awareness and enlightenment has to be given to users in such areas about the effect of such polluted waters. There are predefined criteria and standards as regards the suitability of water for irrigation and other purposes, this study will discuss important factors in assessing the suitability of River Benue for irrigation and other applications.

II. Materials and Methods

Study Area

The study area is Makurdi town; the administrative headquarter of Benue State. The city is one of the fastest growing urban areas in Nigeria. It lies between Latitude 7^0 44′ 1.50"N and Longitude 8^0 31′ 1.700"E; and is located within the floodplain of the lower River Benue valley, (Figure 1). Due to the general low relief, sizeable portions of Makurdi is waterlogged and flooded during heavy rainstorms. It is drained principally by River Benue which divides it into Makurdi North and South with the banks connected by two bridges, adapted from [5]

The climate of the region is generally sub-tropical influenced by two air masses: the warm moist southwesterly air mass and the warm dry north- easterly air mass. The southwesterly air mass is a rain bearing wind that brings about rainfall from the months of April to October with an extended dry period of five months (November - March). Considering the rainfall, atmospheric temperature and evapotranspiration, sizeable portions of Makurdi is waterlogged and flooded during heavy rainstorms. The mean annual rainfall total is 1190 mm and ranges from 775-1792 mm. The mean monthly relative humidity varies from 43% in January to 81% in July-August period. Temperatures are generally high throughout the year, with February and March occurring as the hottest months. The dry northeasterly air mass blows over the region from November to April, thereby bringing about seasonal drought, [6].

Sample Collection

Ten (10) different study sites were selected with respect to concentrated dry season farming activities along the river course within Makurdi metropolis, Benue state as indicated in Fig 1, GPS technology was employed in the selection.

Water samples from River Benue were collected following standard procedure as described by [7]. Pre-cleaned one-litre plastic bottles were used to collect water samples for the physico-chemical analysis. Sample containers were labeled on the field using appropriate codes and water samples were temporary stored in ice packed cooler and transported to the laboratory and stored in a refrigerator at about 4 ºC prior to analysis [7]. These samples were collected on a monthly basis consecutively for a period of eleven months (December 2015 to October 2016).

Sample Analysis

The physiochemical analyses of water samples were performed using standard analytical methods according to procedures outlined in the Standard Methods for the Examination of Water and Wastewater [7].The instrument used chiefly was HACH Lange kits DR/2000 spectrophotometer as

described by [7]. The collected surface water samples were analyzed for pH, electrical conductivity, total dissolved solids, the cations such as nitrogen, calcium, magnesium, potassium, sodium; the anions such as, carbonate, bicarbonate, chloride, sulphate, phosphate and borate according to the standard methods and techniques [8]. The water quality determining indices, such as Sodium Adsorption Ratio (SAR), Residual Sodium Bicarbonate (RSBC), Soluble Sodium Percentage (SSP), Total Alkalinity (TA), Permeability Index (PI), were calculated by using the following recommended relationships.

$$SAR = \frac{N_a^+}{\sqrt{\frac{C_a^{2+}+Mg^{2+}}{2}}} \quad - \quad (1)$$

$$RSBC = (Co_3 + HCo_3) - (Ca^{2+} + Mg^{2+}) - (2)$$

$$SSP = \frac{Soluble\ \ Sodium\ \ Concentration}{Total\ \ Cation\ \ Concentration} x100 \quad - \quad (3)$$

$$RSC = HCo_3 + (Ca + Mg) \quad - \quad (4)$$

$$Total\ Alkalinity\ (TA) = \frac{RSC}{RSBC} \quad - \ - \quad (5)$$

$$Permeability\ Index\ (PI) = \frac{Na^+ + \sqrt{HCo_3}\ x100}{Ca^{2+}+Mg^{2+}+Na^+} - (6)$$

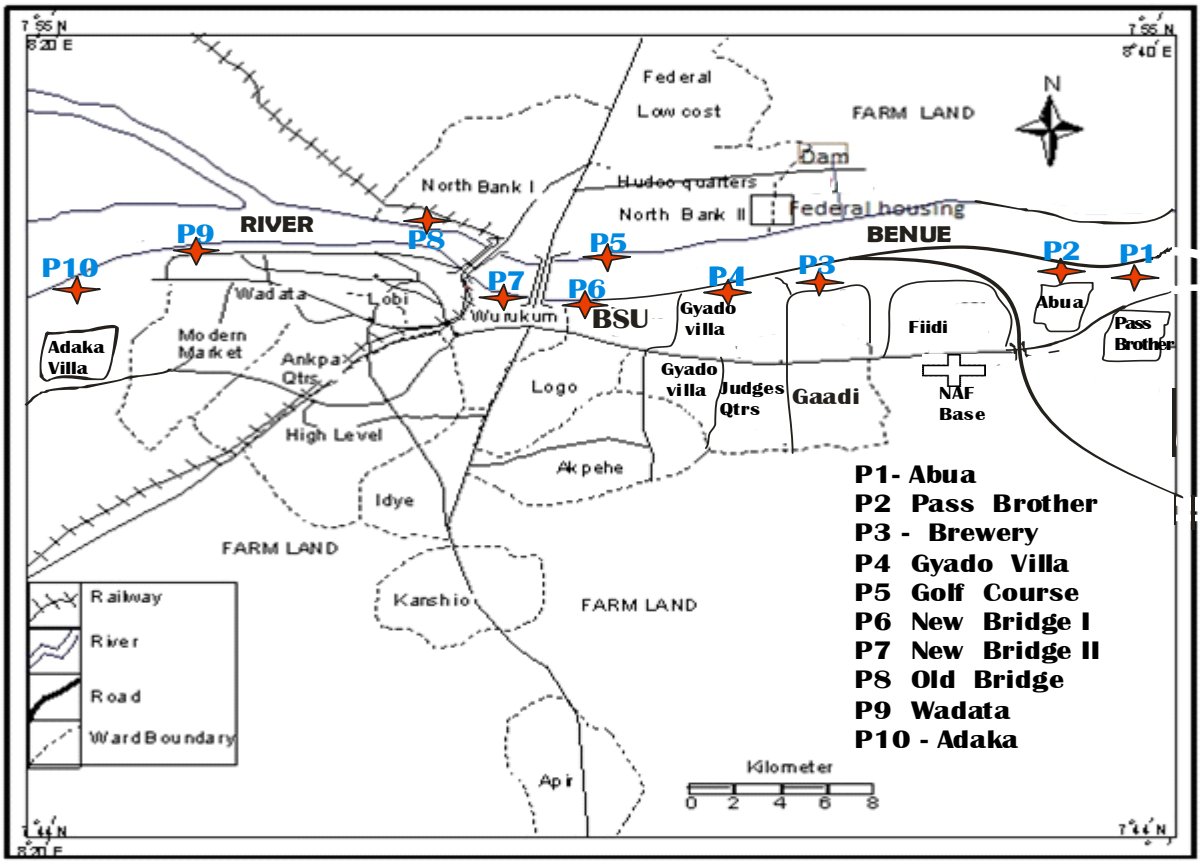

Figure 1: Water Sample Points Location of River Benue at Makurdi.

III. Results and Discussion

Temperature, pH and Electrical Conductivity (EC)

Temperature showed an upward trend from December to April, followed by downward trend from May onwards. The overall temperature range was 18.4^{0C} to 31.6^{0C} between January and April as seen in Table 2. The pH as seen in Table 2 is within permissible limits. The electrical conductivity values within the study area were below the maximum limit of 3.0ds/m as specified by FAO (2016).

Table 2: Summary of Mean values of physic-Chemical Characteristics of River Benue water measured in milligram per litre (mg/l)

Date	Cl	SO_4	CO_3^{2-}	HCO_3^-	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	Fe	Zn	EC	T	pH
Dec' 15	2.48	2.52	1.46	2.59	2.39	5.01	2.64	42.60	23.30	0.030	0.033	0.220	18.60	7.30
Jn'16	2.53	3.56	1.71	3.58	4.32	3.46	2.15	41.60	21.80	0.036	0.034	0.210	18.40	7.20
Feb'16	2.58	3.57	1.95	4.58	5.22	1.91	1.97	40.70	20.30	0.038	0.035	0.121	23.20	7.10
Mar'16	2.58	3.57	1.95	4.58	5.22	1.91	1.97	40.70	20.30	0.038	0.035	0.122	27.20	7.10
Apr'16	2.55	3.57	1.95	4.58	5.22	1.91	1.97	40.70	20.30	0.038	0.035	0.142	31.60	7.12
May' 16	2.23	2.55	1.90	3.27	4.22	8.54	2.12	43.50	22.20	0.028	0.032	0.181	27.00	7.30
Jun'16	1.87	2.45	1.82	2.80	3.35	11.12	2.42	44.93	23.30	0.025	0.029	0.220	24.60	7.40
July'16	1.24	1.42	1.72	2.78	3.19	14.58	2.49	46.80	23.90	0.022	0.021	0.312	22.40	7.43
Aug'16	0.31	0.28	1.26	2.71	1.83	22.60	3.49	50.50	24.10	0.014	0.018	0.325	22.20	7.64
Sep'16	0.31	0.28	1.26	2.71	1.83	22.58	3.49	50.46	24.06	0.014	0.018	0.326	21.20	7.60
Oct'16	0.31	0.28	1.26	2.71	1.83	22.60	3.49	50.50	24.10	0.014	0.018	0.322	20.80	7.60
Mean	1.73	2.19	1.66	2.94	3.51	10.57	2.56	44.82	22.52	0.027	0.028	0.216	23.38	7.34
SD	0.95	1.33	0.28	0.90	1.81	8.32	0.61	3.92	1.52	0.0095	0.0072	0.12	3.79	0.196

Source: Researchers' Field work.2015- 2016

Table 3: Summary of results from water quality analysis

S/No	Parameter	Unit	River Benue in the study Area		Permissible limits for irrigation water		Remarks
			Dry	Rainy	FAO (2016)	WHO (2016)	
1	Temp.	^{0}C	23.80	23.03	<40.00	<40.00	Satisfactory
2	pH	-	7.16	7.50	6.5 – 8.4	6.0 – 8.5	Satisfactory
3	EC	dS/M	0.163	0.281	0 – 30	0 – 3.0	Satisfactory
4	TDS	Mg/L	104.12	179.84	0 – 450	0 – 500	Satisfactory
5	SAR	epm	0.0896	0.503	0 – 15.00	0 – 15	Satisfactory
6	SSP	%	3.10	14.38	0 – 60	0 – 66	Satisfactory
7	PI	%	9.65	18.85	-	-	-
8	SR	-	0.0325	0.1709	0 – 1.00	≤1.0	Satisfactory
9	RSC	Meq/L	-3.1482	-4.2783	≤1.25	≤1.25	Satisfactory
10	RSBC	Meq/L	-3.0881	-4.277	-	-	-
11	SCAR	Meq/L	0.086	0.4781	-	-	Satisfactory
12	Salt Index	Ppm	-36.72	-29.09	Negative value	-	Satisfactory
13	TA	Meq/L	1.0195	1.0003	0 – 2.50	≤2.50	Satisfactory
14	TH	Mg/L	62.46	71.40	0 – 150	0 – 145	Satisfactory
15	Sodicity	-	1.042	1.052	0 – 10	0 – 10	Satisfactory
16	Sulphate	Meq/L	0.1065	0.0422	0 – 5	0 -5	Satisfactory
17	Chloride	Meq/L	0.155	0.373	0 – 10	0 - 10	Satisfactory

Source: Researcher's field work 2015 – 2016.

Sodium Absorption Ratio (SAR)

The values of SAR of the collected water samples range from 0.0896epm in the dry season to 0.503epm in the rainy season, implying that the River has no Sodicity challenge. According to [9], all the water samples collected and analyzed fell under 'excellent' class of water for irrigation. As per salinity classification; all the water samples fell under 'low sodium' hazards (S_1) water which can be used for almost all crops. Irrigation water that has high sodium (Na^+) content can bring about a displacement of exchangeable cations Ca^{2+} and Mg^{2+} from the clay minerals of the soil, followed by the replacement of the cations by sodium. Sodium-saturated soil peptizes and loses their permeability, so that their fertility and suitability for cultivation decreases [10]. High SAR in any irrigation water implies hazard of sodium (Alkali) replacing Ca and Mg of the soil through cation exchange process, a situation eventually damaging to soil structure, namely permeability which ultimately affects the fertility status of the soil and reduction of crop yield [11].

Hardness and Total Alkalinity (TA)

Hardness of the river water fluctuated between 61.00 mg/L and 74.60 mg/L. The results indicates that, the water is soft, based on water hardness classification.
The Total Alkalinity (TA) ranged between 1.0195 and 1.0003meq/L. Total Alkalinity in all the seasons at all the study sites were within low alkalinity limit as described by [11-12].

Cations
Calcium **(**Ca^{2+}), which is a major component of natural waters, comes mainly from the rocks, seepage, drainage, wastewater etc. Ca^{2+} in the samples under consideration varied from 40.70 mg/L to 50.50 mg/L. Magnesium (Mg^{2+})is required as an essential nutrient for plants as well as for animals

and the concentration of 30 mg/L is recommended for drinking waters. The concentration of Mg^{2+} ions in the water samples under this study varied from 20.30 mg/L to 24.10 mg/L. In the study, Sodium (Na^{+}) concentration in water of River Benue ranged from 1.91– 5.01 mg/l in dry season and 8.54–26.60 mg/l in rainy season. The highest average of Sodium concentration (22.60 mg/l) was found during the month of August in 2016 at rainy season. According to [12 – 15] Water Quality Standard, Sodium (Na^{+}) concentration was within permissible limit for irrigation in terms of salinity. When Sodium (Na^{+}) concentration in water reaches above 919.6 mg/l, water becomes saline and unsuitable for irrigation [3, 12].

Anions

In this study, the chloride contents were ranged from 0.31 mg/L to 2.58 mg/L. Chloride content was lower than the accepted limit of 250 mg/L at the sampling sites in the river. The levels downstream were slightly higher than those obtained upstream in all the seasons. Values indicate low seasonal variation of chlorides which show that there is little variation in domestic activities with change in the seasons. Overall, chloride concentration was within the acceptable limits. Sulphate (SO_4^{2-}) concentration in the river varied from 0.28 mg/L to 3.57 mg/L. The concentration of $SO_4^{2-}$was much lower in the Rainy season as compared to dry season. The maximum value was obtained in February while the minimum value was recorded in the month of August. The permissible limit of Sulphate is20.00 mg/l for irrigation water [3]. It was observed that sulphate was present under acceptable limits. This shows that the percentage contributions of Sulphate from domestic as well as industrial activities are still minimal.

Bicarbonate concentration in water of River Benue ranged from 2.59– 4.58mg/l in dry season and 2.71– 3.27 mg/l in rainy season. The highest average of Bicarbonate ($HCO3^{-}$) concentration (4.58 mg/l) was found at dry season during the month of February in 2016. The recommended limit of Bicarbonate ($HCO3^{-}$) concentration in water is 50 –300 mg/l for fisheries [12, 18], and is 53.53 mg/l for irrigation water [3].

Heavy Metals

Nickel (Ni), Copper (Cu), Cadmium (Cd), Manganese (Mn) and Lead (Pb) were undetectable at both the sites in all the season therefore the river water is free from toxic metals. However, Iron (Fe) and Zinc (Zn) were found in traces. Zn values ranged between 0.014mg/L at the rainy season and 0.035 mg/L in dry season. The concentrations of Fe in the water ranged from 0.018 mg/L in the rainy season to 0.038 mg/L in the month of February 2016. Both season's values falls within the background level and the WHO limit of 0.3 mg/L [13].

Nutrient Loads

NO_3^{-} in river water promotes high primary productivity and excess of NO_3^{-}in surface water is taken as a warning for algal blooms. In this study, the NO_3^{-}levels were quite low, varying from 1.80 mg/L to 5.22 mg/L. The highest average (5.22 mg/l) of Nitrate ($NO3^{-}$) concentration was found at dry season during the month of February in 2016.

IV. CONCLUSION

From the assessment of the physical and chemical parameters, as well as the quality determining indices of the River, it is safe to conclude that, the water quality is satisfactory for irrigational applications in the study area. However, regular monitoring and engineering evaluation of the water quality is recommended.

REFERENCES

[1] K. Venkatesharaju, P. Ravikumar, R. Somashekar, and K. Prakash, Physico-chemical and Bacteriological Investigation on the river Cauvery of Kollegal Stretch in Karnataka, 2010 vol. 6.

[2] Islam, F., Sharmin, R. and Junait, J. "A Detailed Pollution status and trends in water quality of the analysis on industrial pollution in Bangladesh," Workshop Discussion Paper. (1997)

[3] Ayers, R. S, and Westcot, D. W. Water Quality for Agriculture. FAO, Irrigation and Drainage Paper No. 29, Rev. 1. FAO, Rome. (1985) 174 p.

[4] Arora, K.R. *Irrigation, Water Power and Water Resources Engineering*. 4th Ed. A.K Jain for Standard Publishers Distributors, New Delhi. (2002).

[5] Ocheri, M. I.; Mile, I. I. and Obeta, M.C. Seasonal variation of nitrate levels in hand dug wells in Makurdi metropolis, *Pakistan Journal of Nutrition*, (2010) 9: 539-542.

[6] Ologunorisa, E. T. and Tersoo, T. The changing rainfall pattern and its implication for flood frequency in Makurdi, Northern Nigeria, *Journal of Applied Science and Environmental Management*, (2006) 10(3): 97-102

[7] APHA (American Water Works Association) Standard methods for Examination of water and wastewater. 21stEdition.APHA-AWWA, Washington, DC, USA. (2005)

[8] Jackson, M. *Soil Chemistry Analysis*. Prentice-Hall, Englewood Cliffs, USA. (1967). pp. 227-261.

[9] Richards, L.A. *Diagnosis and improvement of saline alkali*. USDA Handbook 60, Washington DC (1954)160p

[10] Matthess, G. *The Properties of Ground Water*, John Wiley and Sons, New York, USA. (1982) 397.

[11] Gupta, I.C, Use of water in Agriculture. A study of arid and semi-arid zones of India, Revised ed. Oxford and IBH publishing Co., New Delhi (1990) 308.

[12] FAO Simple Soil, Water and Plant Testing Technique for Soil Resource Management. Land and Water development Division, Food and Agriculture Organization, Rome, Italy. (2016)1-142

[13] WHO (World Health Organization), *Guidelines for Drinking Water*, *WHO Criteria and Other Supporting Information*, World Health Organization: Geneva, (2016)

[14] USEPA(United States Environmental Protection Agency), "Drinking Water Quality Standards," (2000)

[15] Mezgebe, K.; Gebrekidan, A.; Hadera, A.; Weldegebriel, Y. "Assessment of Physico-Chemical Parameters of TsaedaAgam River in Mekelle City, Tigray, Ethiopia, Bull. Chem. Soc. Ethiop. (2015) 29(3): 377-385.