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Geospatial Analysis of Quality Indices of River Oba Water, Ogbomoso, Nigeria

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Abstract Many villages along the River Oba in Ogbomoso depend heavily on river water for crop irrigation, and water quality is important for maximum crop production. The River Oba water course in Ogbomoso was divided into four locations. River water samples were collected in three replicates from each of the designated locations during the dry and rainy seasons and analyzed for various quality parameters. The results indicated that the pH range was slightly acidic in the dry season but more alkaline during the rainy season. Calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), sodium (Na^{+}), bicarbonate (HCO_3^{-}), phosphate ($PO_3^{-}P$), electrical conductivity (EC), nitrate ($NO_3^{-}N$), sulphate ($SO4^{2-}$) and total dissolved solids (TDS) were within the recommended limits set for irrigation standard water, indicating that the river water in the designated locations were suitable for irrigation purposes. The water quality indicators, including SSP, RSC, KR, PI and SAR were all within safe limits for both seasons. Maps showing spatial variations of pH, electrical conductivity (EC), total dissolved solid (TDS), cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), anions ($SO^{2}{}_{4}^{-}$, NO_3^{-} -N, PO_4^{-} and HCO_3^{-}) were produced using geostatistics software. Overall, the findings suggest that the river Oba water in the four designated locations is suitable for irrigation purposes, and farmers in the areas can use it to grow their crops without adverse effects. However, continuous monitoring of water quality is vital to ensure that it remains within safe limits, and appropriate measures should be taken to address any issues that may occur.

Keywords: Irrigation, Water, Quality, River, locations

I. Introduction

Surface water (rivers, ponds, and streams) are parts of the sources of water available to the people in general. Water has become a universal problem, not only the quantity, but also its quality [1]. Its quantity and quality varies from place to place and season to season. Water quality analysis is one of the most important aspects in surface water studies although, it is a crucial factor for the evaluation of environment changes, which are strongly associated with the social and economic development of any nation [2]. Notwithstanding, water for irrigation varies greatly in quality relating to the total quantity of dissolved salts and its ionic composition in relation to the source of the water [3]; [4], its location and time of sampling [1]. Water quality is a term used to describe the physical, chemical and biological parameters of water features concerning its standard for specific uses [5]. A water quality index provides a single number that

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expresses the overall water quality at a certain location meanwhile, the objective of this water quality index is to turn complex water quality data into information.

The total amount of water on the earth is approximately 1.35 billion cubic kilometers. Almost 97.1 percent has been locked into oceans as saltwater. Ice sheets and glaciers have remand 2.1 percent. Only 0.2 percent is impudent water present on the earth, which can be consumed by humans for varieties of uses. The remaining 0.6 percent is in underground form [6]. The available water has been getting polluted daily, due to different anthropogenic activities occurring on the land surface. Rivers are one of the surface water available to use for general purposes. Rivers erode the landscape and change the topography of the earth by carving canyons and transporting soil and sediment that have been washed into it when it rains or snow melts. Thus, sediment in the river can be helpful or harmful to the plants. As rivers run through many communities, it could be fed with contaminants by runoff from different parts into the rivers, unfortunately, contaminated surface waters may not be profitable for agricultural purposes. Although, rivers in its natural environment contains some impurities such as dissolved solids and gases, and it also hosts many of microorganisms, pathogenic and non-pathogenic. Salinity and sodicity hazards have been reported as constant threats in irrigated agriculture, with poor irrigation water quality becoming a major concern as the climate changing [3]. The quality of irrigation water is directly related to its effects on both the crops and soils on which they are grown as well as its management; thus high-quality crops can only be attained by using standard irrigation water.

Thus, there is the need to generate a database on the quality status of this river course so that strategies for mitigation could quickly be put in place. Therefore, the objectives of this study were, to evaluate the physicochemical properties of River Oba water quality status and its suitability for irrigation in four designated locations along its course in Ogbomoso for irrigated agriculture and to produce thematic maps for all the quality parameters consider in this research work.

II. Materials and Method

A. Description of the Study Area

The experiments were carried out in four designated locations along the River Oba course in Ogbomoso, and were represented by Station A Settlement, Station B Settlement, Station C Settlement and Station D Settlement. Ogbomoso is located at Latitude 8° 10' N and Longitude 4° 10' E, with an altitude of about 342 m above the mean sea level. The study area has a bimodal rainfall pattern, with rainfall peaks in the months of July and September and breaks in August. The annual mean rainfall is about 1200 mm while the optimal mean temperature is 33 °C and minimal temperature is 16 °C [7]. The relative humidity of the area is not less than 80% between the months of April-November while it is low between December-March when dry wind (harmattan) blows from the northeastern part of the country [8]. Station A settlement is along Ogbomoso - Old Ilorin road, Station B settlement is along Abogunde village via of Ogbomoso, Station C settlement is along Ogbomoso - Igbeti road, and Station D Settlement is along Ogbomoso - Oyo road.

B. Sampling Points Selection

A total of twelve samples points were uniformly spread across the River Oba course within Ogbomoso. Magellan trailblazer XL GPS handheld device was employed in determining the geographical position of the sampling points across the settlements.

C. Sample Collection and Analysis

At each station, 200 ml samples of water were collected in three replicates. The water samples were collected during the dry season (November 2018) as well as during the rainy season (June 2019). The sampling bottles used were thoroughly cleaned with deionized water before the collections of samples to ensure that they contain no contaminants.

Water samples were collected directly into the bottles. The water surface was disturbed a little to remove any floating material before collection of the samples. After sampling, the bottles were marked, sealed and taken to the laboratory in an ice-packed container for analyses. The water quality indicators that were analyzed are: EC, HCO^{-}_{3}, NO_3^-, SO_4^{2-}, PO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, pH, TDS and CO_3^{2-}. All analyses were done according to [9] standard method.

D. Water Quality Index Calculation

The combined impact of different water quality parameters on irrigation water was assessed by irrigation water quality index (IWQI). The (IWQI) was computed according to [10]. In this study, the certain four chemical characteristics that can affect the suitability of irrigation water quality were used to compute water quality index. EC, SAR, HCO_3^- and Mg/Ca ratio, according to [10].

E. Analysis of Water Samples

River Oba water samples analysis were done for cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) and anions (NO_3^-, CO_3^{2-}, HCO_3^-, SO_4^{2-} and PO_4^{2-}) and calculation of other chemical parameters (SAR and SSP, RSC, PI and KR) were determined. Besides this, *in situ* measurements of pH, EC, TDS were done. Cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) and anions (NO_3^-, CO_3^{2-}, HCO_3^-, SO_4^{2-} and PO_4^{2-}) were determined using standard methods. Paliintest photometer (7100) with colorimetric method was used to determine the cations and anions. Calculation of SAR, SSP, RSC, PI and KR were done as described by [11]. TDS, EC and pH were determined by pH /EC/TDS meter H19810-6 *in situ* (on site) measurement, values gotten were recorded. The physicochemical data that were obtained subjected to univariate (mean, standard deviation, coefficient of variation) and multivariate (Pearson correlation coefficient) statistical analyses using Statistical Package for Social Sciences (SPSS, version 16.0) software.

F. Residual Sodium Carbonate (RSC)

The residual sodium carbonate (equation 1) was calculated simply by subtracting the quantity of $Ca^{2+}+ Mg^{2+}$ from the sum total of carbonates and bicarbonates determined separately in a given sample and expressed in meq/L. Thus,

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+}) \quad (1)$$

G. Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio was calculated using the formula given below. The concentration of Na^+, Ca^{2+} and Mg^{2+} was used to calculate the sodium adsorption ratio (SAR) according to the equation 2

$$\mathrm{SAR} = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+}+Mg^{2+})}} \quad (2)$$

Where, Na^+ is sodium concentration meq/L Ca^{2+} is calcium concentration, meq/L Mg^{2+} is magnesium concentration, meq/L.

H. Soluble Sodium Percentage (SSP)

The SSP (equation 3) was calculated using equation 3:

$$\%Na = \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \, x \, 100\% \quad (3)$$

Where, the concentrations of ions are expressed in meq/L.

I. Permeability Index (PI)

The permeability index was calculated by equation 4:

$$PI = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \times 100 \quad (4)$$

Where, all the values are in meq/L.

J. Kelly's Ratio (KR)

Kelly's ratio was calculated by using the equation 5:

$$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}} \quad (5)$$

Where, concentrations are expressed in meq/L

K. Statistical Analysis and Mapping

The results obtained were subjected to descriptive statistics to determine the minimum, maximum, mean, standard deviation and coefficient of variation of the pooled data, irrespective of sampling locations and sampling periods. All analyses were performed by using (SPSS, version 16.0) software. Ordinary Kriging was used as a spatial interpolation method for the preparation of thematic maps for all the quality parameters considered in this study by using geostatistics software.

III. Results and Discussion

The findings of this study are presented in tables and maps, for easy visualization of the results of the analysis that was conducted.

A. Physicochemical Water Quality Data

In this section, the results of physicochemical properties of River Oba water within the study areas are presented in Table 1 and 2, showcasing the stations covered by each section of the table and compared to irrigation standard recommendations. The pH values across the designated locations of the water samples ranged from 6.40 to 7.04 in the dry season, with a mean value of 6.82, while the values were ranged from 7.02 to 7.32 with a mean value of 7.22 in the rainy season Table 1 and 2, suggesting circumneutral to weakly alkaline river water. The electrical conductivity (EC) ranged from 0.05 to 0.07 dS/m, with a mean value of 0.06 in the dry season, while the value ranged from 0.09 to 0.11 dS/m during the rainy season, thus the coefficient of variation was zero (CV=0). This implies that the salt concentration was fairly uniform across the designated stations. The total dissolved solids (TDS) values varied between 25 and 33.80 mg/L with a mean value of 29.10 mg/l in the dry season, while the value was 44.60 to 66.30 with a mean value of 53.6 across the selected stations during the rainy season. All the samples in all the stations have TDS values below the maximum recommendation permissible limit of 2000 mg/L for irrigation water, indicating good samples for irrigation. The total dissolved solids are an indication of the degree of dissolved substances such as metal ions in the water. The concentrations are significantly high during the rainy season due to erosion of particulate matter and sediments from agricultural fields into the river, as observed by [12]. However, this is a common scenario, in areas where fertilizers have been used for agriculture, and a state of eutrophication has occurred as observed by [12]. A similar result to the findings from this study was reported by [12] in their studies of Assessment of Yatta canal water quality for irrigation, Machakos County, Kenya.

Table 1: Quality of river Oba at different points of water samples collection along its course in Ogbomoso and their comparison with irrigation standard [14]

Parameters	pH	TDS mg/L	NO_3-N mg/L	SO_4^{2-} mg/L	PO_4^- mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^+ mg/L	K^+ mg/L	EC, dS/m	HCO_3^- mg/L
Irrigation Standards	6.0-8.5	2000	10	960	2	400	61	400	2	3	620
Station A settlement (dry season)											
Min.	6.89	25.00	0.03	21.00	0.06	10.00	5.00	1.28	1.90	0.05	120.0
Max.	7.16	25.00	0.04	25.00	0.08	12.00	6.00	1.92	2.10	0.05	120.0
Mean	7.04	25.00	0.03	23.00	0.07	11.00	5.33	1.57	2.00	0.05	120.0
SD	0.14	0.00	0.00	2.00	0.01	1.00	0.58	0.32	0.10	0.00	0.00
CV, %	1.97	0.00	7.70	8.70	15.75	9.09	10.83	20.65	5.00	0.00	0.00
Station A settlement (rainy season)											
Min.	7.20	47.30	0.05	31.00	0.09	14.00	7.00	1.84	2.80	0.09	140.0
Max.	7.41	51.50	0.06	33.00	0.10	16.00	9.00	1.89	2.90	0.10	145.0
Mean	7.30	50.00	0.06	32.00	0.10	15.33	8.00	1.86	2.83	0.10	141.7
SD	0.11	2.23	0.00	1.00	0.01	1.15	1.00	0.03	0.06	0.00	2.89
CV, %	1.14	4.55	7.78	3.13	5.97	7.53	12.50	1.35	2.04	0.00	2.04
Station B settlement (dry season)											
Min.	6.92	28.00	0.04	18.00	0.05	24.00	15.00	1.28	1.80	0.06	180.0
Max.	6.98	28.20	0.05	21.00	0.09	26.00	16.00	1.30	2.10	0.06	180.0
Mean	6.95	28.13	0.05	19.67	0.07	25.33	15.67	1.29	1.97	0.06	180.0
SD	0.03	0.12	0.00	1.53	0.02	1.15	0.58	0.01	0.15	0.00	0.00
CV, %	0.44	0.41	0.00	7.77	31.22	4.56	3.69	0.90	7.77	0.00	0.00
Station B settlement (rainy season)											
Min.	7.20	44.50	0.07	34.00	0.08	26	14.00	1.92	3.60	0.09	210.0
Max.	7.44	44.80	0.07	34.00	0.10	28	16.00	1.94	3.70	0.09	220.0
Mean	7.32	44.60	0.07	34.00	0.09	26.67	15.33	1.93	3.63	0.09	213.3
SD	0.12	0.17	0.00	0.00	0.01	1.15	1.15	0.01	0.06	0.00	5.77
CV, %	1.64	0.39	1.47	0.00	11.11	4.33	7.53	0.52	1.59	0.00	2.71

Min.: minimum; Max.: maximum; SD: standard deviation; CV: coefficient of variation;

Table 2: Quality of river Oba at different points of water samples collection along its course in Ogbomoso and their comparison with irrigation standard [14].

Parameters	pH	TDS mg/L	NO_3-N mg/L	SO_4^{2-} mg/L	PO_4^- mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^+ mg/L	K^+ mg/L	EC, dS/m	HCO_3^- mg/L
Irrigation Standards	6.0-8.5	2000	10	960	2	400	61	400	2	3	620
Station C settlement (dry season)											
Min.	6.36	28.70	0.04	24.00	0.10	23.00	8.00	1.74	2.40	0.06	200.0
Max.	6.43	30.20	0.42	25.00	0.12	25.00	12.00	1.90	2.50	0.06	230.0
Mean	6.40	29.50	0.17	24.67	0.11	24.00	10.00	1.82	2.43	0.06	213.3
SD	0.04	0.75	0.22	0.58	0.01	1.00	2.00	0.08	0.06	0.00	15.28
CV, %	0.59	2.56	130.34	2.34	9.09	4.17	20.00	4.40	2.37	0.00	7.16
Station C settlement (rainy season)											
Min.	7.01	54.50	0.10	38.00	0.19	45.00	24.00	2.12	4.20	0.11	350.0
Max.	7.03	54.60	0.11	39.00	0.20	48.00	28.00	2.14	4.30	0.11	360.0
Mean	7.02	54.53	0.10	38.33	0.19	46.33	26.00	2.13	4.23	0.11	356.7
SD	0.01	0.06	0.00	0.58	0.01	1.53	2.00	0.01	0.06	0.00	5.77
CV, %	0.16	0.11	2.95	1.51	2.98	3.30	7.69	0.47	1.36	0.00	1.62
Station D settlement (dry season)											
Min.	6.87	33.30	0.04	26.00	0.08	36.00	8.00	1.28	2.40	0.07	240.0
Max.	6.91	34.10	0.41	28.00	0.11	38.00	9.00	1.46	2.50	0.07	240.0
Mean	6.89	33.80	0.16	26.67	0.10	37.33	8.33	1.37	2.43	0.07	240.0
SD	0.02	0.44	0.21	1.15	0.02	1.15	0.58	0.09	0.06	0.00	0.00
CV, %	0.29	1.29	130.79	4.33	15.80	3.09	6.93	6.57	2.37	0.00	0.00
Station D settlement (rainy season)											
Min.	7.15	64.30	0.07	35.00	0.11	30.00	17.00	1.86	2.70	0.13	290.0
Max.	7.33	67.50	0.07	36.00	0.12	32.00	18.00	1.88	2.80	0.14	295.3
Mean	7.23	66.30	0.65	25.33	0.12	31.00	17.67	1.87	2.77	0.13	293.3
SD	0.09	1.74	0.00	0.58	0.01	1.00	0.58	0.01	0.06	0.00	2.89
CV, %	1.27	2.63	0.88	1.63	4.95	3.23	3.27	0.53	2.09	0.00	0.98

Min.: minimum; Max.: maximum; SD: standard deviation; CV: coefficient of variation;

The ionic dominance for the major cations and the anions respectively were in these order; Ca^{2+}> Mg^{2+} > K^{+} > Na^{+} and HCO_3^{-}>SO_4^{2-}> NO_3^{-}>PO_4^{-} for dry season, and Ca^{2+}> Mg^{2+} > K^{+} > Na^{+} and HCO_3^{-}>SO_4^{2-}>PO_4> NO_3^{-} for rainy season across the designated locations of River Oba in Ogbomoso. Among the cations, calcium was the most dominant in River Oba water samples at all the designated stations and its concentration varies from 11 mg/l to 37 mg/l with a mean value of 24.42 mg/l in the dry season and 15.33 to 46.33 mg/l with a mean value of 29.83 mg/l in the rainy season. Among the anions, bicarbonate was the dominant, it is concentration varies from 120 to 240 mg/l with a mean value of 188.33 mg/l in the dry season and 141.67 to 356.67 mg/l with a mean value of 251 mg/l in the rainy season. All the major ions contents were under safe limit set by [13] standards for irrigation water. However, this implies that River Oba water along the designated locations was not contaminated by the ions. The coefficient of variation (CV) which reflects the degree of dispersion of the chemical parameters among the samples, indicated that pH, EC, TDS and some ions of the water samples showed CV of less than 10% Table 1 and 2 in both seasons, suggesting weak spatial variability of those parameters. The higher CVs value of ions (> 10%) was observed, in Mg^{2+} PO_4^{-} and Na^{+} at Station A Settlement (10.83%, 15.75% and 20.65%, respectively) in dry season while Mg^{2+} was 12.5% in rainy season, and at Station B settlement, the water CVs of PO_4^{-} in dry and rainy season were (31.22% and 11.11%) respectively, however, NO_3-N was 130.34 at Station C Settlement and Station D Settlement, but PO_4^{-} was 15.80 mg/l in the dry season indicates strong spatial variability of those ions in the analysed water samples, thereby those ions were very sensitive to environmental changes.

B. Suitability Assessment of River Oba Water Course along the Selected Stations for Irrigation

In this section, the results of irrigation water quality indicators parameters were calculated and presented in Table 3 and suitability classification under different delineation limits are presented in Table 4, showcasing the qualities water indicators grades of different designated stations.

Table 3: Irrigation water quality indicators and water quality index of River Oba.

Location	SAR	KR	SSP	RSC	PI	Mg/Ca	IWQI
			Dry Season				
StationA	0.10	0.07	6.42	0.97	138.46	0.82	0.16
StationB	0.05	0.02	2.13	0.38	67.56	1.03	0.20
StationC	0.08	0.04	3.78	1.46	92.95	0.69	0.14
StationD	0.05	0.02	2.28	1.37	78.03	0.37	0.08
Mean	0.07	0.04	3.65	1.05	94.25	0.73	0.14
SEM	0.007	0.006	0.55	0.14	8.32	0.08	0.014
			Rainy Season				
StationA	0.10	0.06	5.39	0.89	106.63	0.87	0.17
StationB	0.07	0.03	3.12	0.89	72.60	0.96	0.19
StationC	0.06	0.02	2.03	1.36	54.94	0.94	0.19
StationD	0.07	0.03	2.62	1.79	73.28	0.95	0.19
Mean	0.07	0.03	3.29	1.23	76.86	0.93	0.18
SEM	0.00	0.00	0.39	0.12	5.82	0.02	0.00

SEM: standard error of mean.

i. Sodium Adsorption Ratio (SAR)

The mean value of SAR in the dry season is 0.07 meq/l with standard mean error of 0.007 meq/l and SAR mean in the rainy season was 0.07 meq/l with standard mean error of 0.00, the waters having SAR values less than 10meq/l are considered excellent, 10 meq/l to 18 meq/l as good, 18 meq/l to 26 meq/l as fair, and above 26 meq/l are unsuitable for irrigation use [13] and [14]. In this research, the SAR values are lesser than 10 meq/l for all samples taken both in the dry and the rainy season in all the designated stations, and therefore it is graded as excellent for irrigation use. SAR is a measure of the tendency of sodium (Na^+) ion to displace Ca^{2+} ion in the irrigation water soil [15]. Low SAR in the study area could be attributed to the abundance of calcium and magnesium in the water in sufficient quantities, to counter the effects of the sodium and help maintain good soil properties [16].

ii. Kelly's Ratio (KR)

KR, an indicator of excess sodium in irrigation water, having an average value of 0.04 meq/l with standard mean error of 0.006 meq/l during dry season and an average value of 0.03 meq/l with standard mean error of 0.00 during rainy season, the Kelly's ratio of unit or less than one is indicative of good quality of water for irrigation whereas above one is suggestive of unsuitability for agricultural purpose due to alkali hazards [17]. Kelly's ratio values of greater and less than unity describes the sampled water as being not suitable and suitable for irrigation, respectively [18]. All river Oba water courses studied as per Kelly ratio are delineated safe when compared to the maximum permissible limit of unity as classified by [19]. From these figures, both in dry season, as well as rainy season were observed to be 100 percent good. The area has good quality water for irrigation purposes due to non-alkali hazards in the water.

iii. Soluble Sodium Percentage (SSP)

The water samples showed that, SSP has the mean value of 3.65 meq/l with standard mean error of 0.55 meq/l in the dry season. However, the mean value of SSP is 3.29 meq/l with a standard mean error of 0.39 meq/l in rainy season. Wilcox (1955) proposed a classification scheme for rating irrigation waters based on soluble sodium percentage (SSP). The values of SSP less than 50meq/l indicate good quality of water and higher values (i.e., greater than 50meq/l) show that the water is unsafe for irrigation [20]. Higher SSP in irrigation water will stunt the plant growth and soil permeability [21]. From these figures, it was observed that, 100 percent of all the designated locations of river Oba water course in the dry season, and rainy season has good quality water and safe for irrigation purposes.

iv. Residual Sodium Carbonate (RSC)

The mean value of RSC is 1.05 meq/l with standard mean error of 0.14 meq/l in dry season and the mean of RSC is 1.23 meq/l with a standard mean error of 0.12 meq/l in raining season. The Residual Sodium Carbonate (RSC) did not exceed a value of 2.5 meq/l across the river Oba water course in designated locations; the water is generally suitable for irrigation. If the value of RSC is between 1.25 meq/l and 2.5 meq/l, the water is marginally suitable while a value less than 1.25 meq/l indicates safe water quality [22]. In this respect, it was evident that, RSC values for two sampling locations (Station A Settlement and Station B Settlement) in the study area, both in the dry season and raining

Table 4: Water Indicators Grades of River Oba Water for Irrigation Uses (meq/L)

SAR	Class	Season Rainy	Season Dry	Mg/Ca	Class	Season Rainy	Season Dry
<10	Excellent	*	*	<1.5	Excellent	*	*
10 – 18	Good			1.5 – 3	Good		
18 – 26	Fair			>3	Unsuitable		
>26	Unsuitable						

KR	Class	Rainy	Dry	SSP	Class	Rainy	Dry
<1	Good	*	*	< 50	Safe	*	*
>1	Unsuitable			> 50	Unsuitable		

RSC	Class	Rainy	Dry	PI	Class	Rainy	Dry
< 1.25	Suitable	A, B	A,B	< 25	Unsuitable		
1.25 - 2.50	Doubtful	C, D	C,D	25- 75	Good	B	D
>2.50	Unsuitable			> 75	Excellent	A, C, D	A, B,C

IWQI	Class	Rainy	Dry
< 1	Safe	*	*
>1	Unsafe		

SAR: sodium adsorption ratio; Mg/Ca: Magnesium-calcium ratio; KR: Kelly's ratio; SSP: soluble sodium percentage; PI: permeability index; RSC: residual sodium carbonate; IWQI: irrigation water quality index. *: All sampling location; L: Ladokun; A: Abogunde; I: Ikose; O: Oja-Oba. Source: (Adhikary and Dash, 2012; Kerala, 2014; Boateng *et al*., 2016)

season are less than 1.25meq/l indicates safe water quality. The other two sampling locations in the study area, both dry season and raining season (Station C Settlement and Station D Settlement) are between (1.25 meq/l and 2.5 meq/l) which indicates marginally suitable, suggesting that, the whole study locations are under safe limit for irrigation use and greater than 2.50 was classified as unsuitable water class for irrigation use based on the recommendation of [23], [24] and [25], RSC greater than 2.5meq/l leads to salt build up which may hinder the aeration and water movement by clogging the soil pores and lead to degradation of the physical condition of the soil.

v. Permeability Index (PI)

Permeability index (PI) of water is a function of sodium, calcium, magnesium, and carbonate in the soil [26]; [27]. The mean value of PI is 94.25 meq/l, with a standard mean error of 8.32 meq/l during dry season. Meanwhile, the mean value of PI is 76.86 meq/l, with a standard mean error of 5.82 meq/l during the rainy season. The Permeability Index (PI) values greater than 75meq/l indicate excellent quality of water for irrigation. If the PI values are between 25 meq/l and 75meq/l, it indicates good quality of water for irrigation. However, if the PI values are less than 25meq/l, it shows unsuitable nature of water for irrigation (Table 4). Based on this assessment, the water samples from three stations (Station A Settlement, Station C settlement and Station D Settlement) in dry seasons have excellent quality of water and Station A Settlement water sample in the rainy season indicated excellent quality of water for irrigation. However, Station B Settlement water sample indicated good quality of water in dry season as well as (Station B Settlement, Station C Settlement and Station D Settlement) in rainy season, therefore suitable for irrigation uses.

vi. Mg/Ca ratio

The mean of Mg/Ca is 0.73 meq/l, with standard mean error of 0.08 meq/l, in dry season and the mean of Mg/Ca is 0.93 meq/l, with standard mean error of 0.02 meq/l, in rainy season. The concentration of magnesium ion is more important than that of calcium ion for irrigation water and their ratio serves as an index for irrigation water quality, just as found in this studied [28]. Though, Mg^{2+} used to have a negativity impact on soil physical properties (by deterioration of soil structure, surface sealing, decreased infiltration, increased runoff and erosion) when it is concentration is relatively high compared to Ca^{2+} [29]. Ca^{2+} plays various structural roles in plant cell membranes, induces the coagulation of soil colloids and is responsible for the crumb–like structure of soil [30]. High Mg^{2+} concentration in river Oba water has been associated with natural or induced by input of dolomitic limestone [31]. Here, it was noted that all the area have no magnesium hazard because the samples results of the area shows the ratio lesser than the desirable limit.

vii. Irrigation Water Quality Index (IWQI)

The computed irrigation water quality index (IWQI) for the studied water samples from the designated locations along Oba River in Ogbomoso ranged between the values of 0.08 meq/l and 0.20 meq/l with a mean value of 0.14 meq/l in dry season while the value was ranged between 0.17 meq/l and 0.19 meq/l with mean value of 0.18 meq/l in rainy season. All the analysed water samples fall in the 'Safe' class (IWQI < 1) meq/l; [10]; [32]; [33] of water quality rating.

Therefore, it was noted that all the areas studied are under the safe limit. It was observed that, 100 percent of all the designated locations of river Oba water course in dry season as well as raining season has good quality water and safe for irrigation purposes. The controlling chemical parameters of the IWQI that were used to compute IWQI are EC, SAR, HCO_3^- and Mg/Ca ratio. All the parameters are within the permissible limits of [31] irrigation water standard, this signified that the surface water along designated locations in Oba river water course in Ogbomoso is not contaminated by the ion.

B. Geospatial Variations in Water Quality Parameters

Based on the thematic maps, spatial variation of TDS and pH values (Fig. 4) indicates that water samples were close to the river bank (Figure 1-4). Low pH levels as it found in the study water indicate weak acidic water and have potential to promote corrosion of pump parts. According to Government of Western Australia (2009) "the pH of a solution is the concentration of hydrogen ions, expressed as a negative logarithm." It indicates the acidity or alkalinity of water. Notably, pH level has implication on other potential toxicants, such as the bio-availability of heavy metals. Flooding and putrefaction of decaying organic matter could be responsible for pH results as observed by [34]. Water with low pH tends to be acidic and may be corrosive, such water could affect metallic plumbing fittings (leaching). Lower pH values as it found in the study water may be due to increased production of CO_2 from microbial respiration [16]. However, the areas may be more auspiciously for microbial growth because of very low water current in the study water. TDS values in water samples may be due to increased dissolution of solids like rocks and sediments because water samples collected was close to the river bank however, total dissolved solids are an indication of the degree of dissolved substances such as metal ions in the water. The concentrations are significantly high during rainy season due to erosion of particulate matter and sediments from agricultural field into the river as observed by [12]. This is a common scenario, in areas where fertilizers have been used for agriculture, and a state of eutrophication has occurred as observed by [35].

Spatial distributions of major ions shown higher contents of NO_3^- N, Mg^{2+}, Na^+, HCO_3^-, SO_4^2 and K^+ in water samples chosen at the middle and towards the southern part of the river in both seasons (Figure 1, 2. and 3). Na^+, Mg^{2+} and K^+ contents in the river water may be originated via weathering of rock forming minerals along the river water course. Higher content of NO_3^- may be due to water contamination from organic effluents like high percentage of nitrogen-based fertilizer used on cropland within the study area, however, it can be household sewage and septic tanks and animal dungs leachates along the river course. The concentrations of NO_3-N are usually built up during the dry season, while in the rainy season; there is high dilution due to high rainfall events as observed by [36]. This resulted in the increase of nitrate levels in the water as the excess nitrate from the fertilizer is washed down into the river course.

C. Spatial Distribution Maps for all the Physicochemical Quality Parameters Considered in River Oba Study

Spatial distribution maps for all the physicochemical qualities parameters considered in the study were generated for rainy and dry seasons Fig. 1 to 4.

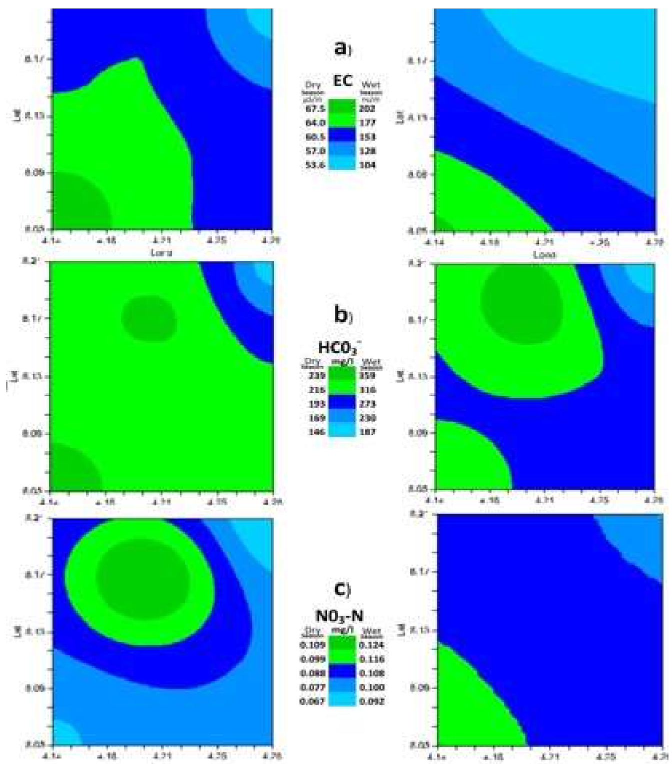

Figure 1: Spatial distribution of a) EC, b) HCO_3^- and c) NO_3-N in River Oba Water

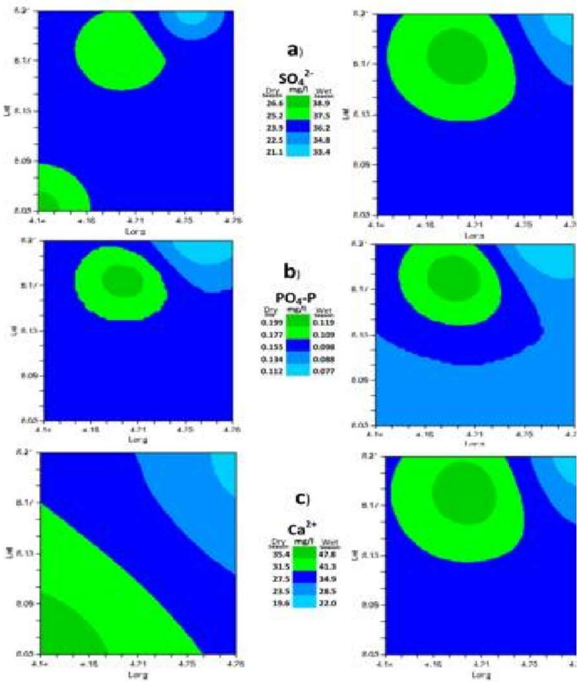

Figure 2: Spatial distribution of (a) SO_4^{2-}, (b) $PO_4^{-}P$ and (c) Ca^{2+} in River Oba Water

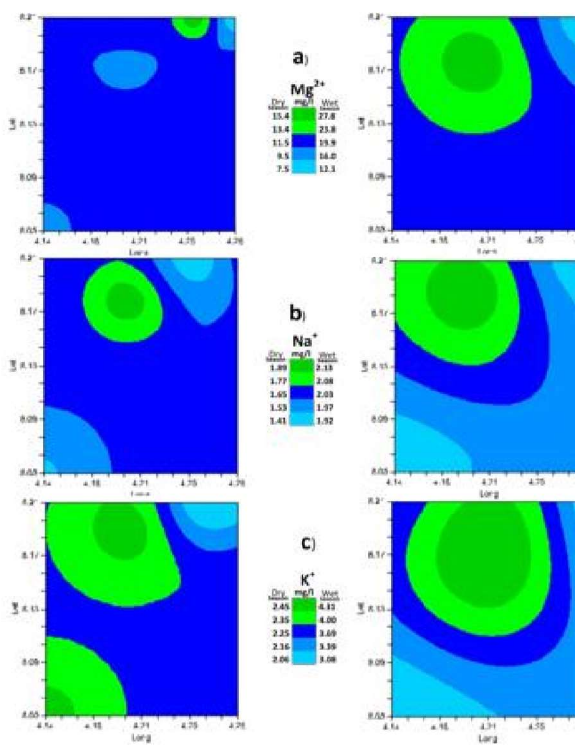

Figure 3: Spatial distribution of (a) Mg^{2+}, (b) Na^{+} and (c) K^{+} in River Oba Water

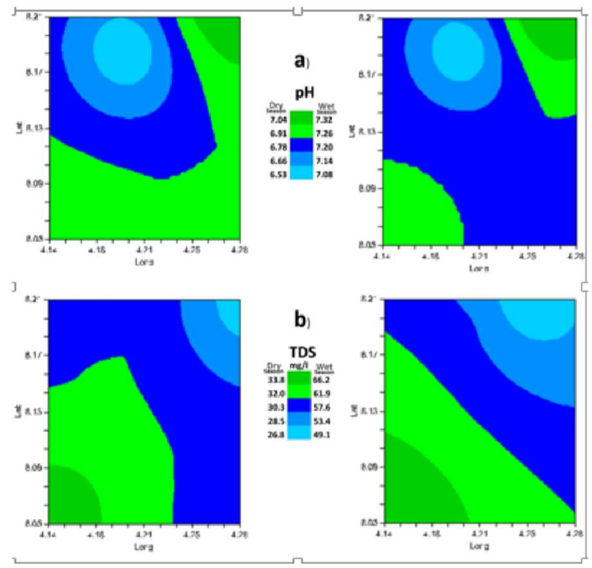

Figure 4: Spatial distribution of (a) pH and (b) TDS in River Oba Water

IV. Conclusions

The geospatial variation in the water quality indices of river Oba at four designated locations along its course in Ogbomoso land (Station A Settlement, Station B settlement and Station C Settlement and Station D Settlement) were assessed in the dry and rainy season. The physicochemical properties are within the recommended standard limit prescribed by FAO for irrigation as the quality of the River Oba water ranges from good to excellent. However, River Oba water, was suitable for irrigation both during the dry and the rainy season as the quality indices ranged from good to excellent. The geospatial analysis revealed weak to strong spatial variability. There is the need for regular monitoring of the water quality so that when necessary, adequate treatment would be provided. There should be a sustainable watershed management in place to protect the quality of river Oba. During the study, it was discovered that there are many anthropogenic activities along the River Oba course. Such activities including irrigation with the use of agrochemicals, cassava processing with effluent being discharged without treatment into the river water course. At some locations (for instance at Station C Settlement) piggery pens are sited on the bank of the river and the waste from the pen is discharged directly into the river.

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